Asia-Pacific
Economic Cooperation

2009 APEC Workshop

Developing Bioenergy and Conserving the Natural Ecosystem

in APEC Member Economies

Seoul, Sep. 15~17, 2009

Dec. 2009

RURAL DEVELOPMENT ADMINISTRATION

Asia-Pacific
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2009 International Workshop on Developing Bioenergy and Conserving the Natural Ecosystem in APEC Member Economies

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Opening Remarks

Jae-Soo Kim

Administrator
Rural Development Administration

I would like to start this workshop by extending my warmest welcome and gratefulness to all participants who gathered here in Seoul for the successful APEC's international workshop. Also, I appreciate for Minister Tae-Pyong, Chang of the Ministry for Food, Agriculture, Forestry, and Fisheries who willingly accepted our invitation and provided the great support to us.

It is true that the revolution of the industry brought a great development to our society. However, it also resulted to adverse effects to our environments such as depletion of water resources, decline of biodiversity and low food production. These are mainly understood to be caused by the current climate change induced by greenhouse gas emissions from an excessive use of fossil fuel. In Korea, we are also experiencing the threatening climate change particularly to our agricultural industry such as the decline of the high attitude agricultural area for vegetable cultivation and outbreak of some special insects such as small brown planthopper and flower cicada. Such adverse effects of the climate change forced us to take an action to solve the problem. I do believe, one of the most effective ways to overcome and mitigate the global warming is the development of green and clean bioenergy with practicing technologies for efficient application of the energy as well as policy making to support those recommendations.

In respect with green and clean bioenergy, recently, the organic resources generated from the agricultural area are taking attention as important materials for bioenergy production. Hence, we at RDA have aligned research programs and are undertaking the studies focusing on the development of the technologies for green and clean bioenergy production using agricultural organic waste and livestock manures. Moreover, we are developing its practical application technologies. Eventually, these projects will be able to deal with reduction of carbon emissions properly as well as to create the job opportunity for the communities. With the foreseen success of our plan, we believe that we can provide a hope to the rural communities, and we can keep our rural area as a clean and green space.

This international workshop titled “Developing Bioenergy and Conserving the Natural Ecosystem”will be a great opportunity for all the participants to share the experiences of the developing countries regarding to the bioenergy technologies. In addition, I expect that this workshop will provide a great change for our country to revitalize the bio-energy industry.

I sincerely hope that all of you will be a great time to visit our country for a productive and memorable experience. Finally, I would like to thank for all people including RDA members for their efforts to organize this workshop.

Sept. 15. 2009

Complimentary Address

Tae-Pyong, Chang

Minister
Ministry for Food, Agriculture, Forestry, and Fisheries

First of all, I am greatly honored to deliver a complimentary address for this international workshop in our country as a member economy of APEC. Distinguished speakers, on behalf of each APEC economy, international participants, and celebrity including Administrator Jae-Soo Kim and other local participants allow me to extend my warmest greetings, and also I am really pleased to meet all of you here.

As you know, climate change which brought about global warming was dealt mainly by scientists in the past. However, recently the whole world is being threatened by the outbreak of diseases and pests that consequently resulted to reduction of crop production as well as global epidemic and natural disasters caused by global warming, making climate change issue to be a common challenge to be addressed by all people on the earth. Global warming has been more serious from green house gas emissions due to the combustion of fossil fuel such as oil and coals. It is rising day by day.

The natural resources required for the survival and exuberance of human beings have been gradually depleted. The concentration of carbon dioxide was 290 ppm in the early 1900s, now it increased drastically to 347 ppm in 2008. In this situation, there will be an intense dispute among nations to attain an agreement for setting goals for reduction of the green house gas emissions in Copenhagen conference scheduled to be held in the late of this year.

So, for building a world-oriented low carbon society, I think it is needed to broaden the functions and values of agricultural by-products to bioenergy production, enhanced material cycling, the preservation of bio-resources and water resources over simple food production.

To make agriculture contribute to build a sustainable and developed society, we all have to gather ideas and wisdom to get a 3 way-effects of production of bio-energy such as methane using agricultural by-products and animal wastes, utilization of the residual slurries as a bio-fertilizer, and offer of job for rural areas through the development of technologies on the utilization of biomass. In addition, it is very important to make Clean Agriculture, Clean World through recycling of biomass. This will be a way to see a new vision for the future in green rural community.

In these aspects, this international workshop on developing bio-energy and conserving the natural ecosystem will be very significant.

Anyway, I hope that all of us will be able to share our knowledge and experiences on technological performances that each country has accomplished so far and this, in turn, will contribute in addressing global warming issue.

Finally, I hope that this workshop will be beneficial to all experts and participants from home and abroad. Again, I would like to express my sincere thanks to all participants and to the APEC side and organizers of RDA. Thank you for your attention and good luck to all of you.

Sept. 15. 2009

Program 1Day /

Opening Session

09:30 ~ 10:00	Registration
10:00 ~ 10:30	Opening Ceremony Opening Remarks (Administrator of RDA) Congratulatory Remarks (Minister of MIFAFF)
10:30 ~ 10:40	Group Photo and Break

Session Ⅰ

Keynote Speech

Moderator : Dr. Masayoshi Saito, MAFF (Japan)

10:40 ~ 11:10	"Low Carbon Green Growth" strategy in Korea Dr. Kuyng-Hwan Toh (Presidential Committee on Green Crowth, Korea)
11:10 ~ 11:40	Biomass Energy From Agriculture, Forestry and Fisheries in Korea Mr. Chung-Won Lee (MIFAFF, Korea)
11:40 ~ 12:10	Bioenergy in New Zealand Dr. Avinash Shrivastava(Ministry of Agriculture and Forestry, New Zealand)
12:10 ~ 13:30	Lunch

Session Ⅱ

Moderator : Mr. Chung-Won Lee ,MIFAFF (Korea)

13:30 ~ 14:00	Biomass Strategy and Biomass Town Project in Japan Dr. Masayoshi Saito (MAFF, Japan)
14:00 ~ 14:30	German Biogas Success Story and the Requested Political Framework Ms. Elisabeth Naria Huba (International Competence Centre for Biogas and Bioenergy, Germany)
14:30 ~ 15:00	Opportunities for Biogas Capture and Use from Animal Waste Management Mr. Christopher Voell (AgSTAR, EPA, USA)
15:00 ~ 15:20	Coffee Break

Session Ⅲ

Moderator : Mr. Christopher Voell, AgSTAR, EPA (USA)

15:20 ~ 15:30	Development of Biogas and Biomass Power Technology in China Mr. Heinez-Peter Mang (University of Science and Technology Beijing, Chana)

Program 1Day /

15:50 ~ 16:10	Case Study of Biogas Production from Plant-Based Materials and Animal Manure Resources Available In the Cocoa and Coffee Farms Dr. Sri Mulato (Indonesian Coffee Research Institute, Indonesia)
16:10 ~ 16:30	Treatment of Wastewater and Sludge in China, and its Perspective as Bio-Energy Sources Around Towns for Supplying Energy Needs Dr. Li Zifu (University of Science and Technology Beijing, China)
16:30 ~ 16:50	Coffee Break

Moderator : Dr. Chang-Hyun Kim, Hankyong Nat, Univ. (Korea)

16:50 ~ 17:20	Biogas Recovery from Piggery Wastewater by Anaerobic Digestion Dr. Jin-Young jung (Korea Institute of Science and Technology, Korea)
17:20 ~ 17:40	Biogas Development in Viet Nam – Opportunities and Challenges Ms. Kim Thi Thuy Ngoc (Ministry of Natural Resource and Environment, Viet Nam)
17:40 ~ 18:00	Biogas System from Swine Waste in Thailand Dr. Sommai Chatsanguthai (Livestock Waste Management, Thailand)

Program 2Day /

Session Ⅳ

Moderator : Dr. In-Seop Chang, GIST (Korea)

10:00 ~ 10:30	Production of Bio-crude and Bio-phenols from Agricultural Residues or by-Products through Direct Liquefaction Dr. Charles Xu (Lakehead University, Canada)
10:30 ~ 10:50	Biodiesel Promotion in Thailand Dr. Anucha Promwungkwa (Chiang Mai University, Thailand)
10:50 ~ 11:00	Coffe Break
11:00 ~ 11:30	Study on Crude Oil Productions and Supercritical Clean and Green Fuels on Application of Liquefaction Technology with Agricultural Biomass Dr. JoungDu Shin (National Academy of Agricultural Science, RDA, Korea)
11:30 ~ 11:50	Outlook of Palm Biodiesel in Malaysia Mr. Chee (Energy Council of Malaysia)
11:50 ~ 13:30	Lunch

Program 2Day /

Session V

Moderator : Dr. Charles Xu, Associate Professor, Lakehead University (Canada)

13:10 ~ 14:00	Biobutanol Production Technologies with Agricultural Biomass Dr. Shang-Tian Yang (The Ohio State University, USA)
14:00 ~ 14:30	Biobutanol : Green Energy Production Dr. In-Seop Chang (Gwangju Institute of Science and Technology, Korea)
14:30 ~ 14:50	Overview of Legal Framework on Biofuels in Viet Nam Dr. Nguyen Trung Thang (Ministry of Natural Resource and Environment (MONRE), Viet Nam)
14:50 ~ 15:10	Development of Biodiesel in China Mr. William Tze Ming Kao (Pro-Tek Industries, COBRA Biodiesel division, Taiwan)
15:10 ~ 15:40	Coffe Break

Session VI

Moderator : Dr. Shang-Tian Yang, Professor, The Ohio State University (USA)

15:40 ~ 16:00	Cultivation of Energy Crops and Their Environmental Effects (Bioenergy Crop Research Center, NICS, RDA, Korea)
16:00 ~ 16:30	Case Study of Energy Crops Production and Utilization In Indonesia Dr. IR. Bambang Prastowo (Indonesia Center for Estate Crops Reseach and Development(ICERD), Indonesia)
16:30 ~ 17:30	Discussion / Director General, NAAS

Appointed Discussant

- Dr. Soon-Chul Park (Korea Institute of Energy Research)
- Dr. Hyunook Kim (University of Seoul)
- Dr. Sae-Jung Suh (Bioenergy Crop Research Center, NICS, RDA)
- Dr. Hee-Seol Kang (National Institute of Animal Science, RDA)
- Dr. Sang-Hoon Kim (BND Co., Ltd.)
- Dr. Sang-Hyoun Kim (Korea Institute of Industrial Technology)

Program 3Day /

Field Tour

10:00 ~ 12:00	Field Tour to Biogas Plant, Anseong
12:00 ~ 13:30	Lunch
15:30 ~ 17:00	Visiting Agricultural Exhibition Hall, RDA, Suwon

Contents

• Session Ⅰ

• Session Ⅱ

• Session Ⅲ

• Session Ⅳ

• Session Ⅴ

Session

I

1. "Low Carbon Green Growth" strategy in Korea
2. Biomass Energy from Agriculture, Forestry and Fisheries in Korea
3. Bioenergy in New Zealand

1

"Low Carbon Green Growth" strategy in Korea

Dr. Kyung-Hwan Toh

Director, Energy Policy Division, Presidential Committee on Green Growth
Email : khtoh1@hanmail.net

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Korea's Green Growth Vision

September 2009

Kyung Hwan TOH
Director-General, Energy Policy
Presidential Committee on Green Growth

Presidential VISION – Low Carbon Green Growth

Creating New 60 years (announcement of a new national vision in the 60th anniversary of the founding of the Republic on August 15th 2008)

Last 60 years	Next 60 years
Economic growth	Green growth

More than just an environmental policy
- a new paradigm of progress
- changing people's behavior and way of thinking

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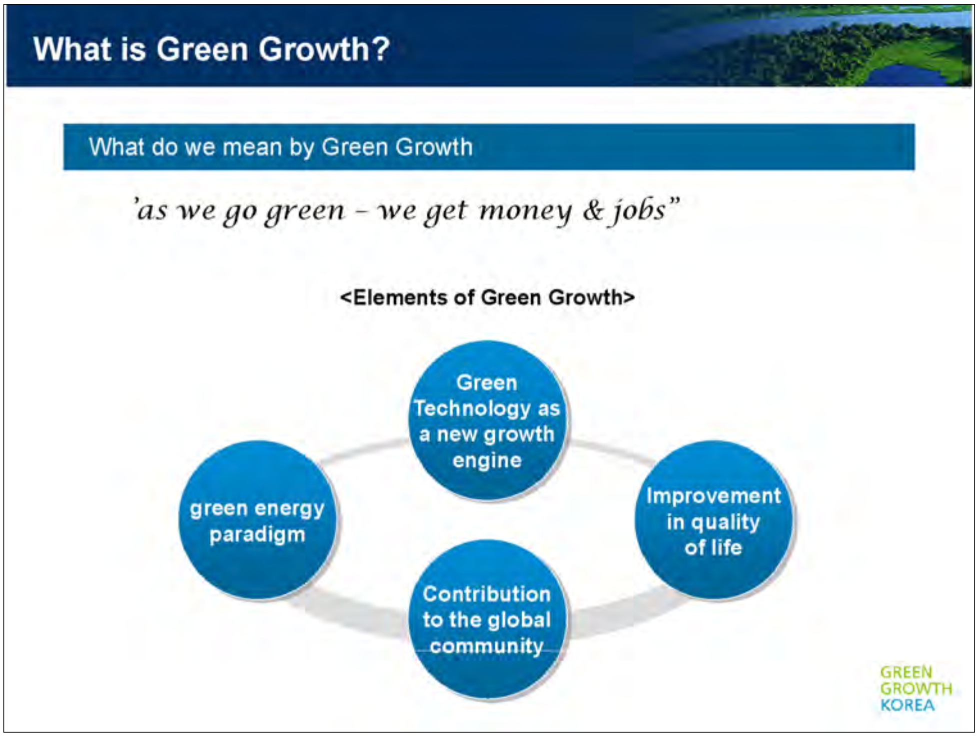

What is Green Growth?

What do we mean by Green Growth

’as we go green – we get money & jobs”

<Elements of Green Growth>

Green Technology as a new growth engine

green energy paradigm

Improvement in quality of life

Contribution to the global community

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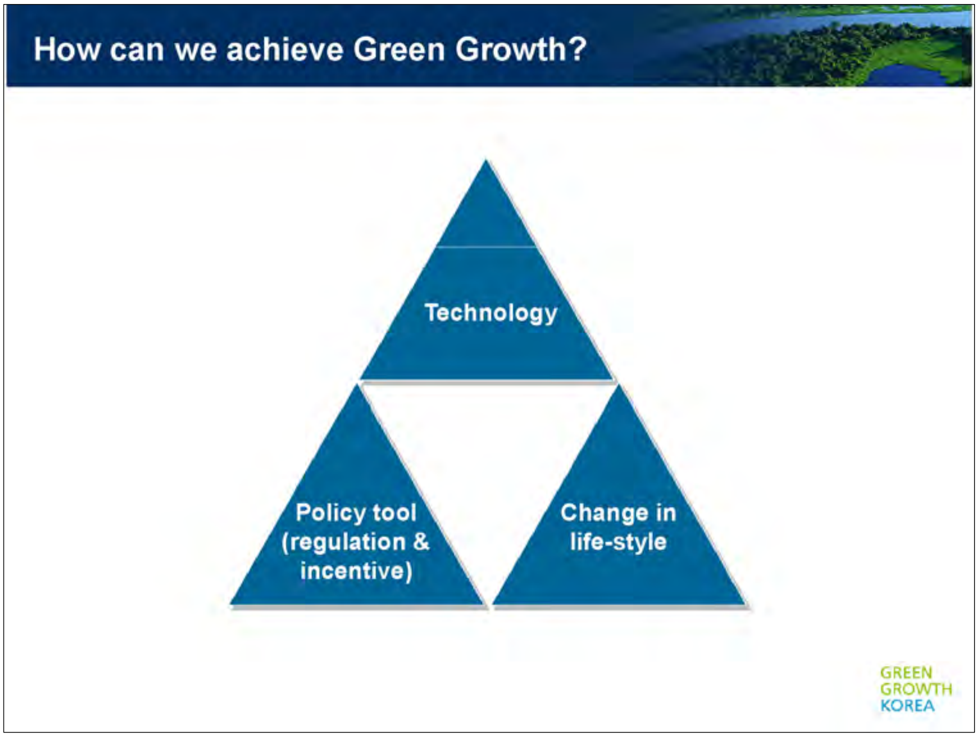

How can we achieve Green Growth?

Technology

Policy tool (regulation & incentive)

Change in life-style

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Why is Korea striving for Green Growth?

Climate Impact
- average temperature rise 1.7℃ (2 times more than world average)

Energy security vulnerability
- 140 billion USD energy bill

Economic slow-down
- growth rate declining since the Asian economic crisis in late 1990s
- growth without rise in employment

"New path is needed"

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The Logic

Source : ESI, Morgan Stanley Research

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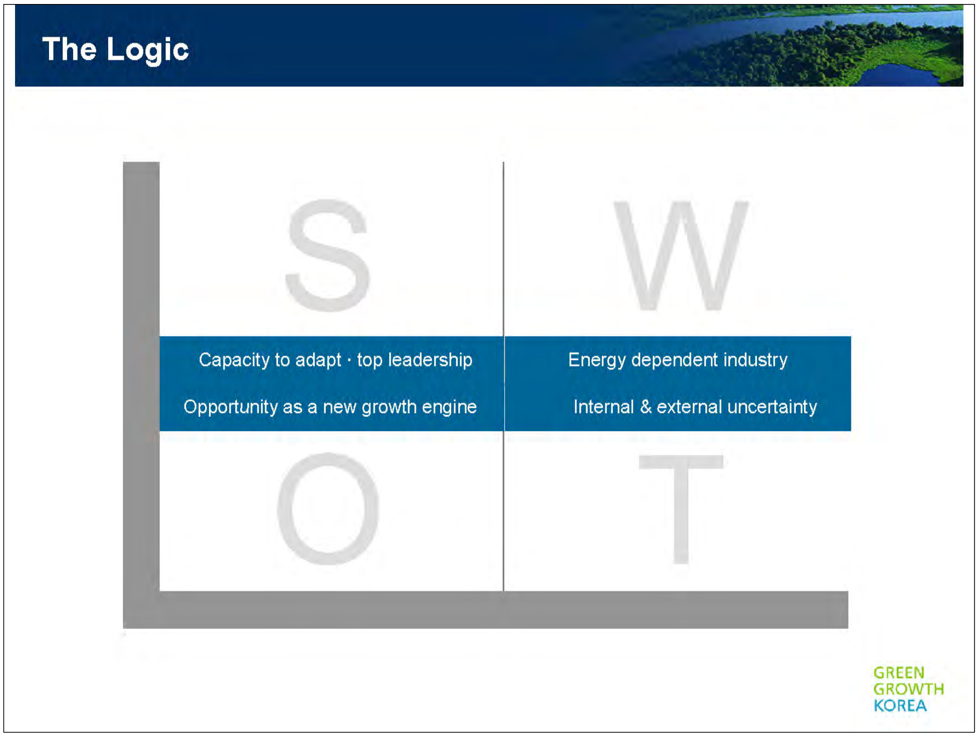


The Logic

S	W
Capacity to adapt · top leadership	Energy dependent industry
Opportunity as a new growth engine	Internal & external uncertainty
O	T

Features of the Green Growth in Korea

Strong Green Leadership

- Presidential Committee on Green Growth

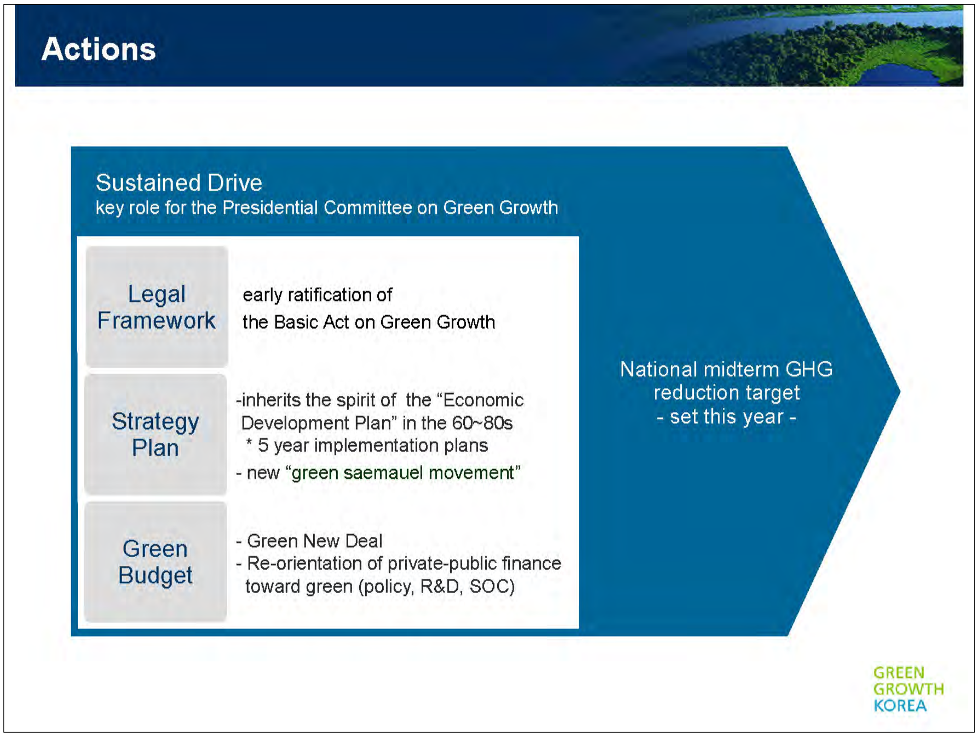
Fast integration of the Vision in all sectors

- meaningful partnership with private council (business, financial sector, technology experts etc.)

Strong industrial base in relevant areas

- large competent players

Turning it into “real actions”



Actions

Sustained Drive
key role for the Presidential Committee on Green Growth

Legal Framework	early ratification of the Basic Act on Green Growth
Strategy Plan	-inherits the spirit of the "Economic Development Plan" in the 60~80s * 5 year implementation plans - new "green saemauel movement"
Green Budget	- Green New Deal - Re-orientation of private-public finance toward green (policy, R&D, SOC)

National midterm GHG reduction target
- set this year -

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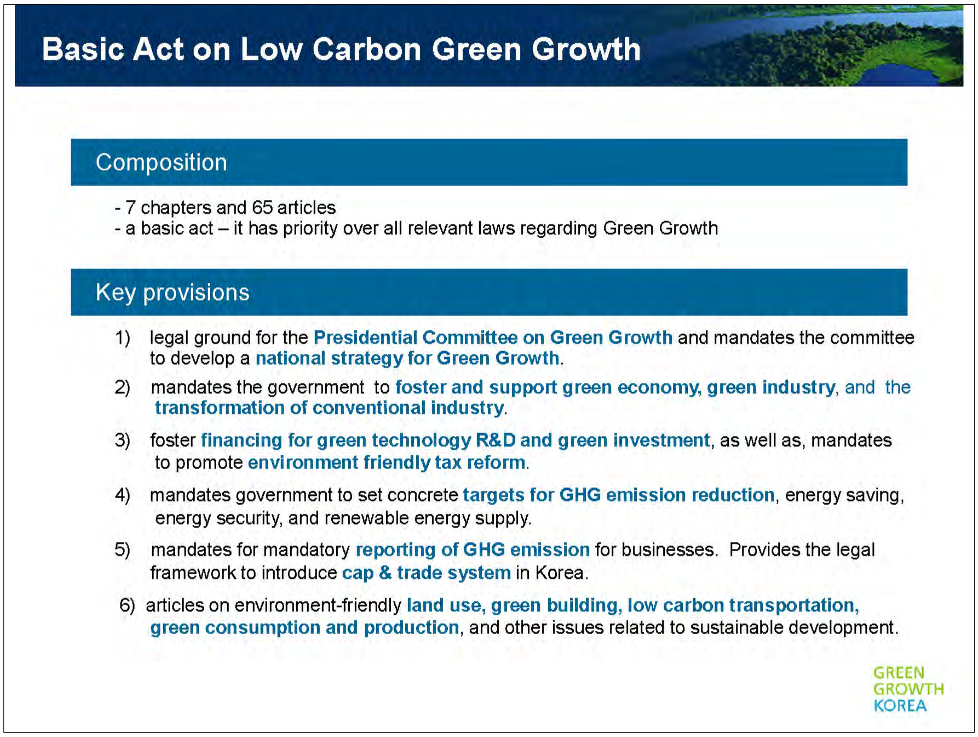

Basic Act on Low Carbon Green Growth

Composition

- 7 chapters and 65 articles
- a basic act – it has priority over all relevant laws regarding Green Growth

Key provisions

1) legal ground for the **Presidential Committee on Green Growth** and mandates the committee to develop a **national strategy for Green Growth**.
2) mandates the government to **foster and support green economy, green industry**, and the **transformation of conventional industry**.
3) foster **financing for green technology R&D and green investment**, as well as, mandates to promote **environment friendly tax reform**.
4) mandates government to set concrete **targets for GHG emission reduction**, energy saving, energy security, and renewable energy supply.
5) mandates for mandatory **reporting of GHG emission** for businesses. Provides the legal framework to introduce **cap & trade system** in Korea.
6) articles on environment-friendly **land use, green building, low carbon transportation, green consumption and production**, and other issues related to sustainable development.

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Green New Deal

Background & Key projects

- Green New Deal announced on Jan. 2009 - 9 key projects and supporting projects
- focused on job creation as well as building the foundation for low carbon economy transition

	Project Name	Budget (billion KRW)			Job Creation (# of jobs)		
		2009	~ 2012	total	2009	~ 2012	Total
	total sum	4,363	45,687	50,049	93,360	863,060	956,420
KEY PROJECTS	• 4 Major River Revitalization	488	13,990	14,478	7,000	192,960	199,960
	• Green Transportation	1,835	7,819	9,654	25,042	113,025	138,067
	• Integrated Territory Management	25	347	372	816	2,304	3,120
	• Water Resource Catchment	185	758	942	3,063	13,069	16,132
	• Green Car & Clean Energy	321	1,732	2,053	1,643	12,705	14,348
	• Waste Resource Reuse	51	879	930	2,377	13,819	16,196
	• Forestry	313	2,104	2,417	22,498	148,204	170,702
	• Green Home, Green School	-	8,050	8,050	-	133,630	133,630
	• Ecological River	5	479	484	393	10,396	10,789
	Support Projects	1,140	9,530	10,670	30,528	262,038	141,639

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National Strategy for Green Growth

Background

- Approved on July 6 by the Presidential Committee & the Cabinet Meeting
- a multi-agency + research institute participating project

Key Objective & Agenda

Vision	A Top 7 Green Nation by 2020, Top 5 by 2050		
Objectives	Climate Change Adaptation & Energy Security	New Engine for Growth	Enhanced Quality of Life & Int'l Leadership
10 Key Agenda	• Efficient GHG mitigation • Greater independence from fossil fuel & energy security • Building climate resilience	• R&D for green tech. • Greening existing industry & fostering green industry • Toward high-tech industries • Lay the foundation for green economy	• Green transportation & land management • Green life-style • International leadership

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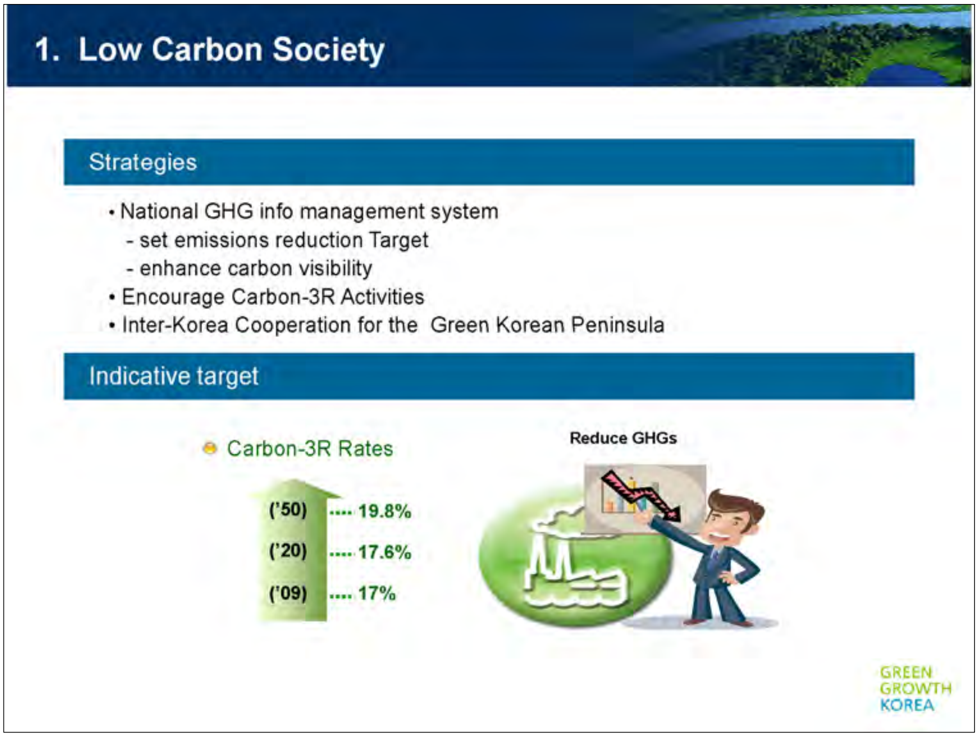


1. Low Carbon Society

Strategies

- National GHG info management system
  - set emissions reduction Target
  - enhance carbon visibility
- Encourage Carbon-3R Activities
- Inter-Korea Cooperation for the Green Korean Peninsula

Indicative target

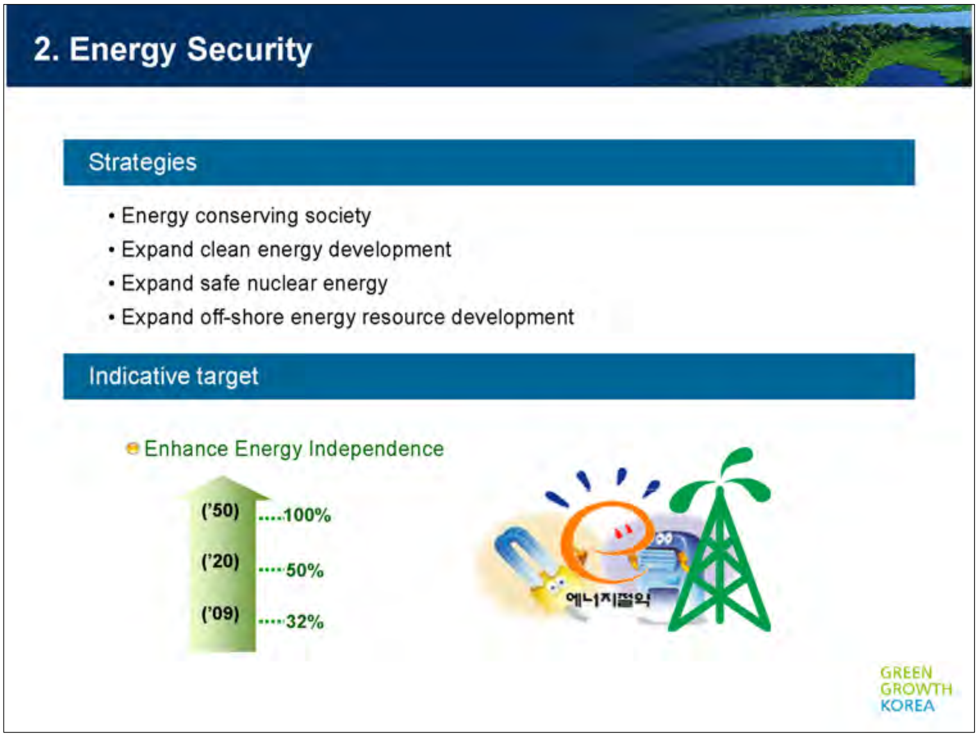
- Carbon-3R Rates

('50) ····· 19.8%

('20) ····· 17.6%

('09) ····· 17%

Reduce GHGs



2. Energy Security

Strategies

- Energy conserving society
- Expand clean energy development
- Expand safe nuclear energy
- Expand off-shore energy resource development

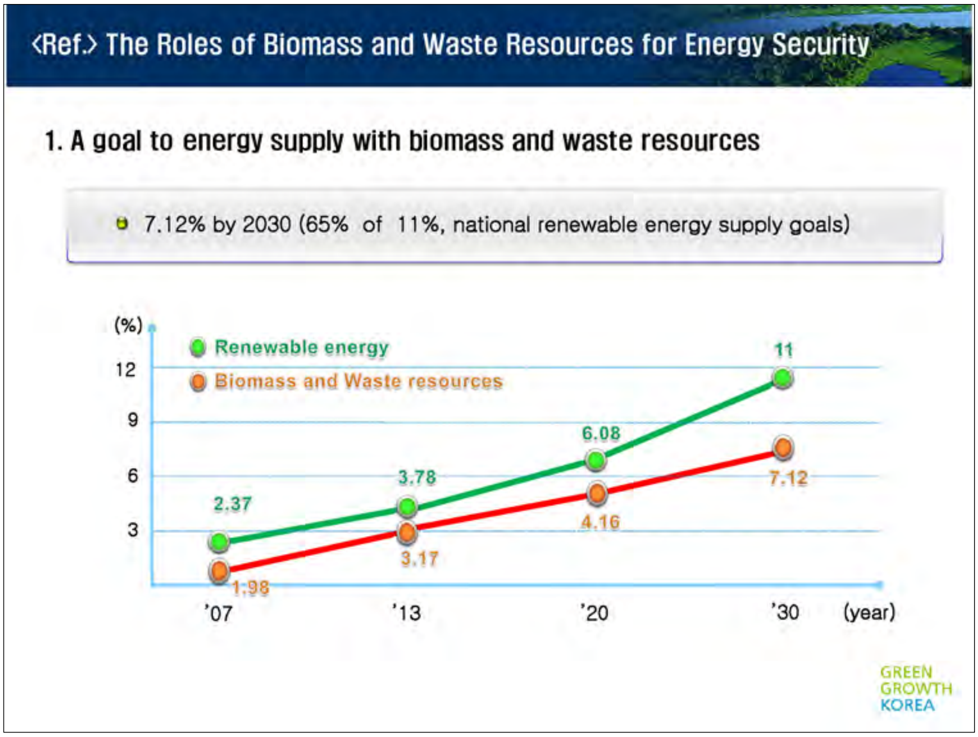
Indicative target

- Enhance Energy Independence

('50) ·····100%

('20) ·····50%

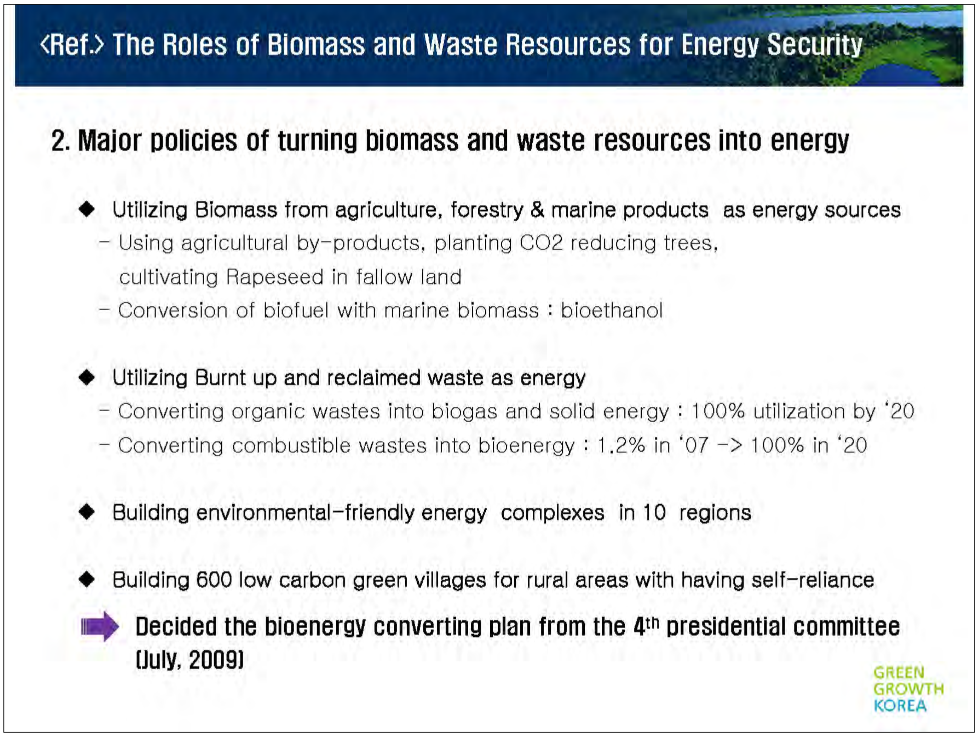
('09) ·····32%



<Ref.> The Roles of Biomass and Waste Resources for Energy Security

1. A goal to energy supply with biomass and waste resources

- 7.12% by 2030 (65% of 11%, national renewable energy supply goals)



<Ref.> The Roles of Biomass and Waste Resources for Energy Security

2. Major policies of turning biomass and waste resources into energy

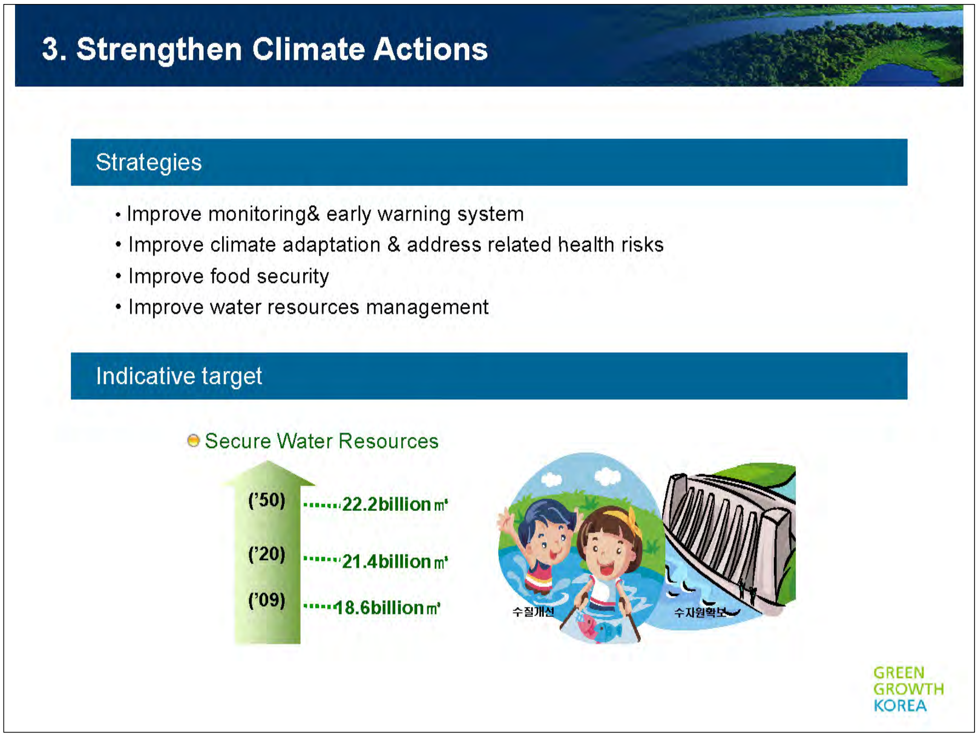
◆ Utilizing Biomass from agriculture, forestry & marine products as energy sources
  - Using agricultural by-products, planting CO2 reducing trees, cultivating Rapeseed in fallow land
  - Conversion of biofuel with marine biomass : bioethanol

◆ Utilizing Burnt up and reclaimed waste as energy
  - Converting organic wastes into biogas and solid energy : 100% utilization by '20
  - Converting combustible wastes into bioenergy : 1.2% in '07 -> 100% in '20

◆ Building environmental-friendly energy complexes in 10 regions

◆ Building 600 low carbon green villages for rural areas with having self-reliance

➡ **Decided the bioenergy converting plan from the 4th presidential committee (July, 2009)**



3. Strengthen Climate Actions

Strategies

- Improve monitoring& early warning system
- Improve climate adaptation & address related health risks
- Improve food security
- Improve water resources management

Indicative target

Secure Water Resources

('50) ……22.2billion㎥

('20) ……21.4billion㎥

('09) ……18.6billion㎥

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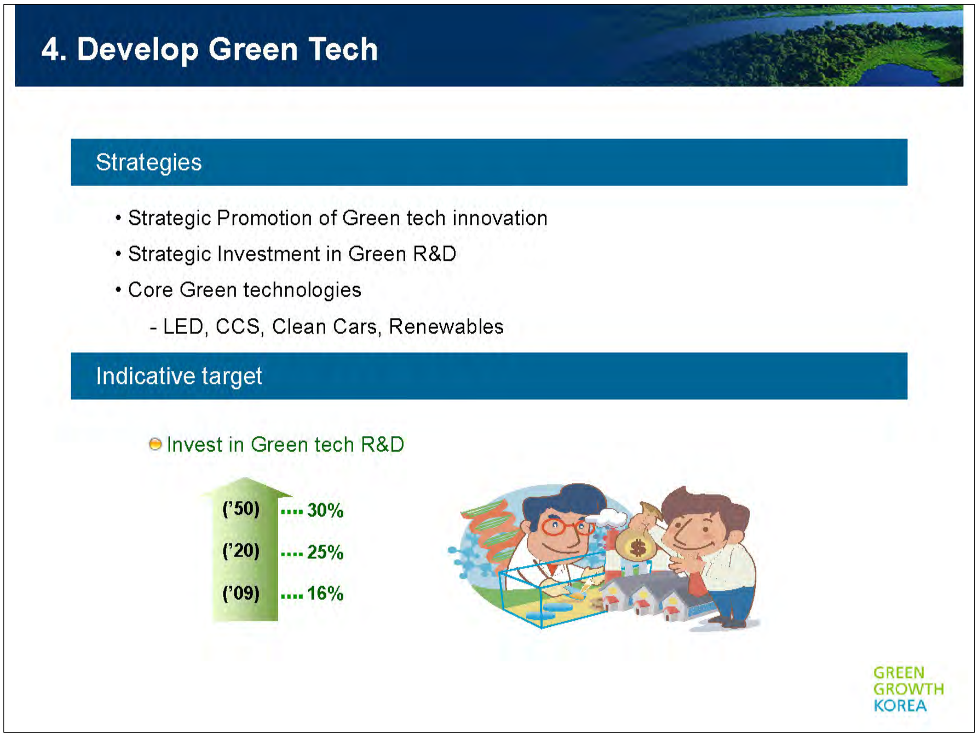

4. Develop Green Tech

Strategies

- Strategic Promotion of Green tech innovation
- Strategic Investment in Green R&D
- Core Green technologies
  - LED, CCS, Clean Cars, Renewables

Indicative target

Invest in Green tech R&D

('50) …. 30%

('20) …. 25%

('09) …. 16%

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5. Fostering Green Industries

Strategies

- Resource-circulating economy & society
- Green conversion of industries
- Foster green SMEs
- Build green clusters

Indicative target

Export in Green Products

('50)	35%
('20)	22%
('09)	10%

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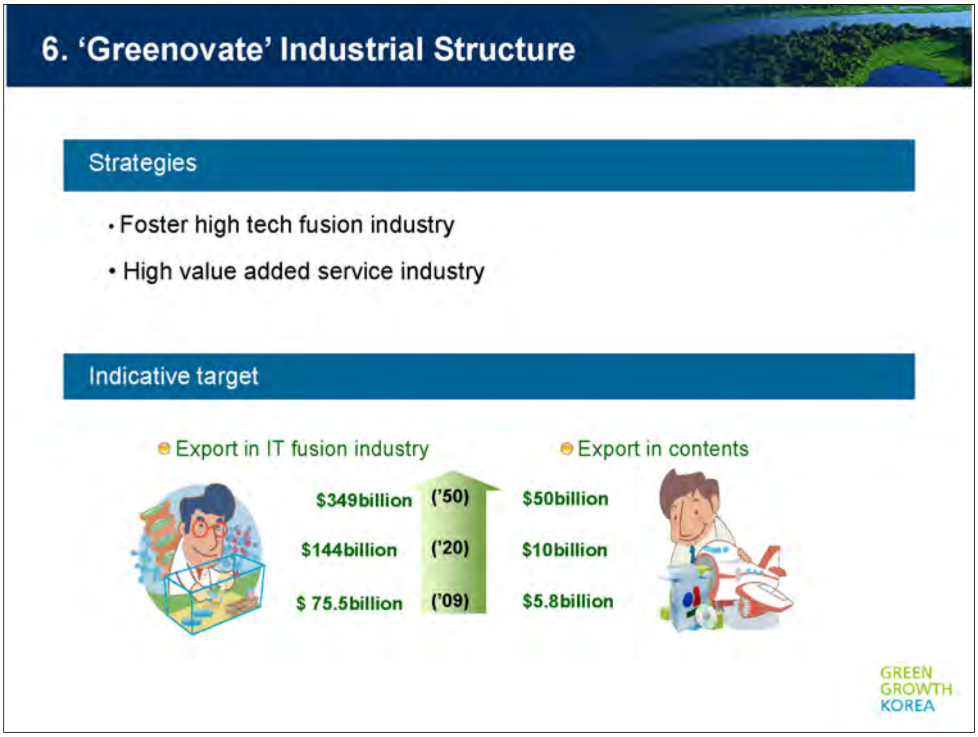

6. 'Greenovate' Industrial Structure

Strategies

- Foster high tech fusion industry
- High value added service industry

Indicative target

Export in IT fusion industry		Export in contents
$349billion	('50)	$50billion
$144billion	('20)	$10billion
$ 75.5billion	('09)	$5.8billion

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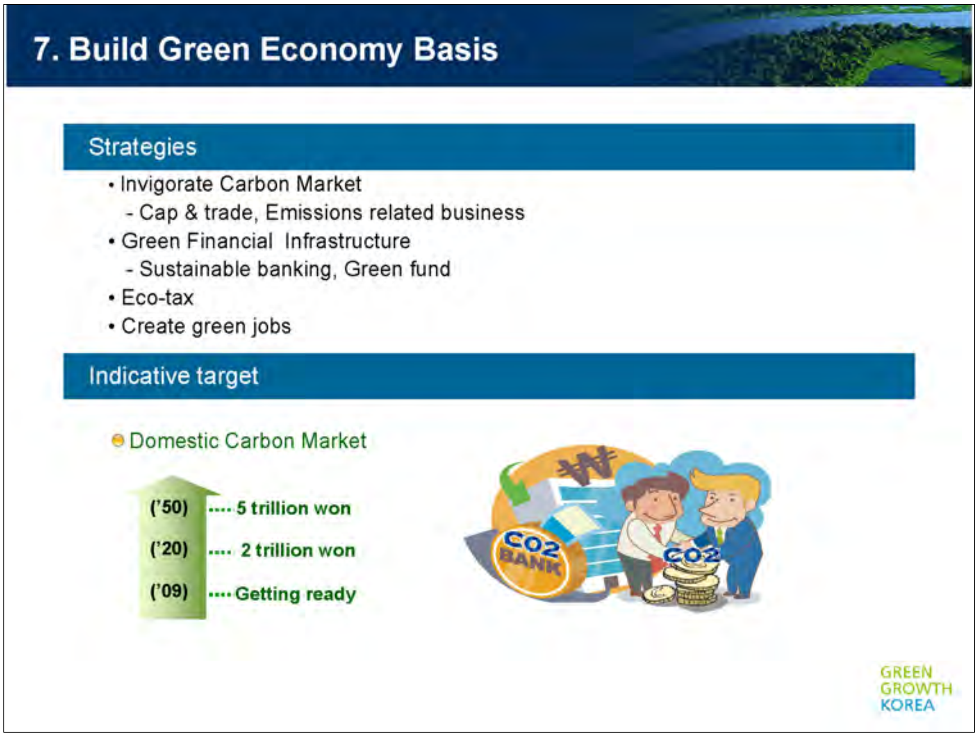

7. Build Green Economy Basis

Strategies

- Invigorate Carbon Market
  - Cap & trade, Emissions related business
- Green Financial Infrastructure
  - Sustainable banking, Green fund
- Eco-tax
- Create green jobs

Indicative target

Domestic Carbon Market

('50) ..... 5 trillion won
('20) ..... 2 trillion won
('09) ..... Getting ready

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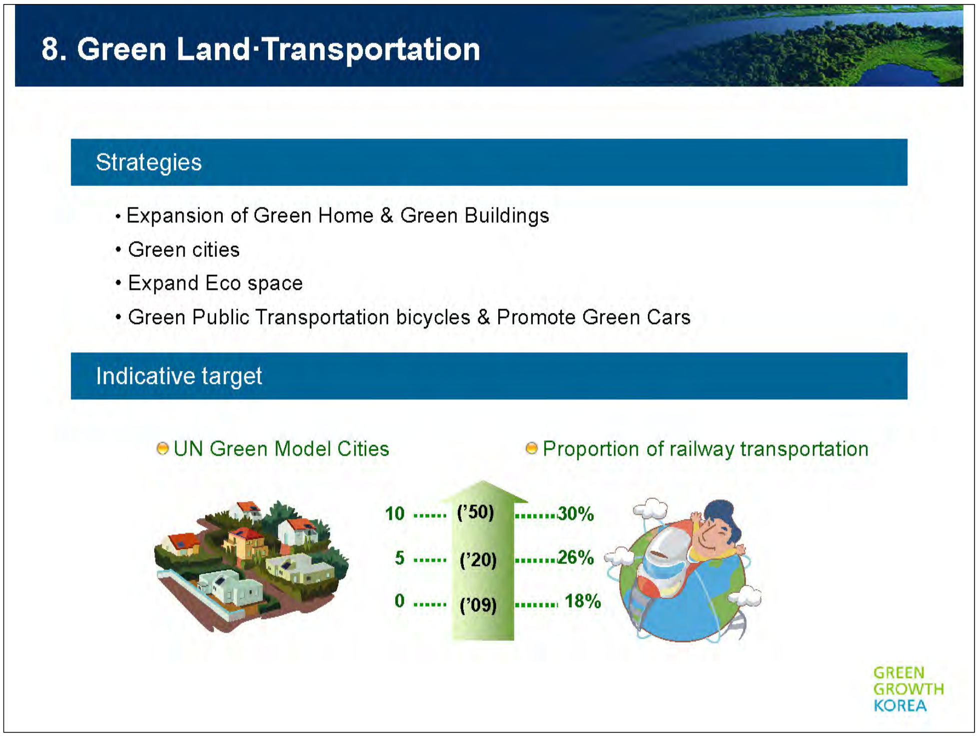

8. Green Land·Transportation

Strategies

- Expansion of Green Home & Green Buildings
- Green cities
- Expand Eco space
- Green Public Transportation bicycles & Promote Green Cars

Indicative target

UN Green Model Cities

Proportion of railway transportation

10 .... ('50) 30%
5 .... ('20) 26%
0 .... ('09) 18%

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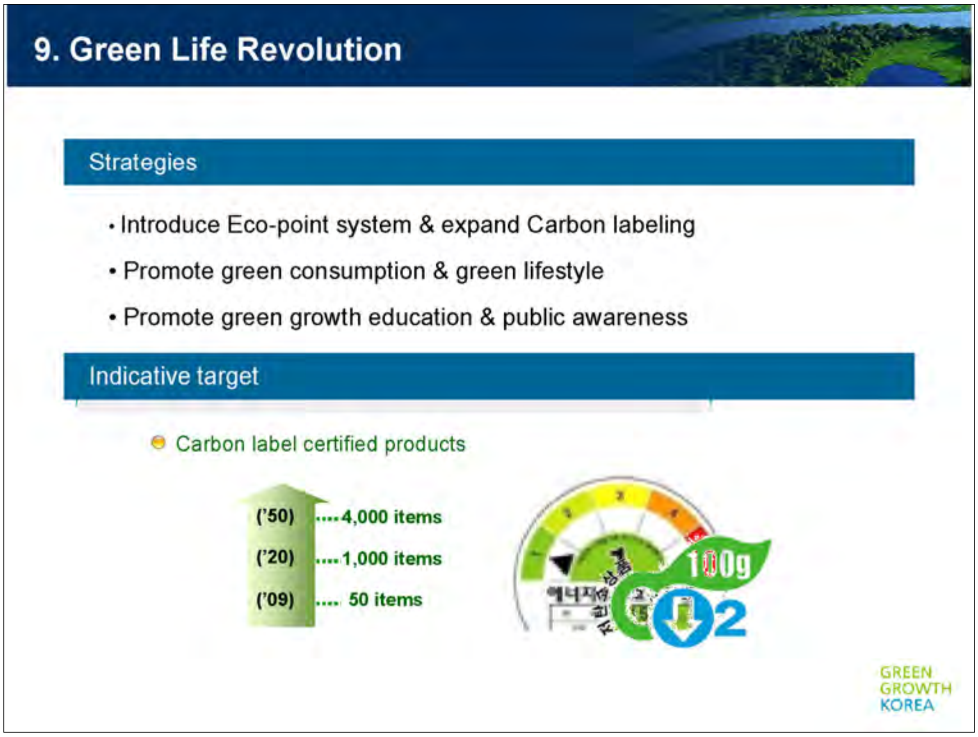

9. Green Life Revolution

Strategies

- Introduce Eco-point system & expand Carbon labeling
- Promote green consumption & green lifestyle
- Promote green growth education & public awareness

Indicative target

- Carbon label certified products

('50) ....4,000 items
('20) ....1,000 items
('09) .... 50 items

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10 Global Green Leader

Strategies

- Enhance int'l cooperation for green growth and climate action
- Increase Green ODA & support developing countries
- Build Green Hub Korea

Indicative target

Green ODA		EPI
40%	('50)	8th
30%	('20)	20th
14%	('09)	51st

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Challenges Ahead

Continued support from the public

- the key to success of Green Growth

Support from business community

- meeting its needs to adapt & change
- setting a price on target
  : emission trading & carbon tax

Green Growth is not an option but, the only option

Green Growth is not plan B, it's the Plan A

It is the strategy of change that jumps over the chasm

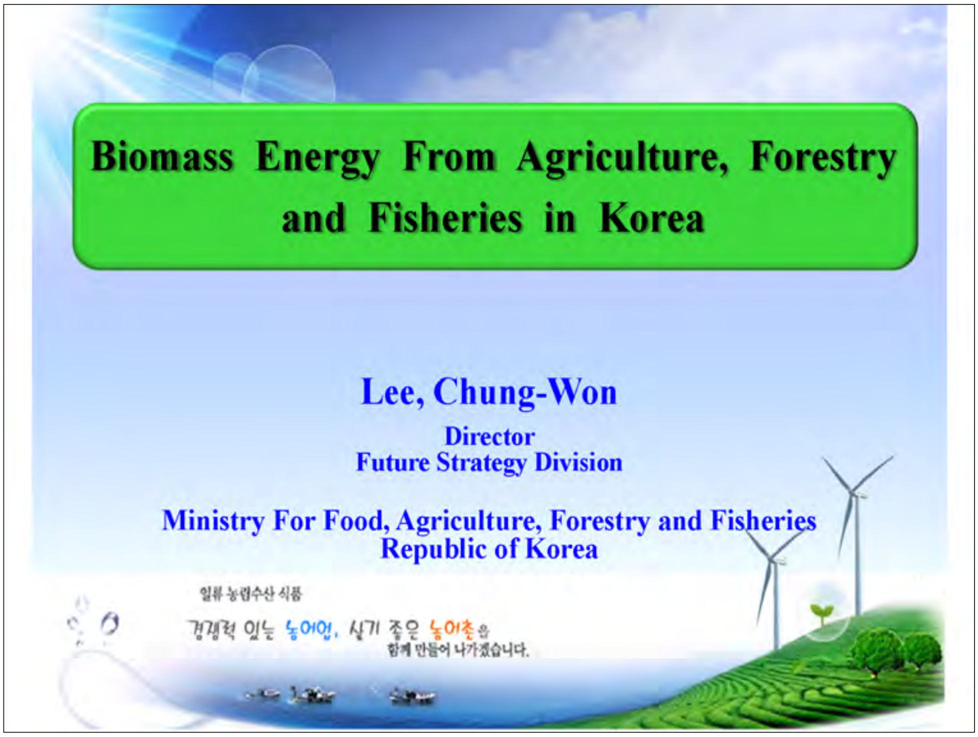
and it is a concept of creativity that opens all possibilities

2

Biomass Energy From Agriculture, Forestry and Fisheries in Korea

Mr. Chung-Won Lee

Director, Future Strategy Division, Ministry for Food, Agriculture, Forestry and Fisheries
Email : chwlee@korea.kr



Biomass Energy From Agriculture, Forestry and Fisheries in Korea

Lee, Chung-Won
Director
Future Strategy Division

Ministry For Food, Agriculture, Forestry and Fisheries
Republic of Korea

일류 농림수산 식품

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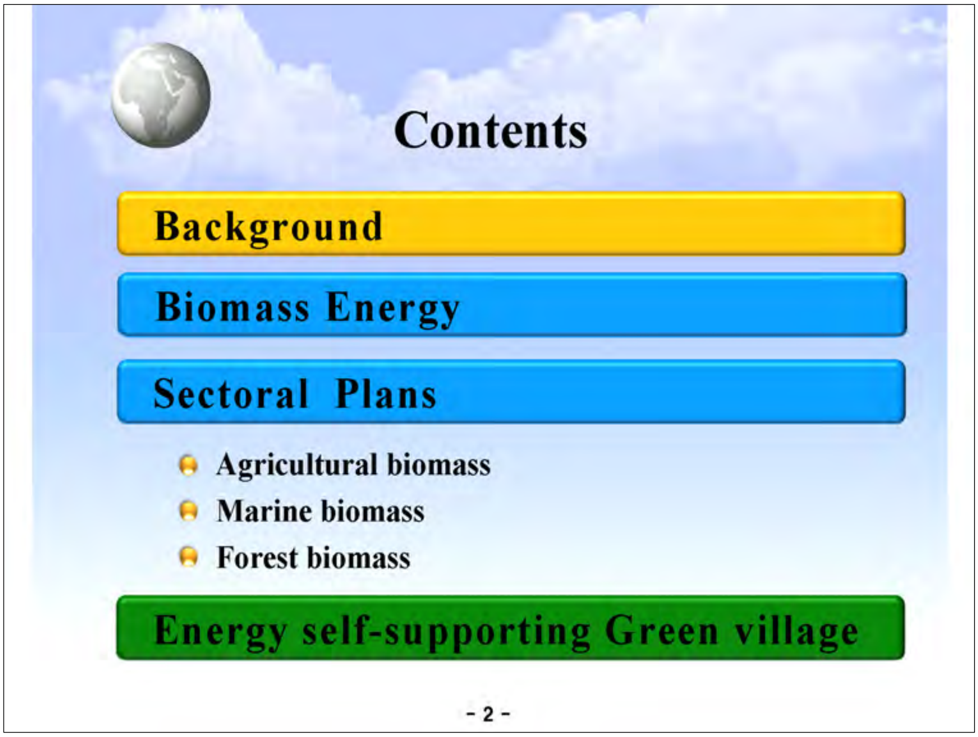
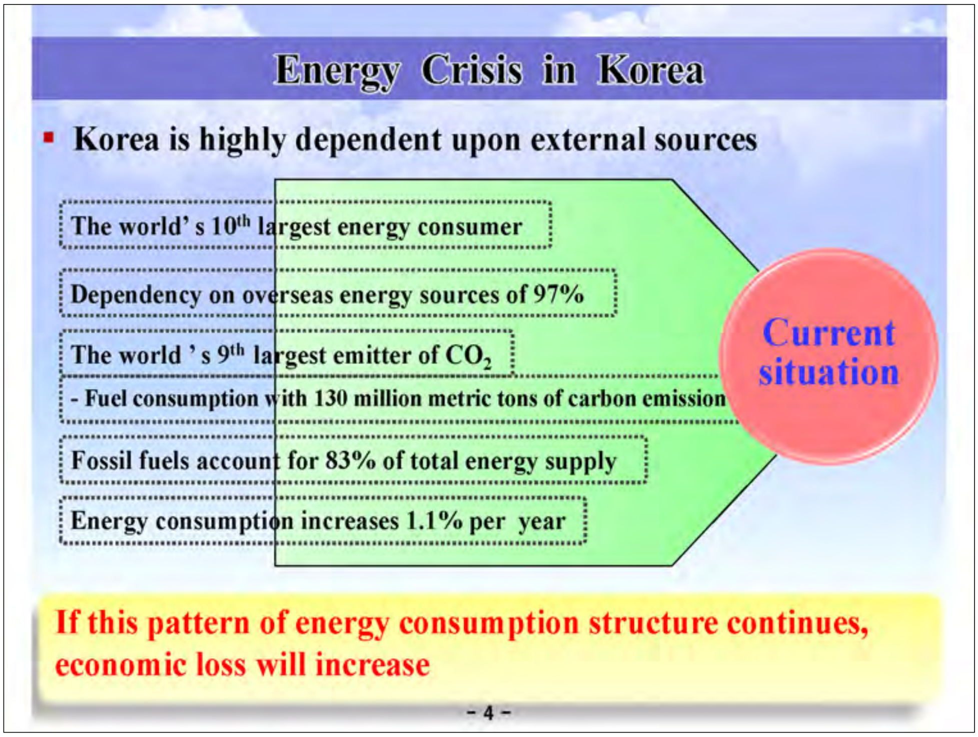


Contents

- Background
- Biomass Energy
- Sectoral Plans
  - Agricultural biomass
  - Marine biomass
  - Forest biomass
- Energy self-supporting Green village

Background



Energy Crisis in Korea

- Korea is highly dependent upon external sources

The world' s 10th largest energy consumer

Dependency on overseas energy sources of 97%

The world ' s 9th largest emitter of CO_2

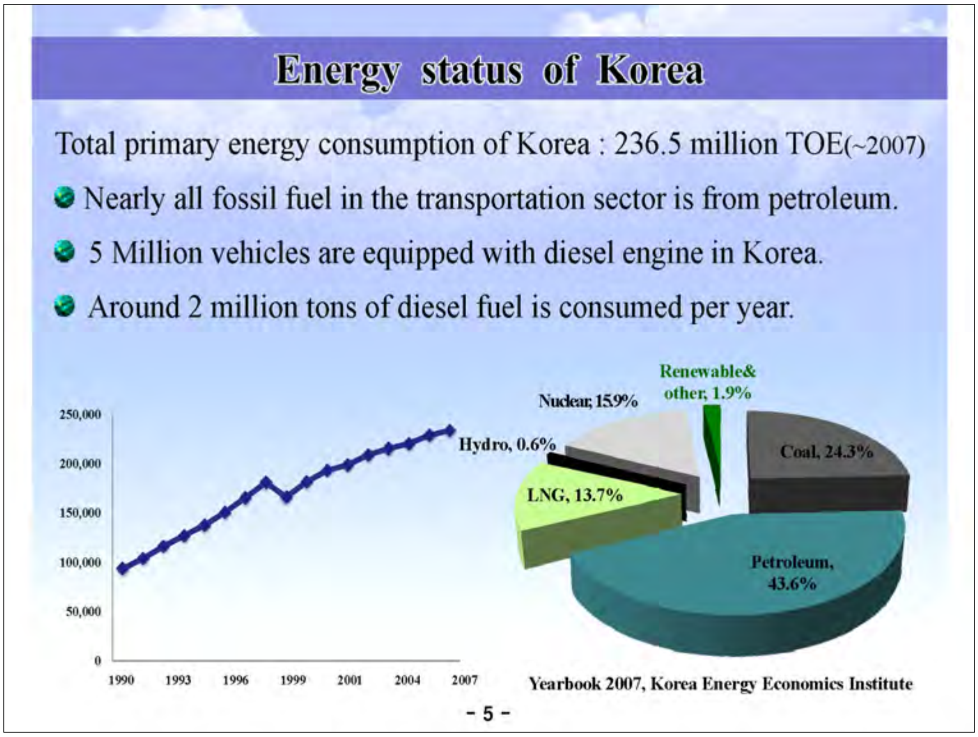
- Fuel consumption with 130 million metric tons of carbon emission

Fossil fuels account for 83% of total energy supply

Energy consumption increases 1.1% per year

Current situation

If this pattern of energy consumption structure continues, economic loss will increase

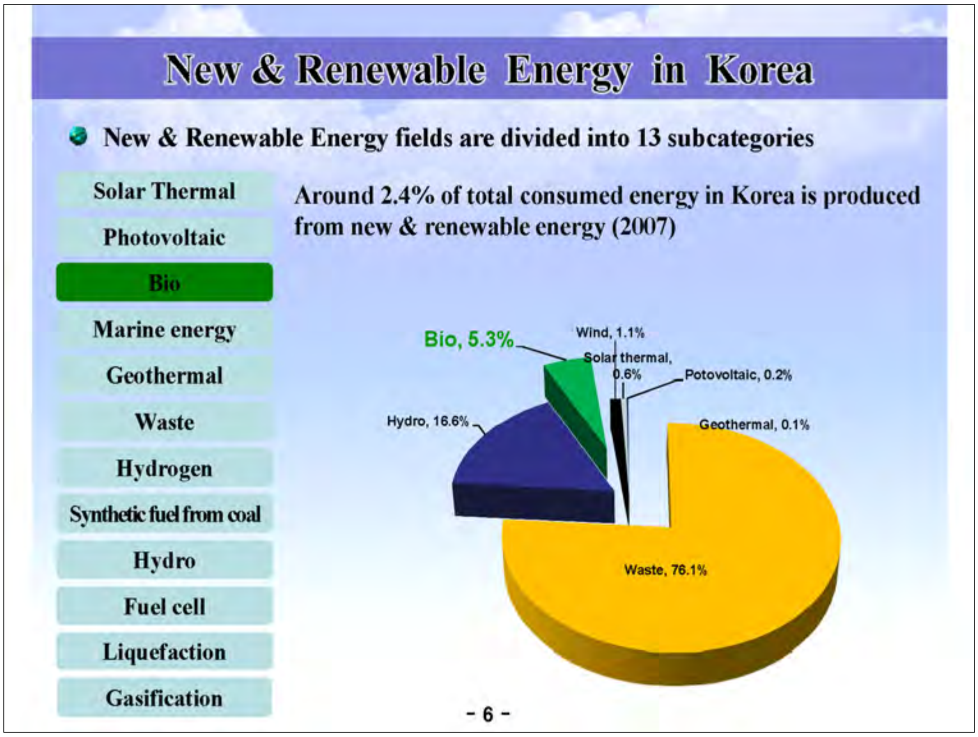


Energy status of Korea

Total primary energy consumption of Korea : 236.5 million TOE(~2007)

- Nearly all fossil fuel in the transportation sector is from petroleum.
- 5 Million vehicles are equipped with diesel engine in Korea.
- Around 2 million tons of diesel fuel is consumed per year.

Yearbook 2007, Korea Energy Economics Institute

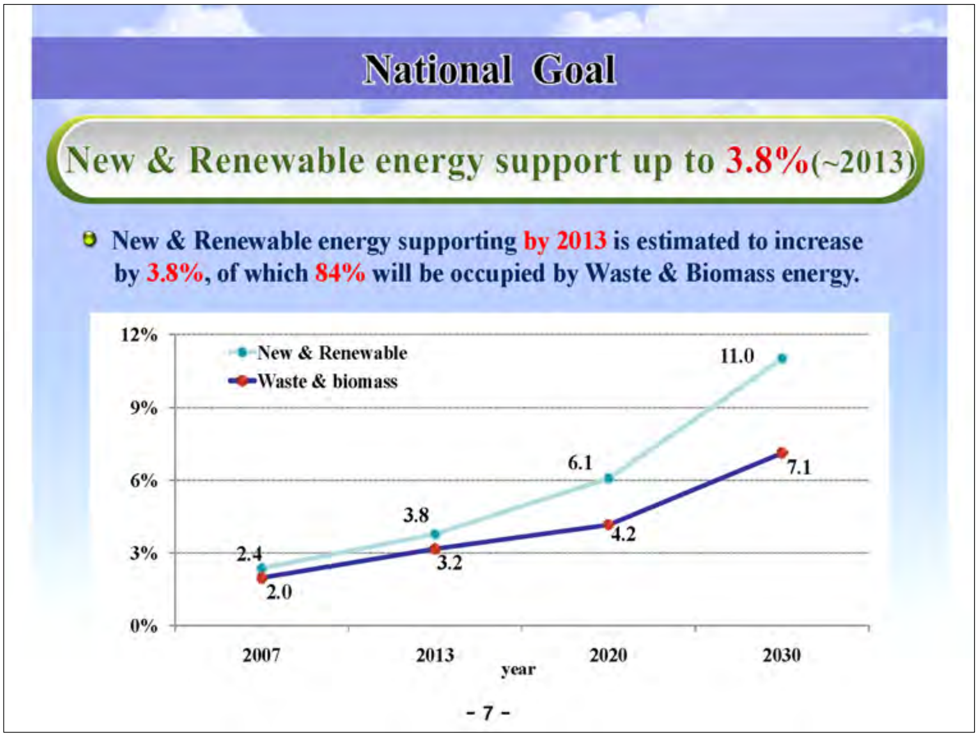


New & Renewable Energy in Korea

- New & Renewable Energy fields are divided into 13 subcategories

Solar Thermal
Photovoltaic
Bio
Marine energy
Geothermal
Waste
Hydrogen
Synthetic fuel from coal
Hydro
Fuel cell
Liquefaction
Gasification

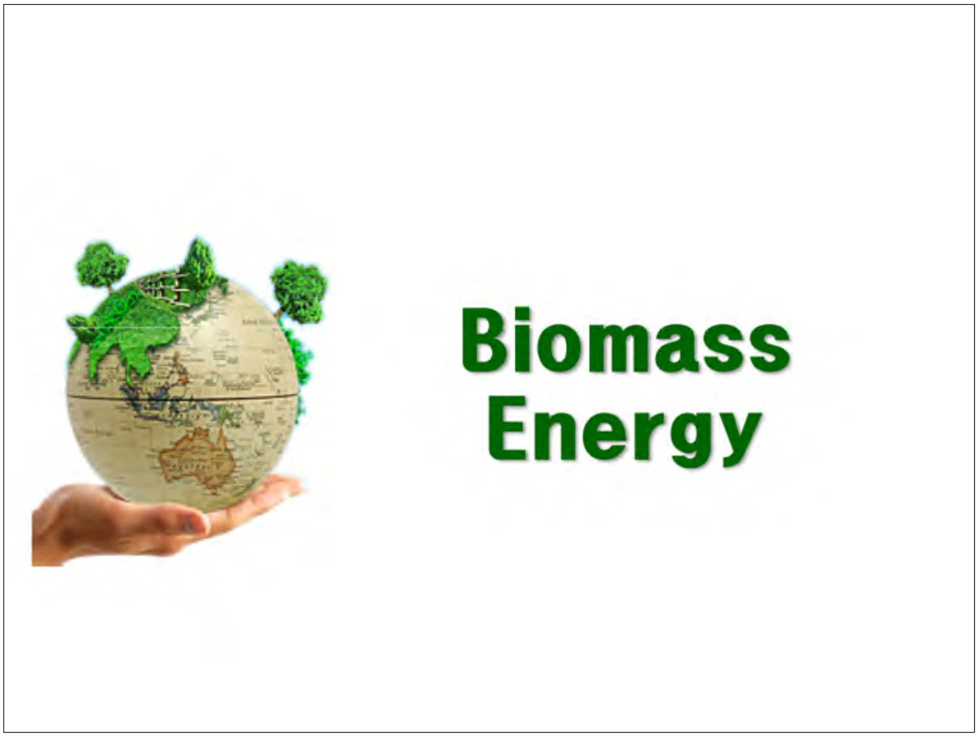
Around 2.4% of total consumed energy in Korea is produced from new & renewable energy (2007)



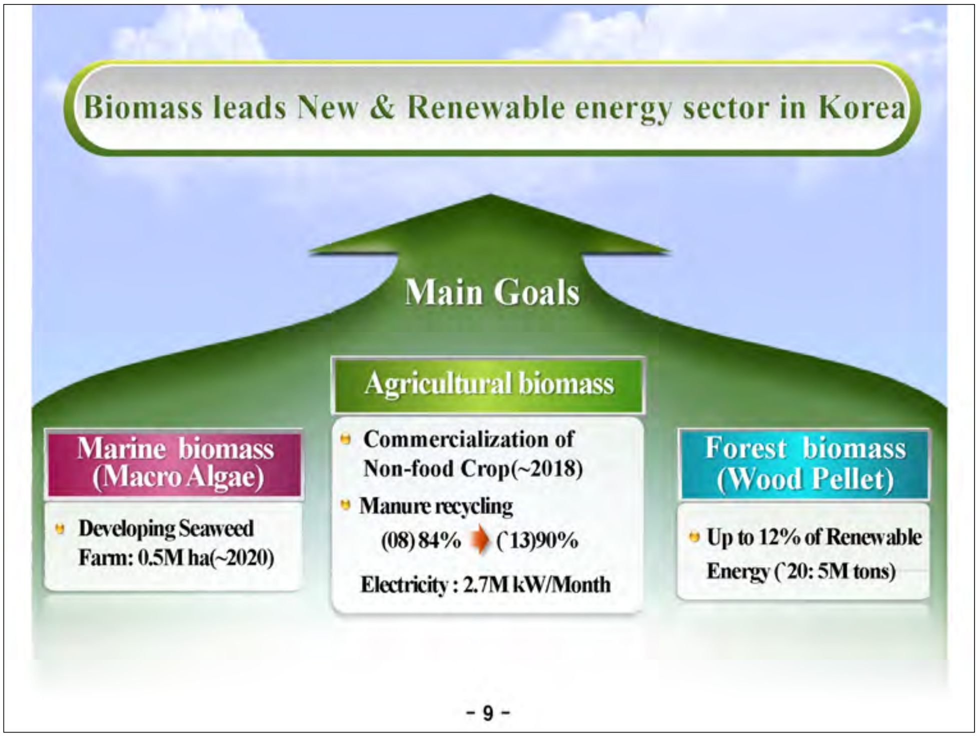
National Goal

New & Renewable energy support up to 3.8%(~2013)

- New & Renewable energy supporting by 2013 is estimated to increase by 3.8%, of which 84% will be occupied by Waste & Biomass energy.



Biomass Energy



Biomass leads New & Renewable energy sector in Korea

Main Goals

Agricultural biomass

- Commercialization of Non-food Crop(~2018)
- Manure recycling
  (08) 84% ➔ (`13)90%
  Electricity : 2.7M kW/Month

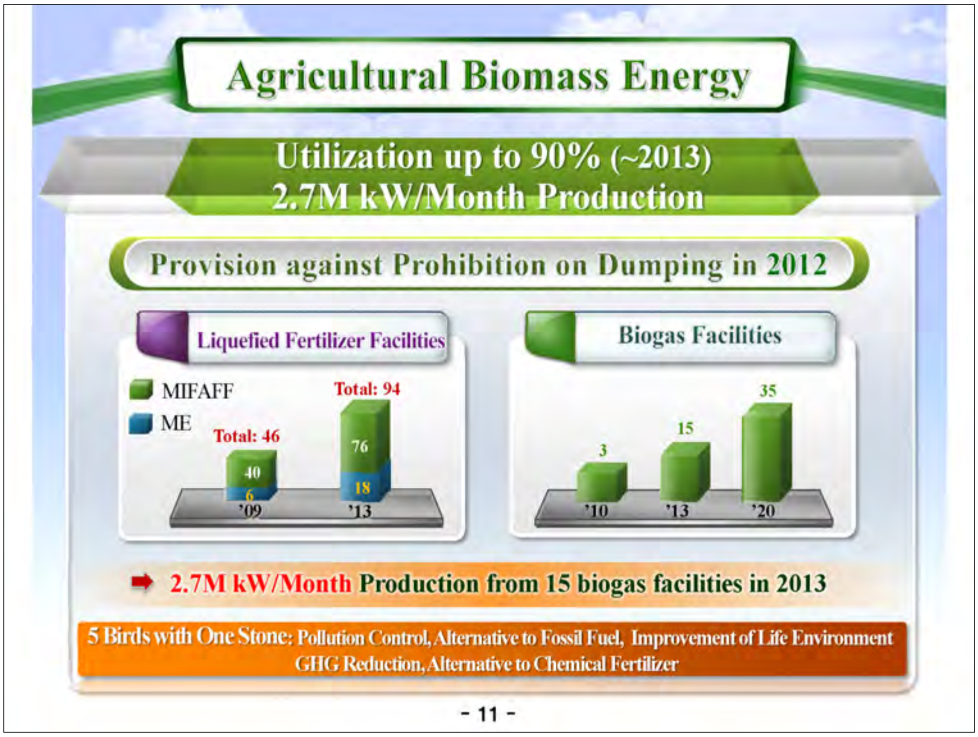
Marine biomass (Macro Algae)

- Developing Seaweed Farm: 0.5M ha(~2020)

Forest biomass (Wood Pellet)

- Up to 12% of Renewable Energy (`20: 5M tons)

Sectoral Plans



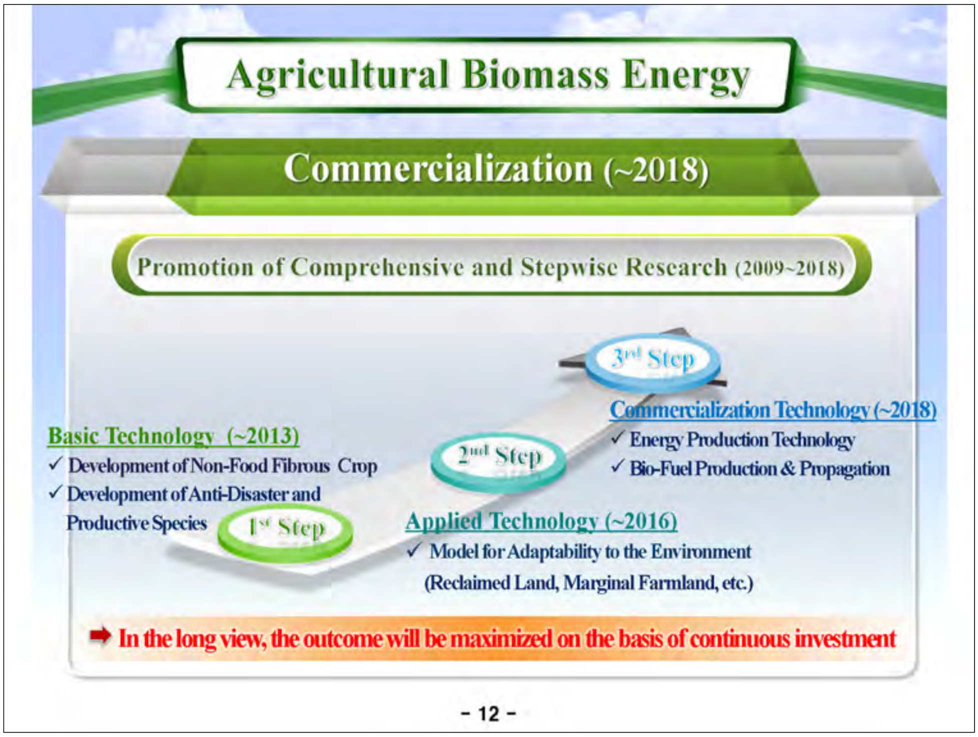
Agricultural Biomass Energy

Utilization up to 90% (~2013)
2.7M kW/Month Production

Provision against Prohibition on Dumping in 2012

➡ 2.7M kW/Month Production from 15 biogas facilities in 2013

5 Birds with One Stone: Pollution Control, Alternative to Fossil Fuel, Improvement of Life Environment GHG Reduction, Alternative to Chemical Fertilizer



Agricultural Biomass Energy

Commercialization (~2018)

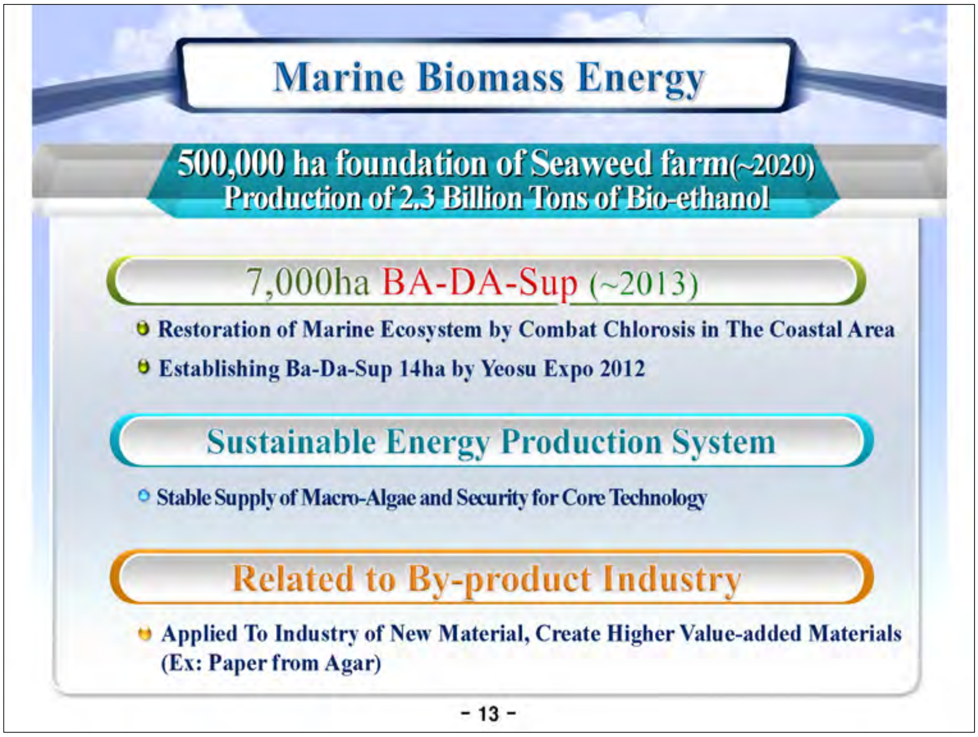
Promotion of Comprehensive and Stepwise Research (2009~2018)

Basic Technology (~2013)
- ✓ Development of Non-Food Fibrous Crop
- ✓ Development of Anti-Disaster and Productive Species

Applied Technology (~2016)
- ✓ Model for Adaptability to the Environment (Reclaimed Land, Marginal Farmland, etc.)

Commercialization Technology (~2018)
- ✓ Energy Production Technology
- ✓ Bio-Fuel Production & Propagation

➡ In the long view, the outcome will be maximized on the basis of continuous investment



Marine Biomass Energy

500,000 ha foundation of Seaweed farm(~2020)
Production of 2.3 Billion Tons of Bio-ethanol

7,000ha BA-DA-Sup (~2013)

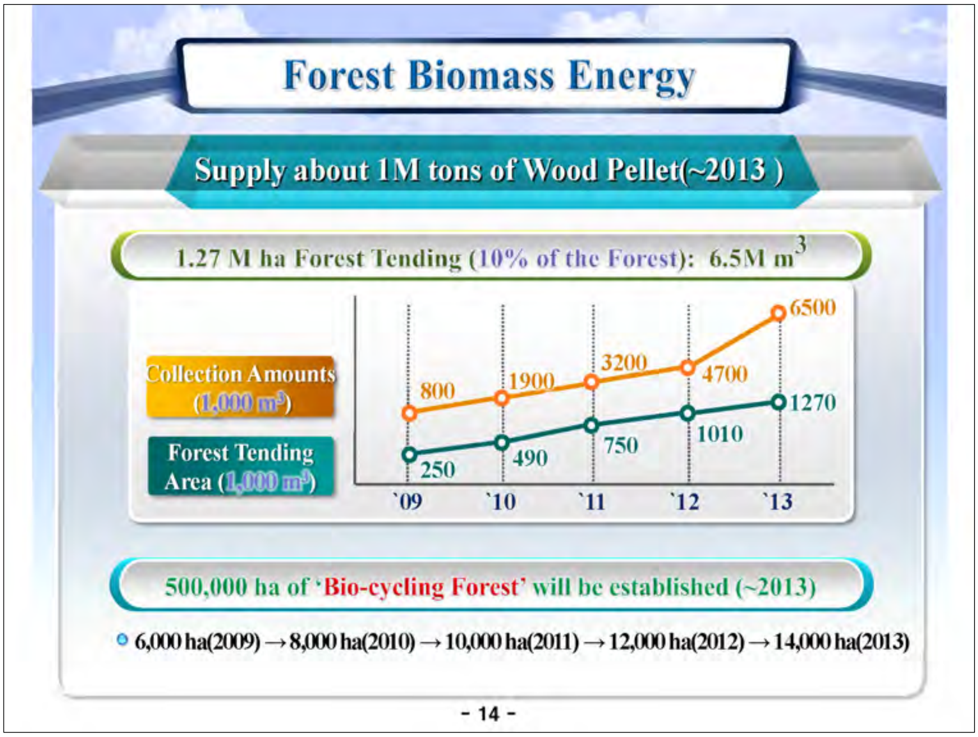
- **Restoration of Marine Ecosystem by Combat Chlorosis in The Coastal Area**
- **Establishing Ba-Da-Sup 14ha by Yeosu Expo 2012**

Sustainable Energy Production System

- **Stable Supply of Macro-Algae and Security for Core Technology**

Related to By-product Industry

- **Applied To Industry of New Material, Create Higher Value-added Materials (Ex: Paper from Agar)**



Forest Biomass Energy

Supply about 1M tons of Wood Pellet(~2013)

1.27 M ha Forest Tending (10% of the Forest): 6.5M m^3

500,000 ha of 'Bio-cycling Forest' will be established (~2013)

- 6,000 ha(2009) → 8,000 ha(2010) → 10,000 ha(2011) → 12,000 ha(2012) → 14,000 ha(2013)

Wood Pellet Facilities Supply Plan

	2009	2010	2011	2012	2013	Total
Pellet Mill (Unit)	5	8	8	10	10	41
Pellet Boiler (Unit)	3,000	4,000	10,000	10,000	10,000	37,000

Wood Pellet and Boiler supply plan

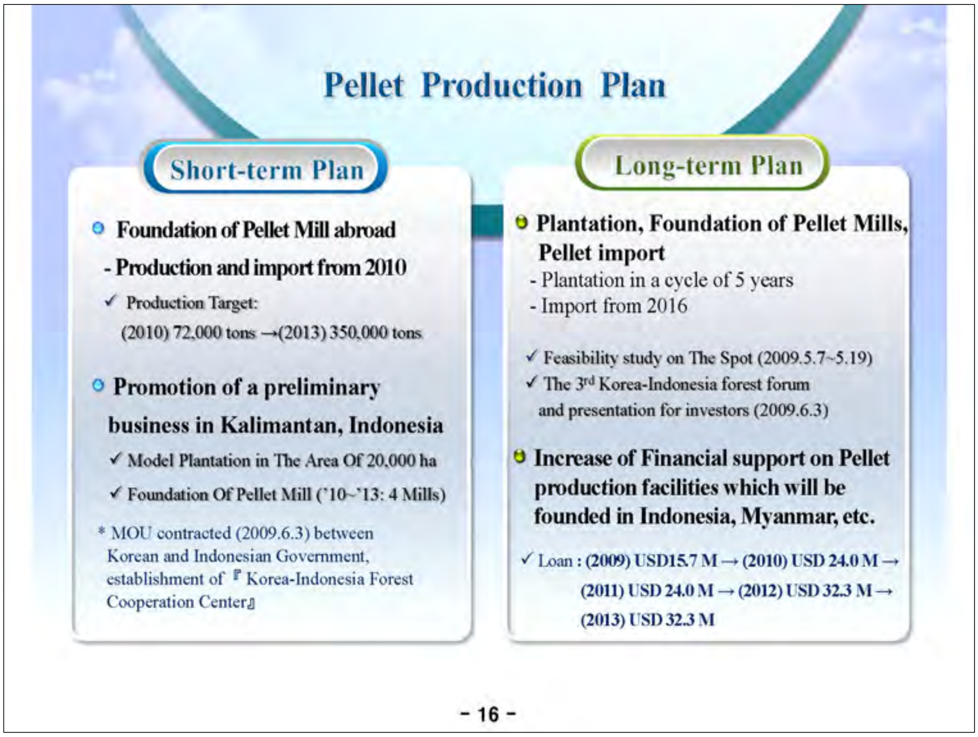
➡ 30(2009) → 190(2010) → 400(2011) → 750(2012) → 870(2013) (unit : 1,000 tons)

- 500,000 tons of Pellet For Greenhouse Floriculture Plants (20% of fuel use in GFP)
- 370,000 tons of Pellet For Houses in Farming and Forest Area (7% of fuel use in the houses)

➡ New installation or replacement of Pellet Boiler for Greenhouse Floriculture Plants from 2010

Preliminary Co-Firing Test In A Power Plant

- '09 .7~9: Dong-Hae Heating Power Plant, Korea



Pellet Production Plan

Short-term Plan

- **Foundation of Pellet Mill abroad**

  - Production and import from 2010

  ✓ Production Target:
  (2010) 72,000 tons →(2013) 350,000 tons

- **Promotion of a preliminary business in Kalimantan, Indonesia**

  ✓ Model Plantation in The Area Of 20,000 ha

  ✓ Foundation Of Pellet Mill ('10~'13: 4 Mills)

* MOU contracted (2009.6.3) between Korean and Indonesian Government, establishment of 『Korea-Indonesia Forest Cooperation Center』

Long-term Plan

- **Plantation, Foundation of Pellet Mills, Pellet import**
  - Plantation in a cycle of 5 years
  - Import from 2016

  ✓ Feasibility study on The Spot (2009.5.7~5.19)

  ✓ The 3rd Korea-Indonesia forest forum and presentation for investors (2009.6.3)

- **Increase of Financial support on Pellet production facilities which will be founded in Indonesia, Myanmar, etc.**

  ✓ Loan : (2009) USD15.7 M → (2010) USD 24.0 M → (2011) USD 24.0 M → (2012) USD 32.3 M → (2013) USD 32.3 M

Energy self-supporting Green village

Energy self-supporting Green village

(Cooperation With Ministry Of Knowledge Economy)

What is Energy self-supporting Green village ?

Farming or Fishing Village
- Scrap Materials, Biomass
- Solar, Wind, Hydro Power

- Systematical and Comprehensive Energy Use
- Energy saving and Energy Efficiency Improvement in Rural Village
  → **Energy self-Supporting Green village**

3

Bioenergy in New Zealand

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Abstract

This paper examines strategies of national energy policy, focusing on measures for increasing the use of bioenergy in the New Zealand. A major driver of growth in bioenergy usage, including biofuels, in New Zealand isclimate change policy. Major New Zealand export sectors such as dairy, meat and forest products will be under pressure to reduce their 'carbon footprint' and counter food-mile arguments by addressing 'hotspots' such as use of coal and natural gas in process heat. The government can influence changes in three principal areas of the energy system: energy use, industrial structure, and energy production. The tools the government may use to exert its influence are: support to research and development, support to demonstration and information dissemination, administrative policy measures, and economic incentives. These instruments may be applied separately or in combination.

The paper also examines the short- and long-term prospects for increasing the share of bioenergy in New Zealand's energy supply, and the policy implications. Bioenergy has played a small role in the New Zealand energy balance so far, accounting for about 7 per cent of the total consumer energy, mainly as process heat. Electricity from cogeneration forms a significant but small proportion of energy production from woody biomass.

The paper concludes that there are opportunities to significantly increase use of biomass as an energy source. New Zealandhas a renewable and sustainable plantation forestry resource. It is underpinned by an excellent climate for growing biomass, downstream processing industry, and technological capabilities. New Zealand has also extensive marginal land available that may not being optimally used or maynot sustainable is pastoral farming. However, there is a need of acoherent and effective policy for supporting the bioenergy development in New Zealand.

Keywords: Renewable energy,biofuels; New Zealand; bioenergy policy.

Introduction

Energy is one of the main challenges that mankind is currently facing, particularly because of the need to address climate change and the dwindling oil and gas resources. Current trends in energy supply and consumption are environmentally, economically and socially unsustainable (IEA 2008a). The world is looking for a pathway for the energy sector to achieve a transition to a low-carbon world.

Bioenergy can make a substantial contribution to supplying future energy demand and help the world to move to a low carbon world. It is presently the largest global contributor of renewable energy, and has significant potential to expand in the production of heat, electricity, and fuels for transport (IEA 2009).

In developing countries, bioenergy has always been a dominant household energy source. It is a dominant source of energy for a large section of the world’s population who are living in extreme poverty and use this energy mainly for cooking. For some 2.4 billion people it is the only energy option (FAO 2007). Bioenergy is also an important option in industrialized countries because it is based on locally available, renewable and environmentally friendly raw materials.

In New Zealand bioenergy is seen as part of the solution to climate change, as a renewable source of energy, as well as providing opportunities for the agriculture and forestry sectors in the country. At the same time, it is apparent that the sustainable use of bioenergy requires balancing many factors, including the competing uses of land and water resources, impacts on the environment, biodiversity and others factors.

This paper provides an overview of bioenergy in New Zealand. The paper also examines the current and future prospects for increasing the share of bioenergy in New Zealand's energy supply. It also discusses the bioenergy research efforts and polices to promote bioenergy in New Zealand.

Bioenergy in New Zealand

Bioenergy plays a relatively small role in fulfilling consumer energy demand in New Zealand. In 2008, it contributed just over 7 percent of New Zealand’s total consumer energy of 503 PJ. Consumer energy in New Zealand is dominated by oil at 50% of the total. This is followed by renewable at 28%, gas at 14% and coal at 8%. More than 65 percent of electricity comes from renewable sources like hydro (52 percent), geothermal, wind and biomass. Figure 1 below illustrates the New Zealand’s consumer energy supply by fuel type including bioenergy.

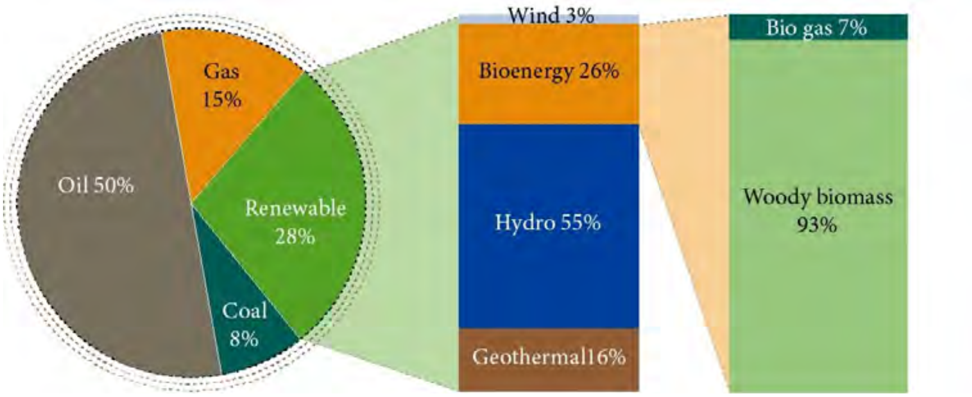


Figure 1: Total consumer energy by fuel in New Zealand
(Source: Ministry of Economic Development, 2009).

Bioenergy accounts for about 26% of the total renewable energy in New Zealand. At present, forestry residues, and wastes are the main feedstocks for the generation of bioenergy, mainly process heat and likely to remain the main feedstock in the future. Therefore this paper focuses on forestry residue. In addition, a very small share of tallow, whey and vegetable oil crops are used as feedstocks for the production of liquid biofuels.

Woody biomass direct use is mainly in the timber industry, which burns residue wood to provide heat energy. Wood is also burned to heat many private homes in New Zealand. A small amount of biogas extracted from wastewater treatment plants and landfills is also used in specific scenarios as a fuel source for vehicles and other machinery.

The latest international comparisons show New Zealand has the third highest percentage of renewable primary energy supply of all OECD countries, behind only Norway and Iceland (IEA 2008b). New Zealand's historically high level of renewable primary energy is largely due to plentiful hydro and geothermal resources. In recent times, there has also been considerable interest and uptake in the use of wind, bioenergy and solar resources.

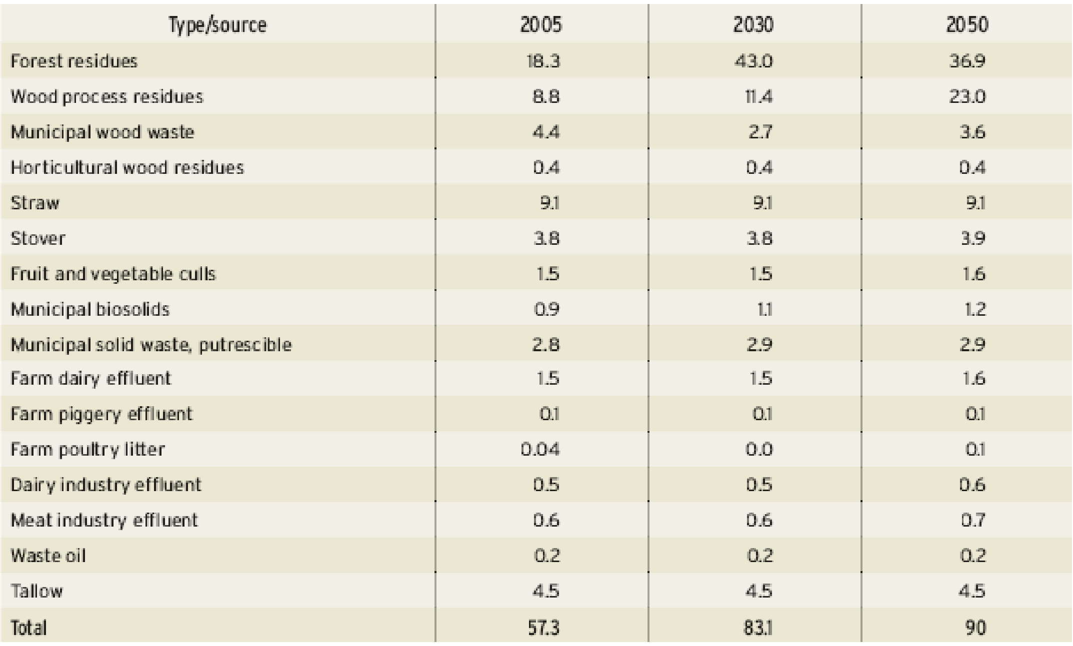
Current situation and future potential

Bioenergy has been an important energy source for process heat, and in some cases for co-generation of heat and electricity in New Zealand. There is significant potential to expand its contribution to New Zealand's energy future. A recent study suggests that New Zealand has the potential to fuel itself from renewable resources (SCION 2007).

New Zealand has a variety of biomass resources suitable for energy production which arise from forestry, agriculture, processing and municipal sources. Forestry residues are the single largest resource for bioenergy in New Zealand followed by agriculture residues. Tallow could potentially make a significant contribution to the production of liquid biofuel, but there is competition for the resource, with the bulk of it already being sold, much of it for export. Gas from municipal waste could also make a contribution of several PJs. Effluents and biosolids come from a variety of sources and are widely dispersed around New Zealand.

The contribution that various resources could make to New Zealand's energy demand is illustrated in the following table.

Table 1: Total possible residual biomass resource for energy production (PJ/year)



Type/source	2005	2030	2050
Forest residues	18.3	43.0	36.9
Wood process residues	8.8	11.4	23.0
Municipal wood waste	4.4	2.7	3.6
Horticultural wood residues	0.4	0.4	0.4
Straw	9.1	9.1	9.1
Stover	3.8	3.8	3.9
Fruit and vegetable culls	1.5	1.5	1.6
Municipal biosolids	0.9	1.1	1.2
Municipal solid waste, putrescible	2.8	2.9	2.9
Farm dairy effluent	1.5	1.5	1.6
Farm piggery effluent	0.1	0.1	0.1
Farm poultry litter	0.04	0.0	0.1
Dairy industry effluent	0.5	0.5	0.6
Meat industry effluent	0.6	0.6	0.7
Waste oil	0.2	0.2	0.2
Tallow	4.5	4.5	4.5
Total	**57.3**	**83.1**	**90**

Source: Adapted from SCION 2007

Wood residue from all sources are currently over half of the total biomass resource in terms of energy content which is likely to increase to 65 percent by 2050.

In the short to medium term, the large volumes of unused logging and wood processing residues could be utilised. In the medium to long term, lignocellulosic crops (both herbaceous and woody) could be produced on marginal, and degraded lands and provide the bulk of the biomass resource.

Woody resources

Wood residues arising from forest harvesting and wood processing provide an important bioenergy resource for producing heat, electricity and, potentially, fuel for transportation. Common fuel options include wood chips for industrial heat, or converting chips into wood pellets for space heating. Many wood processing plants use wood processing residues as boiler feedstock. The future use could be directed towards liquid biofuels production provided it becomes commercially viable.

Wood residues from forests

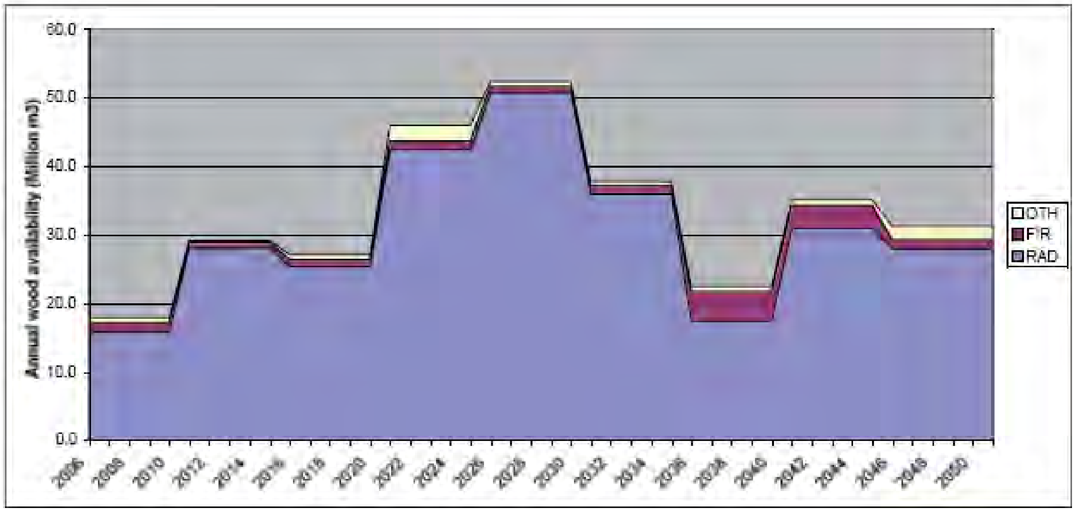
There are 1.8 million hectares of plantation forests, which cover 7 percent of New Zealand’s land area. Plantation forests are dominated by radiata pine (89 percent by area). In the year ended March

2008, 20.6 million cubic metres of roundwood were harvested in New Zealand, of which 99.9 percent came from plantation forests.

The forests contain a large resource of woody biomass that has potential to be used for bioenergy. Residues from routine harvesting operations offer a significant resource that is already available. The use of these harvesting residues potentially creates a new value stream for forest growers.

About 250,000 tonnes of residues are currently collected and used by wood processing facilities. This is approximately about 7 percent of the total residue resource. The economics of this use are driven by the proximity of wood-burning heat and power plants. The users are commonly large scale operations (both forest production and energy use), who have access to off-highway transport networks with low transport distances. Their use of forest residues is also driven by environmental or economic pressures to remove residues from the site where it is originally produced and/or address fuel shortages.

The availability of forest residues over the next 30 years will be largely determined by the current extent and age of plantations together with the rotation age. The Figure 2 below illustrates the potential wood availability until 2050.



(Source: SCION 2007)

Figure 2: Annual wood availability forecast

Forests planted in the 1990s will start maturing in the 2020s and there will be a huge increase in the harvest; this situation is popularly called the ‘wall of wood’ in New Zealand. This harvest will contribute to the bulk of residues. Woody residues from harvesting are estimated to peak around 5 million tonnes in 2025-30. The wide distribution of forests throughout New Zealand means that some of the resource is available in many regions. Woody resources can cater a range of demands from small to large scale plants.

The factors limiting the development of this resource are the cost of transportation to heat plants, the cost of storage and the lack of appropriate infrastructure to collect the waste material from harvest sites. For example, processing and transport make up the bulk (60 to 70%) of the costs to recover and deliver forest residues to plants. Other issues and barriers that need to be addressed include guarantee of supply, integrating the residue operation with the conventional harvesting system, and environmental issues such and nutrient removal.

Wood processing residue

The wood processing industry is one of the largest users and producers of Bioenergy in New Zealand. The use within the industry is driven by the fact that wood processors have a large demand for heat and electricity.

New Zealand sawmills and other processors produce about 4 million tonnes of wood residue arising from debarking and primary breakdown operations. Approximately 3 million tonnes of this is used in other wood processing or for bioenergy.

If processing increases, volumes of wood residues will rise, enhancing the potential for bioenergy production. While volumes of processed wood are increasing in New Zealand, they are not keeping pace with increases in the wood available for harvesting. The processing industry may not be able to handle the coming ‘wall of wood’ and the future does not appear to be optimistic. There has not been any significant investment in wood processing in New Zealand during the last decade and low profitability has been a constraint on processing investment (MAF 2009)

Municipal wood waste

Over 500,000 tonnes of woodwaste are dumped into landfills each year in New Zealand. These include green waste from gardens, and timber waste arising from construction and demolition activities. This municipal wood waste represents a potential resource for bioenergy options as incentives are put in place to reduce volumes going landfills.

The main issue that limits the use of municipal woody biomass in New Zealand is resource quality (moisture content and contaminants). Overall it is likely that the municipal wood waste resource will have lower energy content than wood from forests or wood processing sources due to higher levels of moisture and contamination.

Purpose grown forestry crops

The total amount of energy available from residual biomass is relatively small (around 10%) in comparison to total energy demand. There is a potential to grow medium- to long-rotation forests on marginal lands in New Zealand without competing for land with food crops. According to SCION (2007) an estate of 700,000 ha would be required to meet the country's total heat demand. To meet the liquid fuels demand a further 2.5 to 2.8 million ha would be needed.

Use of biomass from forests (including purpose grown forests) to produce biofuels has fewer environmental concerns than intensive cropping of arable land because forests do not:

- require intensive fertilisation;
- require irrigation;
- cause nutrient rich run-off;
- compete for high value land used for production of food crops such as corn, wheat and vegetables; and they provide a range of environmental services including water quality, soil conservation and biodiversity.

Forests also provide an energy store that can be used when required or processed into other valuable products. New Zealand has at least 830,000 ha that could be cost effectively used for forestry. A combined energy forest estate of approximately 3.2 million ha could provide most of New Zealand's heat and liquid fuel demand. This is achievable based on the amount of marginal and lower quality grazing land available.

The major constraints to energy forests are land use competition and the costs of growing and harvesting. They have to compete with oil, coal and electricity. The economics of bioenergy for heat production are currently marginally attractive against gas and coal even with the avoided cost of waste disposal. The relative costs may change significantly in favour of bioenergy as fossil fuel prices increase over the next few years in response to the supply constraint and climate change policies.

The issue of tree health must also be carefully managed to avoid resource collapse if the genetic base is not kept robust. Plantings of mixed clones are required to avoid total crop failure from a new insect or disease outbreak. Wastewater systems could be used for energy forests. Uncertainty around the future of planned development is mainly due to the lack of commercially proven conversion technology.

However the biggest challenge for the liquid biofuel is to compete with fossil fuel. Most of the commentators suggest that liquid biofuels from woody biomass is at least a decade away from being commercially viable.

Bioenergy research in New Zealand

The New Zealand Government is committed to utilising our international energy relationships to help facilitate the swift uptake of new energy technologies, particularly second generation biofuel technologies. New Zealand does not have the resources to undertake the fundamental research in this area but the local industry has been establishing strategic partnerships to ensure the country can use this developing technology.

Most of the bioenergy research in New Zealand if funded by the government. A crown research institute SCION leads bioenergy research in New Zealand. Its current research is mainly focused on woody biomass and involves initiatives across the whole production chain, from resource establishment through to conversion into consumer energies.

SCION has recently completed a resource assessment of the woody biomass resources in New Zealand. It has developed a Geographic Information Systems model of biomass recovery, which enables the assessment of (current and future) potential feedstock volumes and delivered costs to a centralized energy plant. The model can also be used to optimise resource establishment and plant scale and siting. Scion has also been involved in a number of life-cycle assessment studies of the environmental impacts of biomass to energy pathways.

A research programme, the New Zealand Lignocellulosic Biofuel Initiative, aims to develop a bioethanol pilot plant based on New Zealand’s softwood feedstocks. This research programme is focused on the pre-treatment phase of the bioethanol conversion process, with the aim making wood fibres more susceptible to enzymatic conversion and maximizing co-product potential. Scion has partnered with a number of international industry partners in this programme including Verenium Inc, a US company.

SCION is also working on the biorefinery concept, where high value products are produced in addition to fuels, analogous to a petroleum refinery.

Other current research at SCION involves the development of novel thermo-chemical processes to enhance the energy generation from municipal waste and woody-biomass resources.

LanzaTech New Zealand Ltd, a privately owned company, is working on developing an ethanol production process that can be retrofitted to industrial facilities to produce ethanol from the carbon monoxide component of waste flue gases. This biotechnology research and development company is working to develop a technology to use microbes to convert carbon monoxide and other industrial gases into ethanol. It is also developing technology for gasification of biomass then via fermentation to make ethanol. Lanzatech is working with Range Fuels in Colorado, USA.

Pure Power Global, a Hong Kong based company with interests in New Zealand, is looking to develop a second generation ligno-chemical process using short rotation as the feedstock. Pure Power owns the BioJoule technology developed by a New Zealand company Genesis R&D.

Another crown research institute, National Institute of Water and Atmospheric Research (NIWA) and a private company Aquaflow Bionomic Corporation are working on algae. Aquaflow Bionomic has set itself the objective to be the first company in the world to economically produce biofuel from wild algae harvested from open-air environments. It is focussed on advanced technologies for biofuel production other than traditional methods producing methyl ester biodiesel. NIWA has a project for conducting algae to biofuel scaled-up pre-commercial trials. NIWA has taken two approaches:

i. Production of algae from wastewater, followed by harvesting and "total biomass" conversion.
ii. Production of biogas from wastewater sludge and algal biomass. .

Taharoa C Block, a Maori company, is aiming to develop a biofuel production business using miscanthus grass as the feedstock. It hopes to partner with a specialist lingo-cellulosic to bio-fuel producer to build a facility. At the moment it has 30,000 Micanthus plants in a greenhouse in New Zealand.

Government policies and programmes to encourage bioenergy

Bioenergy policy is a subset of the energy policy which is shaped by the wider economic and climate change policies. The 2007 National Energy Strategy (currently under review) encourages the clean and efficient use of bioenergy. The 2007 National Energy Efficiency and Conservation Strategy set targets for bioenergy. These targets encourage the uptake of forestry residue left over from forest harvesting operations and wood pellets, firewood, fire-logs and wood chips in residential and commercial wood burners.

The government has several programmes to promote bioenergy. These include:

- Research funding – The government provides research funding for bioenergy research through the Foundation of Research Science and Technology.
- Pre-commercial grant - A ‘Low Carbon Energy Technologies Fund’ has been established to support renewable energy technologies that are at the demonstration and pre-commercial deployment phases.
- Capital grants, information and demonstration funding for woody biomass projects – Forestry Industry Development Agenda (FIDA) provides capital grants for woody biomass projects to overcome information and financial barriers to the uptake of woody biomass.
- Grants for woody biomass projects are also available through the Energy Intensive Businesses programme.
- Pilot scheme to convert school coal-fired boilers to woody biomass – In 2007 a pilot programme was launched this year to convert 30 coal-fired school boilers to woody biomass fuels.
- In May 2009, the Government announced a grant program for biodiesel production to help kick start the industry. The program makes grants available to domestic biodiesel producers.
- Bioenergy projects are also eligible for funding from a recently announced NZ$ 70 million per annum Primary Partnership Growth fund.
- Working with and supporting renewable energy industry associations to promote woody biomass.

In addition, the Ministry of Agriculture and Forestry has established two biochar professorial positions to encourage further research which could lead to applications in biochar and bioenergy co-production.

The Government considers liquid lingo-cellulosic biofuels industry is a long-term energy option for New Zealand that meets its economic and climate change policy goals. However, it will require careful consideration by government, research agencies and the forestry sector.

Conclusion

The bioenergy industry is still in its infancy and considerable research is needed to bring the cost down to a level where it can compete effectively with fossil fuel. There are opportunities to significantly increase New Zealand’s use of biomass as an energy source. This could be supported New Zealand’s extensive land availability that is not being used for food production or is not sustainable in pastoral farming.

New Zealand has renewable and sustainable plantation forestry resource. It is underpinned by an excellent climate for growing biomass and a down-stream processing industry. It provides us with an opportunity to increase bioenergy from wood and wood residue from wood harvesting and processing. We need to realise this renewable resource to create a more sustainable energy system. Possible approaches include:

- increase support for R&D on bioenergy relating to breeding, production , harvesting and transport of woody biomass;
- support strategic research on 2nd generation biofuels;
- develop opportunities in areas such as solid wood energy for industrial process heat and bioenergy and bio-char co-production
- A supportive regulatory and standards-setting process for bioenergy;
- ensure that the negative environmental effects of GHG emissions (and value of replacing it with renewable energy technologies) are reflected in investment decisions and product prices;
- introduce measures to check negative environmental impacts of biofuels on soil, water and overall GHG emissions; and
- consider possible impacts on other sectors and trade-offs between different land use options.

Acknowledgement

The section on ‘Current situation and future potential’ has largely been drawn from SCION (2007).

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Session
Ⅱ

1. Biomass Strategy and Biomass Town Project in Japan
2. German Biogas Success Story and the Requested Political Framework
3. Opportunities for Biogas Capture and Use from Animal Waste Management

1

Biomass Strategy and Biomass Town Project in Japan

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Summary

The government of Japan developed Biomass Nippon (Japan) Strategy to promote utilization of biofuels and Biomass Town Project. Biomass Town is a community which comprehensively utilizes local biomass resources. "East Asia Biomass Town Concept Promotion Project" is also in progress based on global needs for sustainable biomass usage.

Introduction

Using crops, such as sugar beets and corn, as raw materials of biofuels triggers rising food prices in the world. Biofuels are thought to be carbon neutral. However, it is pointed out that resource production, transportation and manufacture of such fuels are accompanied by CO_2 emission.

A system of biofuel production in Japanneeds to be established taking into consideration the conditions peculiar to the nation; many kinds of biomass resources are distributed widely, but most of them are in small quantities. And, we have to produce biofuels from materials which do not compete against food. It is also critical that a Life Cycle Assessment (LCA) system should be established, which can comprehensively evaluate the environmental loads in the whole process from resource productions to the use of biofuels.

The government of Japandeveloped the Biomass Strategy in 2002. Following that strategy, the promotion of utilization of biofuels and the Biomass Town Project are being carried on.

1. Biomass strategy of Japan

The government of Japan approved the Biomass Nippon (Japan) Strategy in a Cabinet meeting in December, 2002 in order to promote comprehensive utilization of biomass resources strategically. This Strategy has four major targets; to prevent global warming, to formulate a recycling-oriented society, to nurture industries strategically and to vitalize the agricultural community.

This strategy was revised in March, 2006 from the viewpoint of "Acceleration of Biomass Towns" and "Promotion of utilization of biofuels".

The roadmap for significant boost of the production of domestic biofuels was authorized in February, 2007. Remarkable increase in the production of domestic biofuels is feasible by around 2030 if appropriate technical developments, such as cost-reduction methods in collection and transportation, successful development of biomass resource crops and improved efficiency in ethanol conversion processing, are achieved.

2. Utilization of biomass resources in Japan

Storage and use ratio of biomass in Japan is shown in Fig. 1. Waste biomass resources such as animal feces and lumber residues were highly utilized for making compost or materials for paper, whereas unused biomass resources such as non-edible parts of farm crops and forestry residues were not utilized efficiently. Therefore, we have to promote the effective utilization of those resources.

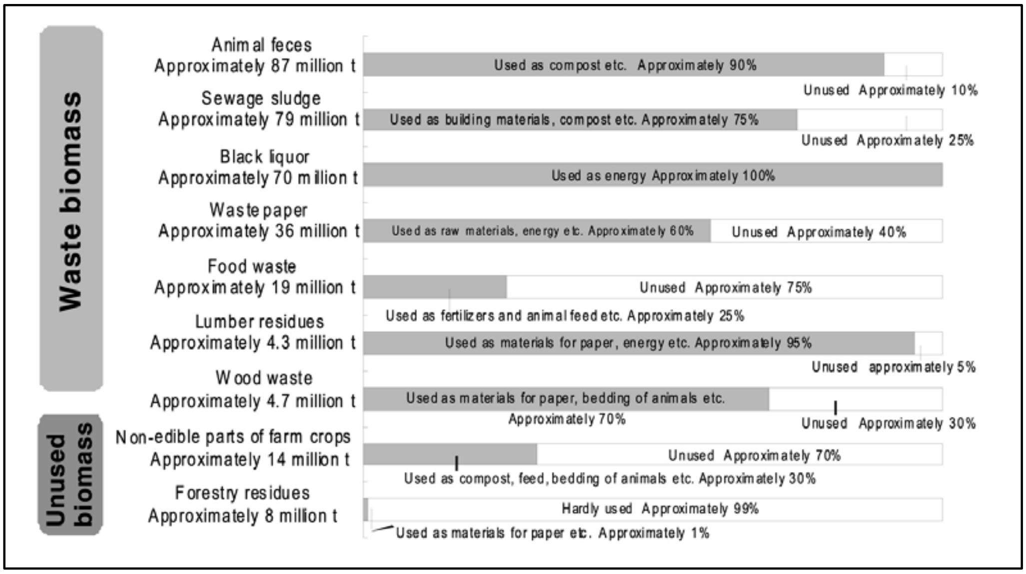

Fig. 1 Storage and use ratio of biomass in Japan (as of 2008)

There are two ways of utilizing biomass materizls; one is to use these as end products such as compost, feed, charcoal deodorizeror plastic, and the other is to use these as sources of energy such as biofuels, generating electricity and heat. What kind of biomass material should be used and how to use the resources depend on the region, therefore policy goals in each region usually vary from place to place.

3. Biofuels production

There are mainly four types of biofuels: bioethanol, biodiesel fuel, woody solid fuel and biogas.

The practical scale activity of bioethanol production has not been launched yet in Japan. Although, a verification test for bioethanol has already been conducted at six places in Japanand the amount of ethanol production was estimated to be as low as 90 kl as of March, 2008. The cost of bioethanol is still high (Fig. 2), and to compete with gasoline, the following are needed:

methods of procuring cheap raw materials such as substandard farm products and byproducts in the food-producing process and of reducing manufacturing cost.

Major raw materials for biodiesel fuels are waste cooking oil. Total amount of biodiesel fuel production was estimated at about 10,000 kl as of March, 2008. NPOs and local governments engage in producing biodiesel fuels by using small plants all over Japan.

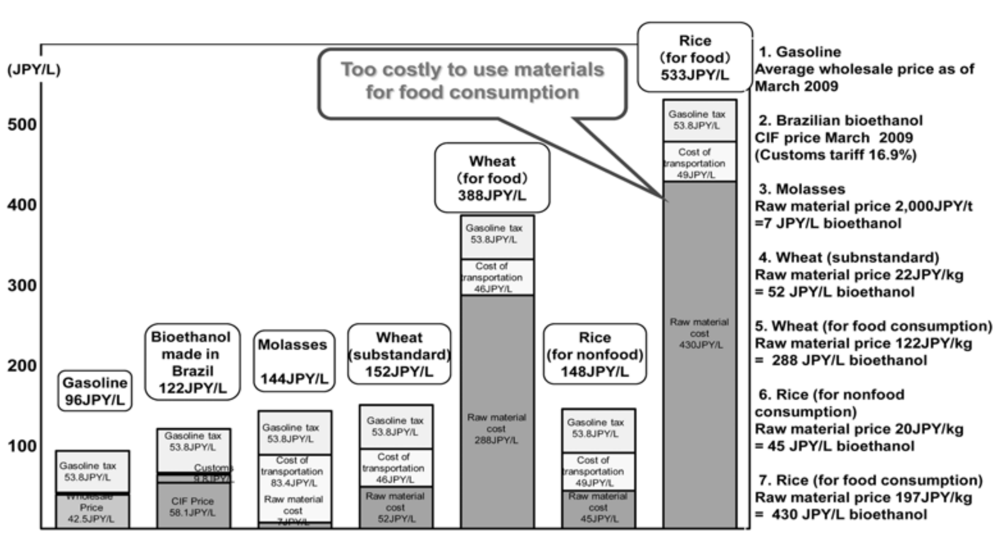

Fig. 2 Cost of bioethanol in Japan

In the northern part of Japan, wood pellets are actively produced. Using wood pellets in pellet stoves tends to increase, because they are safe and convenient. Wood pellets are alternative fuel to heating oil, so they contribute not only to tackling theescalating gasoline prices but likewise to the reduction of greenhouse gases emission.

Methane gas is produced from animal wastes or food residues by biological reaction. Gasification by chemical reaction produces hydrogen and carbon monoxide from woody biomass such as forestry residues. Using biogas in facilities and selling surplus electric power contribute to the reduction of emission of greenhouse gases. The number of facilities for producing biogas is increasing, but their scale is generally small and they are only used for supplying home-use fuels.

4. Biomass Town project

Biomass Townis a community which comprehensively utilizes biomass with strong ties between the community and local stakeholders. The government of Japan promotes Biomass Town for the achievement of one of the goals of Biomass Strategy: 300 Biomass Towns by 2010. There are more than a couple of issues to be considered for the promotion of Biomass Town: framework for corporation among concerned parties, a variety of ways to use biomass corresponding to local needs and efficient ways to collect, transport, convert biomass resources and use biomass energy.

There are 208 Biomass Towns as of April, 2009. Fig. 3 shows major Biomass Towns in Japan. Technology developments in Biomass Towns include methane fermentation, gasification of wood and biomass-converting system suitable for the local region. This project covers the provision of information and capacity-building in the different regions.

Based on global needs for sustainable biomass usage, "East Asia Biomass Town Concept Promotion Project" is in progress with support from MAFF, Japan. East Asia and Japan belong to the same climatic classification, "Asian Monsoon,"and East Asia is endowed with massive biomass reserves, but most of them are not utilized effectively. Wide-ranging support for effective use is needed in that region. This project is designed for a three years-period from April, 2008, and major goals are to build Biomass Town models in East Asian countries, promote industry-government-academia collaboration on Biomass Town Project and enhance mutual cooperation between Japanese and other countries' Biomass Towns. This project includes activities of on-site training for town development, providing information of Biomass Town to the local people and building and expanding human resource networks in model regions. With Japanese Biomass Town know-how, we can contribute to rural redevelopment in East Asiaand help counter global warming.

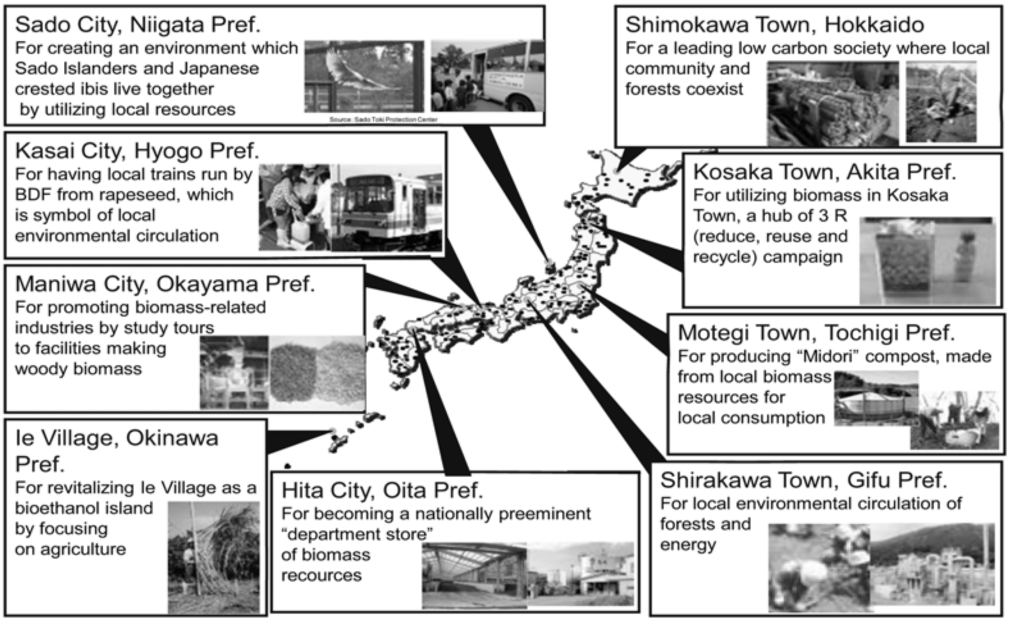

Fig. 3 Major Biomass Towns in Japan

2

German Biogas Success Story and the Requested Political Framework

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Abstract

The presentation highlights the situation of Germany's biogas sector looking at supporting energy policies, climate protecting technologies and market oriented economy of biogas plant operation. Starting from the current situation, it summarizes the development of the sector since the German Renewable Energy Law entered in force in 2000, and outlines several technologies that provide increased biogas yields and thus financial benefits for biogas plant operators. The German Ministry of Environment announced within a new law amendment in 2008 that the targets for 2020 had increased to 30% from the previous 27% (amendment in 2004). The EEGobligates grid system operators to give priority to plants generating electricity from renewable energy sources (solar, wind, hydro, biomass and geothermal energy) in connecting them to their grid as well as in purchasing the electricity generated. Although remarkable progress has been made, the market potential is still not satisfied. Key findings are: (1) nowadays more than 4600 biogas power plants are operating achieving an installed power capacity of about 1700 MW. (2) Energy crops are widely accepted as feedstock due to the special situation of Germany's agriculture which is strongly integrated in the European agriculture market; therefore the production of food crops is regulated by market forces and policy rules (3) Co-fermentation and Dry Fermentation as technology option provide farmers as plant operators higher gas yields and economic benefits. (4) The German government is aware of the economic and ecological potential and facilitates investment in renewable energies.

Key words

Germany, enabling political framework for biogaspromotion, Co-fermentation, Dry Fermentation, economy of renewable energies

Introduction

GERBIO, the German Society for Sustainable Biogas and Bioenergy Utilisation, is a German Non-Governmental Association, created in 2001, with the objective to promote the sustainable generation and use of energy made out of biomass. Its Fields of Work are therefore biogas technology, plant oils for energetic use, wood gas generation and use, the liquid and solid manure and digestate treatment as well as decentralized bioenergy-generating wastewater management. The activities of GERBIO related to biogas technology focus on Know-How transfer in international workshops, study tours, and training events, consultancy services, contacts to experts in planning, design and construction, contacts to specialized companies, and national and worldwide networking with members in different regions and countries.

The number of biogas plants in Germany has significantly increased since 2006; there are focal points in Germany in the south and in the north-western part of the country where within a relatively small region over 40 medium and large scale plants are operating.

Overview

Since the Renewable Energy Law has been launched in 2000, Biogas development in Germany experienced a steady increase not only in numbersof installed plants but also in public recognition as future oriented high tec.

	2005	**2006**	**2007**	**2008**	**2009**
Number of installed plants	2600	3500	3710	3900	4600
Electrical installed capacity (MWel)	650	1100	1270	1370	1740
Electricity (TWh/a)	2.8	>5	7.4	10.3	
Contribution to overall electricity production	0.5%	>1%	1.4%	1.6%	
Manufacturers income generation (Billion EUR)	0.5	1	0.65	0.6	1.05
Operators income generation (Mio EUR)	360	650	750		
Participation in exporting sector	8%	12%	>15%		
Employments	5,000	10,000	10,000	8,500	10,500
CO2 Reduction (Mio t/a)	2.5	5	6.4		

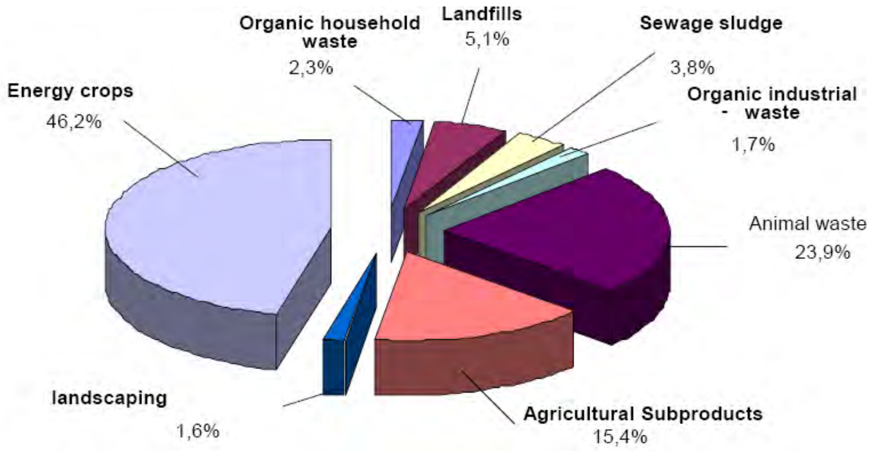
Reasons for the speed-up of Biogas Market Development could be named as (1) high standards in technical development implemented and respected by skilled technicians and manufacturers; (2) Different but standardized types of digesters and plant technologies – all well tested and reality proofed, supervised by Certifying Authorities (TUEV) – thus resulting in a healthy competition between different engineers and enterprises; (3) consolidation of the Dry Fermentation Technology as appropriate technology for water saving measures; (4) automatisation of system control and operation reducing labour cost and supporting the continuity of the biological processes involved (5) enabling environment and economic incentives through consolidated political framework that supports future oriented ecological technologies.

Over 1000 enterprises are currently working in the sector about 4600 biogas plants are operating. Technologies for upgrading to bio-methane (23 projects) and biogas as transport fuel (2 projects) are implemented as well, also advanced technologies for the efficient use of thermal energy and sludge treatment towards its application as fertilizer.

Over the last 10 years a new industrial biogas sector has emerged with specialist engineering consultancies, plant manufacturers as well as service and maintenance providers. Some of these companies have become relatively large, often able to raise substantial capital by going public. The renewable energy industry has engaged in cross-border investment, both within and beyond Europe, and this has enabled German companies to profit from international trends in alternative energy deployment, including biogas.

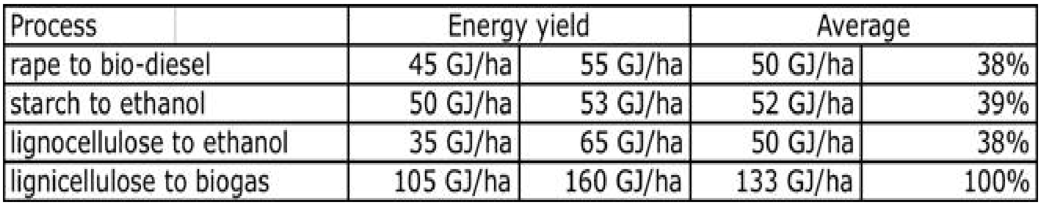
The total potential in Germany is estimated at 24 Bln m³ biogas for the generation of 50mio MWh electricity and 72mio MWh heat. Currently biogas contributes to about 1mio MWh power generation, corresponding to 2 % of its theoretical potential.

Feedstock for Biogas Production in Germany



It is obvious that – since 2005 - Energy Crops play by far the most important role in the success story of biogas in Germany. But the figure shows also very clearly that biogas production in Germany relies on a large variety of feedstock. As corn and plant silage are the predominant energy crop feedstocks for these plants, they are now grown on more than 500,000 hectares (2008) of farm land.

Why energy crops? There exist different efficient ways to produce energy from biomass:

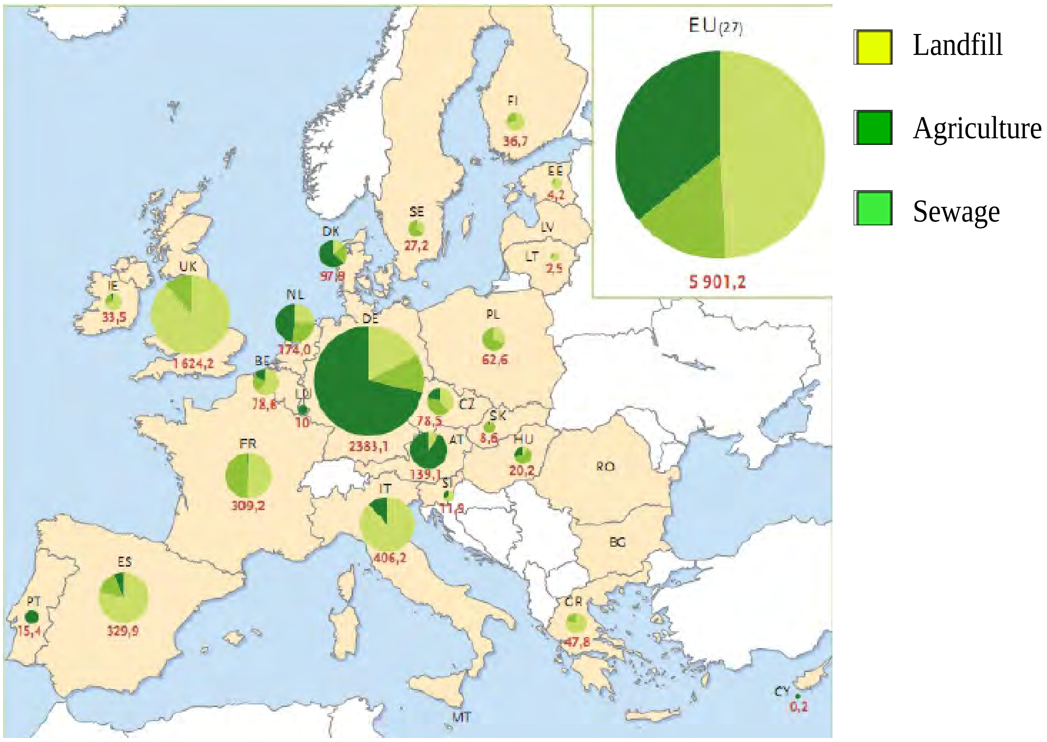


Process	Energy yield		Average	
rape to bio-diesel	45 GJ/ha	55 GJ/ha	50 GJ/ha	38%
starch to ethanol	50 GJ/ha	53 GJ/ha	52 GJ/ha	39%
lignocellulose to ethanol	35 GJ/ha	65 GJ/ha	50 GJ/ha	38%
lignicellulose to biogas	105 GJ/ha	160 GJ/ha	133 GJ/ha	100%

Source: *Institute for Energy and Environment, Leipzig, 2007: Kosten und Ökobilanzen von Biokraftstoffen*

Biogas Production in Europe (2008)

Landfill, agriculture and sewage are the most common sources for biogas feedstock, not only in Germany but also in other European countries:



Biogas Market Potential (***Source:*** EUROBSERVER 2008)

According to the Fachverband Biogas, the oldest and biggest Biogas Producing Farmer and Plant Manufacturer Association in Germany – founded in 1992 by nearly the same group of professionals and farmers who set up later GERBIO –the market for medium and large scale Biogas Plants with capacity for power generation has not yet achieved its saturation. The following graph shows the development of the number of biogas plants and the amount of installed power capacity.

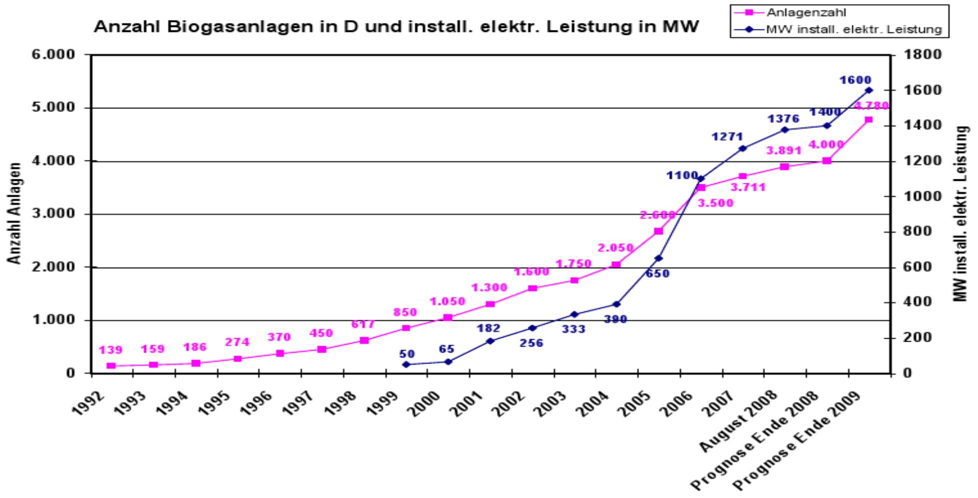


Abb. 1 Quelle: Fachverband Biogas e.V. 2008

It is further a trend towards the future of Biogas technology to discover the advantages of "bio-methane" which is like natural gas, but produced locally, with guaranteed supply, and always economical. Both, the potential consumer and the political decision makers are looking for import independent and thus "cheaper" fuel and energy supply. Environmental aspects may range at a second place but are also understood by the public as important reasons for investment.

Talking about the potential it has to be considered that 10 billion ㎥ bio-methane could be produced on 10% of agricultural land with an energetic yield of 62.000 kWh/ha. Options to improving this yield up to 100.000 kWh/ha are within reach. For Germany the following comparisons are interesting: 16 Billion ㎥ de bio-methane corresponding (1) to 50% of gas imports from Russia (2) up to 17% of the consumed electricity (3) up to 20% of the consumed natural gas (4) up to 35% of the consumed transport fuel.

Most of the potential lies in the application of energy crops, esp. in those crops that are grown just for biogas production. Here again it is important to clarify that Germany's agricultural production scheme is just one part of the European agriculture puzzle: farmers have to follow strict production regulations and international market and price planning.

Perspectives

The amended Renewable Energy Law focuses on thermal efficiency, ecology and emission reduction of 12.5% until the year 2010 although Germany has already achieved significant emission reduction, but the long term goals may not be reached with the current efforts.

From January 2009 on, new regulations feed-in-law for biogas are in place; they provide more incentives for agricultural biogas plants and for the treatment of waste.

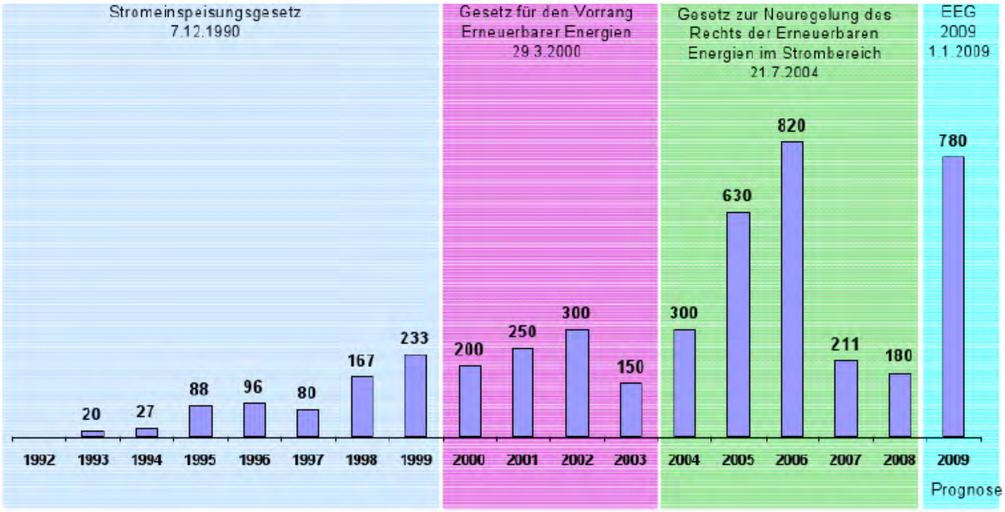
Today, 23projects for bio-methane injection into the natural gas grid have been approved so far and are already in operation or in the implementation process. The Governmental goal defines that until 2030 within the natural gas grid at least 10% of biogas should be contained.

Renewable Energy Law and incentives for biogas utilization

Biogas	Plant size	2009, present in EUR Ct(kWh)	2009, draft in EUR Ct(kWh)	Difference in EUR Ct(kWh)	For existing plants
Basic compensation	Up to 150 kW	10.67	11.67	1.00	Yes
	150 to 500 kW	9.18	9.18	-	
	500 kW to 5 MW	8.25	8.25	-	
Energy Crop Bonus	Up to 500 kW	6.00	7.00	1.00	Yes
	500 kW to 5 MW	4.00	4.00	-	
Manure Bonus	Up to 150 kW	-	4.00	4.00	Yes
	150 to 500 kW	-	1.00	2.00	Yes
Heat Bonus[1]		2.00	3.00	1.00	
Technolgy Bonus		2.00	2.00	-	Yes[2]

1: pro kWh

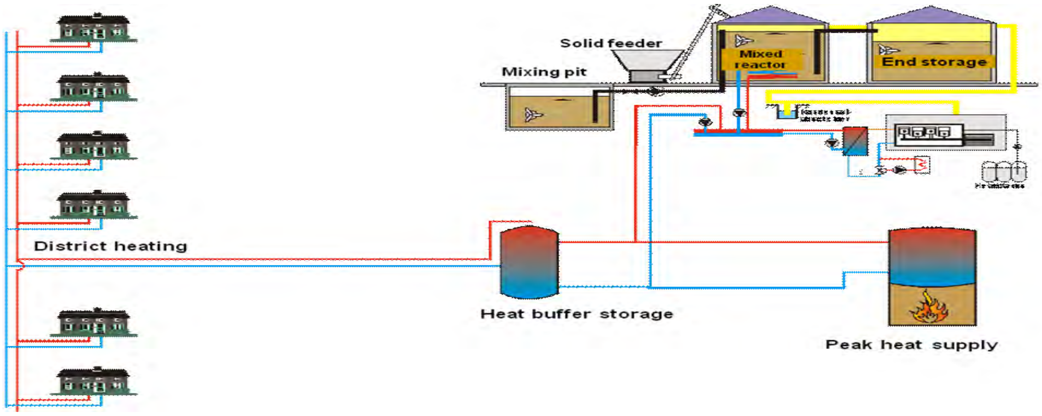
Increase of the number of biogas plants related to changes in laws and regulations



Source: Fachverband Biogas e.V., 2008

To make biogas production economic feasible, the efficient use of the generated heat is crucial.

Components of a biogas plant with CHP unit



The following examples from 3 biogas plants show the different concepts and technologies that anyhow lead to economical and ecological benefits for both owners and environment

Biogas Plant Thomas Karle - Kupferzell	**Biogas Plant Gebeke**	**Dry Fermentation Plant (Biomassehof Langenau)**
General Information - In operation since 2001 - Added new plant in 2004 - Gas turbine and sludge drying system (2007) - Agricultural area: aprox. 100 ha	**Production data** Volume of Biogas: **7300 m^3/d** CH4 content: **53.- %**	**Production data** Electricity input for operation: **aprox.2%** Electricity production: **4,050 MWh/a (7.500 h operation/a)** Investment Costs: **1.9 Mio. Euros**
Substrates - Liquid manure (cattle) - Corn sillage - Oat sillage - Harvest and production waste (DM~15%)	**Substrates** Green sillage: **27 t/d** Corn sillage: **4.7 t/d** Cattle manure: **2 m^3/d** Agricultural land: **75 ha (greenland) + 7 ha (corn)**	**Substrate** Landscaping: **4.000 t/a** Corn sillage: **8.000 t/a** Green and Grain Sillage:**2.000 t/a** Cultivated land: **150-200 ha energy crops.**

Technical description
- Digester : **1 x 600 m^3**
- Digester (new plant) : **1x1600 m^3**
  - Storage tank (covered w/ double memb): **2000 m^3**
  - Feed-in system for substrate: **45 m^3**
- CHP: **MDE gas motor320 kWel**
- Microgas turbins (2): **130 kWel**
	Technical Description
	Volume digester: 2 x **1,000 m^3**
	Post-digester : **1000 m^3**
	Temp. of operation: **48 °C**
	Sludge storage: **3600 m^3**
	Installed electrical capacity: **500 kWel.**
	CHP: **CES – MAN gas motor**
	Electrical capacity: **500kW**
		Technical Description
		Garage Digester: 7 x **500 m^3**
		Percolation Tank: **320 m^3**
		Gas container (2 hours full CHP) : **600 m^3**
		Sludge storage: **3600 m^3**
		CHP: **(3) MAN 180 kWel. c/u**

- Heat surplus production: **"electrical pig"**using greenhouse system for electrical drying of sludge		Use of surplus heat: **Wood drying, District heating (planned)**

Improving biogas yield with co-substrates and co-fermentation

Examples for biogas yields from different feedstock:

Substrate	Biogas Yield
Concentrated fat, fish silage etc.	200 – 1000m^3/t
Fish waste water, fat and flotation sludge, slaughterhouse waste, dairy waste, organic household waste etc	50 – 200m^3/t
Fruit and vegetable waste, industrial wastewater, sewage sludge	10 – 70m^3/t

Anaerobic treatment of manure and sewage sludge is the preferred process for sludge stabilisation and for manure treatment installed in wastewater treatment plants (WWTPs) they can meet about 30 - 50% of their own demand of the electrical energy and nearly 100 % of the thermal energy. Co-fermentation of sewage sludge, manure and bio-waste is a relatively new process in Germany but it could soon become a common treatment process of sewage sludge or manure together with bio-waste as co-substrates in digesters of WWTPs, farms, or specialised centralised waste treatment biogas plants.

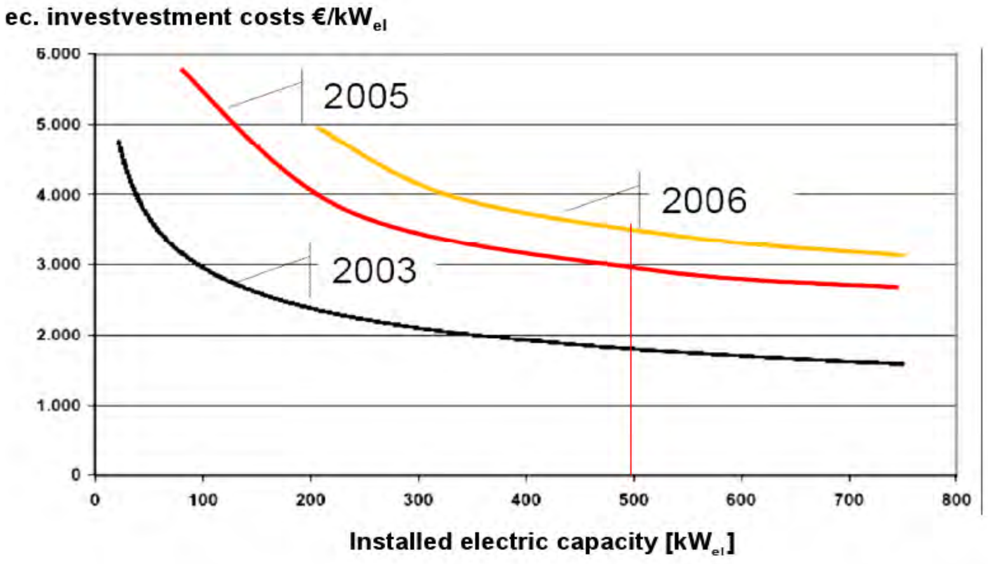
A centralized Biogas Plant by generating heat and power could (1) provide sanitation and homogenization of all organic wastes, (2) produce a nutritionally defined product to serve as fertilizer on the fields , (3) reduce air pollution and is (4) a CO_2 neutral renewable energy source.

However there is a conflict behind Co-Fermentation: while co-fermentation is an important tool in the promotion of a Circular Economy, using organic products as much as possible for renewable energy generation and recycling on fields (fertilizer) it must be taken care that this recycling doesnot contaminate soil, water, food with secondary products from energy carrier production. In this regard farmers and biogas plant operators (interesting in high gas yields) could easily stand against health and environmental authorities. The central question is to give priority either to Sustainable Energy Generation or to Ground water and soil protection. Therefore national and European laws and regulations are set-up to control the final products on their residues and pathogens content (European Fertilizer and Waste Management Regulation).

Economy

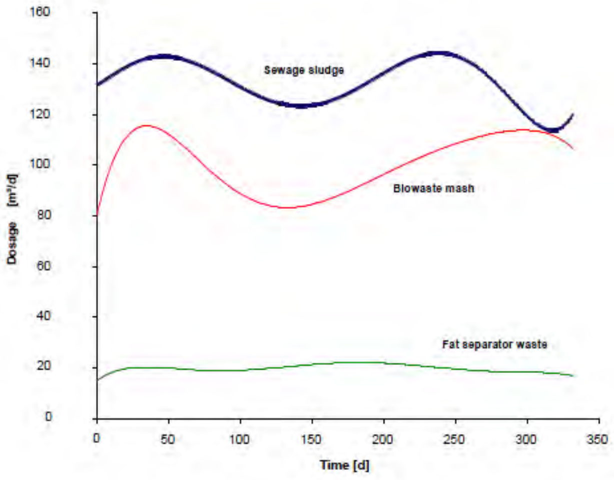
The operator of a **co-fermentation biogas plant** increases his earnings in two ways: (1) just by taking the co-ferments from those who should/wants to dispose them; (2) through higher gas production. Co fermenting materials are generally all materials which are fermented in addition to the basic substrate. This could be agricultural residues but also any biologically degradable residues from outside of agriculture. It make sense to add co-fermenting materials in order to maintain closed natural cycles, increase biogas yields, and achieve income from waste treatment and disposal. There are 3 main fractions of co-substrates: (1) Industrial waste, (2) Agricultural residues, (3) Biodegradable Municipal waste.

Investment costs of a biogas plant



Source: DZ-B

Example: daily feed of bio-waste mash, fat separator waste and sewage sludge processed



Energetic evaluation of decentralized household waste water treatment as co-fermentresults in the following key findings: (1) the German regulation defines: waste water containing human excreta could be treated in a biogas plant if the amount is less than 8 m^3a^{-1} (2) one person (in Germany) produces each day 80 to 120l of waste water; (3) this waste water contains feces andorganic waste from kitchen and meals (4) in addition it contains (biodegradable) detergents, shampoos etc. (5) one person could potentially generate approx. 0.9 kWhel/day (6) 150 EUR/year represents savings of waste water treatment fees in current tariff system and savings of sewage system connection fees.

Advantages and Disadvantages of co-fermentation could be summarized as follows: (1) Co-substrates increase organic content of substrate resulting in increasing biogas yields; (2) co-fermentation is only profitable if co-substrates are sourced within an economic distance (3) content of DM should be 2 –12% to ensure functionality of available standardized sludge pumps and proper mixing (4) Co-substrates pose higher hygienic risk and needs sometimes specific pre-treatment (5) co-substrates like residue fat contain nitrogen-rich nutrients (6) co-fermentation presents an active contribution to combating climate change and –in view of the shrinking reserves of mineral phosphate – the technology produces fertilizer from secondary raw material.

More Info

www.fnbb.org, www.gerbio.org, info@gerbio.org, www.biogas-zentrum.de

3

Opportunities for Biogas Capture and Use from Animal Waste Management

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Abstract

Methane is both the primary constituent of natural gas and a potent greenhouse gas when released to the atmosphere. Reducing methane emissions can yield substantial economic, environmentaland energy benefits. In the agriculture sector, the implementation of anaerobic digestion technology can lead to improved air and water quality, odor control, improved nutrient management, a reduction in greenhouse gas emissions, and the capture and use of biogas, a source of clean, renewable energy. Methane is a potent greenhouse gas when released to the atmosphere with a global warming potential over 20 times as high as carbon dioxide. However, methane it is also a clean burning fuel that can be captured and used for renewable energy generation and to replace fossil fuels.

The liquid manure management systems found in large livestock operations promote anaerobic (i.e. oxygen free) environments leading to methane emissions from anaerobic decomposition of organics in the waste. Anaerobic digester systems (AD) are designed to capture methane released from liquid manure and allow the recovered biogas to be flared or used as a clean energy source to produce electricity, heat, or combined heat and power in medium Btu gas-fired equipment such as engines, boilers, or chillers or as a raw material for the production of pipeline quality gas or vehicle fuel. Digester biogas is usually 60-80% methane, with an energy content of about 600 to 800 Btu per standard cubic foot.

Project development in this sector can help to reduce greenhouse gas emissions and provide alternative energy sources. In addition, AD systems offer other environmental benefits including significantly reduced odor and improved water quality protection while also providing opportunities for agricultural diversification.In the U.S. odor control is often a major driver for implementing AD systems. The benefits of controlling odor can lead to a better and more productive relationship with neighbors, an easier time getting appropriate permits, and being viewed as a good environmental steward.

Overview of Emissions from Manure Management Systems

Each day millions of tons of livestock wastes are disposed of in lagoons, tanks and other structures which result in variable emissions of methane. Total emissions from manure management systems in the U.S. livestock industry accounted for about 7% of total anthropogenic methane emissions in the U.S. Globally, it is estimated that livestock manure management contributes roughly 4 percent of total anthropogenic (human-induced) methane emissions. Three groups of animals account for more than 80 percent of total emissions: swine (40 percent); non-dairy cattle (20 percent); and dairy cattle (20 percent). Given the global trend toward larger farms, liquid manure management is expected to increase.

Globally, livestock wastes are handled and disposed of in a myriad of systems. In many countries where there is no regulation or enforcement wastes are directly discharged (point sources) or indirectly discharged (non-point sources) into surface waters which can cause eutrophic conditions, fish kills, and poor water quality. These types of discharges are one of the major causes of measureable nutrient loadings in the Gulf of Thailand, South China Sea, and Black Sea. In countries where wastes are regulated, they are typically land applied to crops and other vegetation as a means of fertilizationand reducing or eliminating discharges to surface water. Wastes that are improperly managed or handled are known to cause disease and gastro-intestinal disorders.

Overview of Anaerobic Digestion Systems for Livestock Waste Management

AD systems are typically used in the primary treatment of high strength organic materials, such as livestock and food processing wastes handled as either liquids, slurries, or semi-solids where biogas is recovered and combusted for energy use, process heating, or flared as an odor control or greenhouse gas management method. Anaerobic digestion also results in a number of environmental and human health benefits such as reductions in biological oxygen demand (BOD), pathogen reduction, and odor control. In many cases the value of the gas as an energy source can pay for these benefits and add to a farm’s revenue where utility markets are favorable.

An AD system consists of the following components: a digester, a gas-handling system, a gas-use device, and a manure storage tank or pond to hold the treated effluent prior to land application. Biogas digester systems can generally accommodate manure handled as liquid, slurry, or semi-solid. The total solids content of the manure – a measure of manure thickness – determines these classifications. Facilities best suited for biogas digester systems typically have stable year-round manure production, and collect at least 50 percent of the manure daily. Several gas-use options are available ranging from simple flaring to engines, chillers, boilers, and cogeneration power systems.

Reducing emissions and improving the environmental and human condition by utilizing AD and using it as an energy source can yield significant energy, economic and environmental benefits. Internationally, significant opportunities exist for expanding AD and an increasing number of conventional and emerging technology applications are becoming commercially viable to target this market. These systems can vary in operational complexity and cost depending on scale, climate, and type of energy use.

AD is currently used in a variety of applications worldwide for a variety of energy purposes, such as: 1) generation of electricity 2) use in thermal applications 3) use as cook fuels and lighting to replace biomass in poorer regions 4) creating pipeline quality gas and 5) use as fuel for vehicles.

Types of AD Projects

The following are brief descriptions of conventional AD technologies:

- ***Covered anaerobic lagoons*** are constant volume reactors that are operated at ambient temperatures. Manure is treated under anaerobic conditions producing methane, which is recovered by using impermeable floating lagoon covers.
- ***Complete mix digesters*** are heated digesters constructed of concrete or steel designed to enhance anaerobic decomposition and maximize methane recovery.
- ***Plug flow digesters*** are heated systems for semi-solid dairy manure that operate at a constant temperature year round, producing gas at a stable rate.

Projectsthat produce a beneficial product such as electricity or process heathave two greenhouse gas reduction components. The first is that the project directly reduces methane emissions from the manure management system, and the second is that the project produces renewable energy that offsets greenhouse gas emissions from the combustion of fossil fuels and biomass.

Opportunities and Challenges in Developing AD Projects

AD of various types, scales, and costs are a proven technology. The U.S. EPA, Department of Energy, and Department of Agriculture implement a voluntary partnership program called AgSTAR that aims to reduce the environmental impact of livestock waste management and fossil fuel power generation. In the past 10 years, the AgSTAR program has helped develop over 120 AD projects in the U.S. These projects contribute more than 250,000 MWh/ year equivalent.

Projects operating in the U.S. typically range in size from 50 - 400 kW. About 60% of the existing projects are listed as cogeneration projects. These AD projects are located across 26 states. In addition, there are 56 projects that are either planned or under construction.

AD projects that include cogeneration can create additional environmental benefits by offsetting fossil-fuel based electricity and heating demands with a renewable fuel. In addition, using the waste heat from biogas-fired generators in a utilizing cogenerationcan improve a return on investment by offsetting the costs of conventional fuels. Reciprocating engines using biogas have similar heat conversion efficiencies as small natural gas generators and are approximately 28-33% efficient. In comparison, engines with cogeneration systems have been found to have an effective energy efficiency of 69-84%.

Although AD projects often make good economic and environmental sense, financing can pose a barrier due to high upfront capital costs and/or competition with low electricity prices in some markets. Countries and states have different policy strategies and incentives to help overcome these financial barriers to implementation. In the United States, the Department of Agriculture offersloans, loan guarantees, and grants to farmers, ranchers, and rural small businesses to purchase renewable energy systems and implement energy efficiency projects. In addition, states themselves may provide various types of funding opportunities or incentives to improve financing. A listing of state and federal funding opportunities is available on the AgSTAR website at: http://www.epa.gov/agstar/resources.html.

Another potential source of funding for AD projects is through the sale of carbon credits. These credits are generated as a direct result of the collection and destruction of methane and as offsets from using a renewable energy source to generate electricity. A number of AD projects have taken advantage of both carbon credits and renewable energy credits. In developing countries AD projects can take advantage of the Clean Development Mechanism which allows emission-reduction projects in developing countries to earn certifiedemission reduction credits that can be traded and sold and used by industrialized countries to meeta part of their emission reduction targets under the Kyoto Protocol. In the U.S. there are a variety of voluntary markets where carbon credits may be sold.

One important issue for project development in many developing countries is that direct discharge to water is often the predominant disposal option. This type of management causes a host of environmental problems including surface water contamination, dispersal of disease, fish kills etc... These sites can realize significant environmental benefits from improved sanitation and reduced odor, by installing AD systems and implementing improved manure handling practices. In the developing world where warm climates predominate, farms or AD projects may be limited in the amount of waste heat that can be utilized via cogeneration.

Another important issue for AD energy project viability in both developing and developed countries is energy price structure. Government policies on energy can promote or hinder the beneficial use of AD. An uncertain regulatory environment is often a concern among potential investors. For example, project developers can be subject to different and sometimes conflicting laws at the local, regional and national levels. Moreover, a lack of regulations governing manure handling and discharge (i.e., no requirement or incentive to manage manure in an environmentally sustainable manner) in some countries can inhibit project development.

As countries begin to implement laws, regulations, and policies to improve manure management practices, promote alternative energy, and address greenhouse gas emissions, the economic viability of AD projects including those that utilize cogeneration is expected toimprove. Moreover, creating an atmosphere where potential investors (private sector, international development banks, and financiers) are secure in the technical and policy framework that supports AD energy projects will be essential to project development.

The Methane to Markets Partnership brings together the collective resources and expertise of the international community to address technical and policy issues and facilitate AD projects. Early initiatives will include:

- Assessing opportunities for AD projects
- Performing initial feasibility studies including the potential for CHP applications.
- Demonstration projects
- Capacity building within a country to allow for replication of demonstration projects

Activities to Promote AD Internationally through Methane to Markets

Through the Methane to Markets Partnership U.S. EPA and U.S. AID are working to support a variety of activities to promote acceptance and use of AD projects internationally. As an example, USAID and EPA are working with Mexico’s SEMARNAT to demonstrate appropriate AD systems in medium to large scale farms in the Lerma-Chapala region Mexico. These and other biodigesters will create a basis for national standards and certification used to reduce risk and improve product reliability that will promote the benefits of technology and project replication in the region. In India, U.S. EPA is working with the International Institute for Energy Conservation to develop an AgSTAR India program initially targeted at the dairy industry and expanding to other relevant industries. The program will develop a nationwide institutional system that promotes capture of methane from livestockand food processing wastes in the Indian milk producing and processing sector throughanaerobic digestion technology and various gas uses.

Methane to Markets Partnership

In the area of anaerobic digestion, the Methane to Markets Partnership centers on identifying opportunities for AD projects and on promoting cost-effective electricity generation or direct use of the resulting biogas. Efforts include the identification of barriers to project development, the improvement of enabling legal, regulatory, and institutional conditions, and the creation of efficient energy markets. The active involvement by private sector entities, financial institutions, and other non-governmental organizations is considered essential to build capacity, transfer technology, and promote private investment that will ensure the Partnership’s success. For more information on Methane to Markets please visit the website at : www.methanetomarkets.org.

The AgSTAR Program

AgSTAR, a collaborative effort of EPA, US Department of Agriculture, and US Department of Energy, is an outreach program designed to reduce methane emissions from livestock waste management operations by promoting the use of biogas recovery systems. This program helps to reduce methane emissions by encouraging livestock owners and operators to install AD systems and use the collected biogas as an energy resource. AgSTAR was launched to encourage productive use of this resource as part of the United States' commitment to reduce greenhouse gas emissions under the United Nations Framework Convention on Climate Change. AgSTAR provides an array of information and tools designed to assist producers in developing projects, including:

- Conducting farm digester extension events and conferences
- Providing "How-To" project development tools and industry listings
- Conducting performance characterizations for digesters and conventional waste management systems
- Operating a toll free hotline
- Providing farm recognition for voluntary environmental initiatives

- Collaborating with federal and state renewable energy, agricultural, and environmental programs

For more information go to the AgSTAR website at www.epa.gov/agstar

Session

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1

Development of Biogas and Biomass Power Technology in China

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Abstract:

The presentation analyses the situation of China's large scale biomass and biogas energy production facilities from a technology point of view. It summarizes the number and capacity of biomass and biogas power plants in operation and currently under construction. It also provides an overview of possible bio-mass handling processes in China, an outlook on Chinese biomass energy generation capacity and displays key findings of the study such as most suitable provinces for construction of biomass power facilities with regard to different technologies, available support from governmental site, legal pitfalls and rules for biomass and biogas utilization. Key findings are: (1) More than 80 biomass combustion power plants with 6, 12, 25 or 50 MW each are operating or have been approved. The overall potential is estimated for 30 GW. (2) It is expected that the biogas installation potential will be 200 MW in 2015, 1/3 for agricultural large scale biogas power plants, 2/3 for agro-industrial plants; and for 2020 then 1500 MW with 1/2 agriculture and livestock and 1/2 agro industry. (3) The Chinese government is aware of the huge implementation potential and facilitates foreign engagement.

Key words: China, biomass power, biogas, energy

Introduction

China's energy industry achieved rapid development, realized demand-and-supply balance in the first half year of 2008. Energy structure became more perfect, energy-saving and emission reduction obtained remarkable results, strengthened technology solution efforts, policy and rule of law, as Renewable Energy Law of P.R. China were constantly improved, which provided powerful guarantee for sustainable, rapid and coordinate development of national economy. Meanwhile, some problems in the energy sector are still very serious, and requires specific consideration in the future: energy consumption and demand are increasing while-at same speed - energy environment constraints are increasing; structural contradictions are outstanding and the country's sustainable development is facing challenges; the international energy market is experiencing intense fluctuation leading to an increase in potential energy security challenges. China's biomass science and technology level is comparatively backward, although national innovation efforts are shouldering strong responsibilities esp. within the "new socialist countryside" policy where the energy problem is prominent and the urging need should be solved immediately. However, system constrains are still serious and reforms are still waiting to be implemented or intensified. The sustainable development of Chinese energy supply still needs perennial and unremitting efforts.

Overview

Technology evaluation of suitable and currently applied technologies in China

Basic and general process of direct-fired biomass power generation: Biomass power generation uses biomass feedstock (crop stalks, fruit tree branches, forestry processing waste, municipal and industrial organic waste, livestock manure, or others) to generate power. The basic and general process of direct-fired biomass power generation uses the heat generated during the direct combustion of biomass in the biomass boiler to produce steam, and the steam will push gas turbines to generate power.

The major types of the biomass boilers currently adopted in China are as follows:

1. Technology imported from Denmark: The water-cooling vibration grate boiler is manufactured by Danish technology, adopting high pressure and high temperature parameters while steam pressure 92MPa, temperature 540°C, output 130t/h and 48t/h, with 25MW and 12MW turbine respectively. This kind of boiler has been adopted in many projects with good performance.
2. Domestic CFB boiler: The biomass power plant CFB boiler technology is co-developed by China Energy Conservation Investment Corporation (CECIC) and Zhejiang University, adopting medium temperature and medium pressure parameters with steam pressure 3.9MPa, temperature 450°C, and output 75t/h with 12MW turbine, which has been put into operation in Jiangsu Suqian Biomass Power Plant.
3. Domestic water-cooling vibration grate boiler: The biomass power generation water-cooling vibration grate boiler is independently developed by Huaguang boiler group Co. Ltd, Beijing Guodian Longyuan Hangguo Lankun Energy Engineering Company and Huaxi Energy Group Co., Ltd etc. The boiler has two parameters (so-called secondary high temperature and secondary high pressure, medium temperature and medium pressure) and two kinds of output 110t/h and 75t/h, with 25MW and 12MW turbine respectively, which have been utilized in the projects located in Jinzhou in Hebei province, Donghai and Hongze of Jiangsu province.
4. Reconstruction of small thermal power unit: Sifang Boiler Plant under Shanghai Electrical (Group) Corporation reconstruct chain boilers for small thermal power unit into biomass combustion boiler with 75t/h medium temperature and medium-pressure, which has been applied in Chang'ge project in Henan Province.

Biogas generated in medium and large scale plants is planned to be utilized in two forms:

1. Distribution in a biogas grid at village or township level to provide thermal cooking fuel to households and cantinas, or as a heat process source to small and medium sized enterprises. 200 medium pressure biogas cooking grids exist at village level none of them mix biogas with other gas sources. 1.4 million users directly apply biogas as cooking fuel provided through village biogas grids.
2. Electricity power generation in “island” mode, mainly on South Chinese livestock farms in Guangdong province, and in island mode operated demonstration units in Beijing and Gansu provinces. No feasible demonstration of heat use from CHP units has been identified so far, apart from some application in food processing industries. If there is no demand for the ‘waste’ heat about 2/3 of the energy are lost. A significant percentage of the biogas production from medium and large scale digesters is used for generating 400 Mio kWh per year. Only in the land-fill biogas sector electricity and some few MW scale biogas plants are generating to be fed into the public grid.

Especially in Chinese city suburbs, much of the increased risk of pollution is caused by rupturing the traditional “short cycle” between livestock production and crop production. In less intensive, mixed rural farming systems animal waste is recycled as fertilizer by farmers who have direct knowledge and control of their value and environmental impact. Industrialized livestock and dairy production leads to a longer cycle in which large quantities of wastes accumulate far from croplands where they could be safely and productively recycled. So even though intensive systems tend to make more efficient use of resources, with lower levels of water use, nutrient excretion and gas emissions per kilogram of meat or milk produced, they often generate more pollution than less intensive farms where manure is better managed. Dense concentrations of industrial livestock production create regions surrounding the Chinese cities with vast quantities of excess manure. Although much lower on a national scale, concentration of pig and poultry production in parts of China is approaching and surpassing levels found in Europe and North America. This pollution poses threats to water, soil and air from concentrations of animal wastes.

Energy Approach

This option prevents releasing animal waste to surface water bodies. After treatment of the semisolid or liquid animal wastes in a biogas digester, the effluent is applied as bio-fertilizer for food production farms in the vicinity of the biogas plant. This model has significant economic benefit while realizing a zero emission target of the organic waste treatment. But it fits only in locations where sufficient agricultural lands, fish ponds or productive lagoons are available for further post-treatment. Biogas output is higher compared to the environmental optimized approach described second.

Environmental Approach

After initial separation of liquid and solid wastes, the liquid part is sent to the anaerobic treatment and aerobic post-treatment to accomplish with the national standards for waste water effluent discharge at least for irrigation purposes. The solid parts are marketed as organic fertilizer after composting or drying. The cost of installation and operation is higher and the biogas output is lower than for the previously described energy optimized approach due to separation and the necessity for two process lines for liquid and solids.

Needs and demands in the Chinese market (North, South, West)

Agricultural straws

Grain production is mainly located in the provinces of Hebei, Inner Mongolia, Liaoning, Jiling, Jiangsu, Henan, Shandong, Hubei, Jiangxi, Sichuan, Yunnan etc. Considering the collection costs, the regions presenting the highest density of straw per capita are Jilin, Heilongjiang, Xinjiang, Liaoning, Shangxi, Henan, Hebei.

Agricultural residues

Apart from the stalks and straws listed above, there are other agricultural residues which offer potential feedstock for bioenergy production

- Cotton: in 2003 the production of cotton in the provinces of Hebei, Jiangsu, Anhui, Shandong, Henan, Hubei, Tianjin and Hunan achieved 4.86 million tonnes12, generating stalks and cotton-seed husks which could be used as feedstock for bioethanol production. Cottonseed oil is the second main product of this industry. Low-grade oil can be used for biodiesel feedstock. Detailed data, separated from the overall market for low-grade oil, are not available at present.
- Fibre crops: jute and ambary hemp fibres normally represent only 4% of the total leaf weight. The waste generated annually from this sector in China fluctuated between 1997 from 10.32 million t/a to 2.4 million t/a in 2003, mainly in Hubei, Henan, Guangxi and

Anhui.

- Coffee: only produced in Hainan Island; coffee husks represent 20% of the harvested gross weight. National data is not available.
- Rice: husk production per tonne of grain is estimated at 0.33t, resulting in an annual biomass production of 53 million tonnes, mainly in Heilongjiang, Jiangsu, Anhui, Jiangxi, Hubei, Hunan, Guangdong, Guangxi and Sichuan.
- Cashew nut: yields a large quantity of shells and husks, which are potential bioethanol feedstock for cellulose rich process technologies. In 2003 the national yield ranged at 13.42 million tonnes of raw nuts generating about 4.47Mio t of residues in the provinces of Hebei, Shandong and Henan.

According to NDRC 900 million t/a of these types of residues are available for biomass energy projects. With the implementation of China's Natural Forest Protection Programme and its Sloping Cropland Conversion Programme, it is expected that the amount of scraps from forestry and forest product industries to be used in energy applications will increase substantially, with the potential of reaching 12,000 PJ/a by 2020.

Livestock waste for biogas production

There are generally two levels of raising domestic feedstock:

- Traditional method; individual small-sized farms and families’ excrements are scattered or collected in household small-scale biogas plants.
- Industrial scale: large and medium-sized farms where manure is available in large quantities.

The amount of livestock waste is expected to increase in relation to improving living standards and changing meat consumption habits. The industrial livestock breeding facilities are facing severe problems due to non-utilization of waste, as farms are either agro-industrial parks for animal production without fields, or the adjacent fields are not capable of bearing the organic load. Over 90% of these plants are not equipped with adequate pollution prevention systems. Furthermore, farmland is often distributed among different private households; therefore, the application of animal waste as organic fertilizer is complicated by operational and administration procedures and costs. Based on that figure it is expected that the biogas installation potential is 200 MW in 2015, 1/3 for agricultural large scale biogas power plants, 2/3 for agro-industrial plants, and for 2020 then 1500 MW with 1/2 agriculture and livestock and 1/2 agro-industry.

Results and Discussion

Successful commercial engagements are limited by Chinese energy market monopolization, the low degree of law and regulation implementation, the lack of technological, social and ecological standards. Economic incentives, practical and economical technology and professional personnel are still missing in the Chinese bioenergy sector, thus characterizing the biomass energy business currently as a risky business where most of the involved firms are operating at marginal profit. Some fields of further development are:

Combustion technique

- Ash and corrosion in process of biomass (straw) combustion is a key issue.
- Foreign companies only sell boiler equipment but no technical transfer.
- Lack of experience in respect of straw boiler production and operation.
- Lack of feedstock technique and equipment.

Co-firing technique

- Co-firing less than 20% biomass of the total caloric value in coal boil is technically mature.
- With larger percentage of biomass fuels mixed, the problem reveals in straw pre-treatment.

Biogas plants

- All kinds of mixing devices.
- Sludge pump technology and products, especially for the transportation of biogas slurry with TS% > 8%.
- Biogas co-generation units (CHP) with more than 8,000 hours per year operational time.
- Biogas purification technology and relevant equipments.

- Biogas slurry post-treatment and equipments.
- Biogas engineering and plant process optimization, especially for colder regions.
- Optimization of waste heat utilization.
- Impact analysis of mixing systems on anaerobic treatment and relevant technology.
- Peak load parameters for typical crops to consume biogas slurry and reuse of fermented and separated solids as fertilizers.

Conclusion

Main Challenges for the Development of Biomass Power Plants and Biogas plants

Areas of Focus Challenges: Feasibility Studies

- Lack of development procedures and feasibility guidelines.
- Big gap between early stage feedstock investigation and purchase reality.
- Unable to realize full favorable policy commitment.

Areas of Focus Challenges: Construction

- Contracting method shall be reviewed with consideration of the biomass characteristics that are different from the coal or natural gas.
- Managing equipment procurement methods well developed for smaller projects and rural areas.
- Contractors are not properly managed.
- Cost control needs improvement.
- Design problem feedback needs to be improved, design to be optimized.

Areas of Focus Challenges: Construction Management

- Operation responsibility to be emphasized.
- Plant reliability to be improved.

- Operational skill to be improved.
- Housekeeping to be improved.
- Operational preparation during construction stage to be improved.

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2

Case Study of Biogas Production from Plant-Based Materials and Animal Manure Resources Available In the Cocoa and Coffee Farms

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Abstract

One of the proposed alternatives to overcome environmental and energy issues faced by Indonesian cocoa and coffee farms is the application of co-digestion technology to convert wastes to produce biogas. Four digesters are therefore installed in the ICCRI Experimental Station as a field observation to convert cocoa and coffee wastes to biogas at a pilot scale. The digester is designed using an in-ground rectangular type reactor made from concrete materials with total volume of substrate 4 ㎥ and 2 ㎥ of gas holder per digester. The daily co-digestion inputs are fixed at 75 kg per 12 to 13 % solid content. At the first four months prior to the coffee harvesting season, 1/1 [by weight] water diluted-fresh cow dung substrate is fed into the first two digesters, to initiate the anaerobic digestion process. The following 5 months duration, the biogas digester is fed fully with a neutralized coffee factory waste water substrate. At the last three months period, when the coffee harvesting is over, the digesters are reloaded again with a fresh cattle dung substrate as inputs. During cocoa season, the same treatments are used to produce biogas from cocoa factory waste material and cattle manure [1/3 by weight] in the last two digesters. After a 45 days retention time, the co-digestion cattle manure-coffee waste produces more biogas [0,55 m^3/day/m^3 digester] than that of from cattle manure-cocoa waste [0,33 m^3/day/m^3 digester]. The digester also shows significant reduction in organic pollutants of the slurry as indicated by its low COD/BOD values. A simple biogas stove can boil 5 liters of water and cook 500 g of rice within 35 and 45 minutes which consume about 170 and 210 liters of gas respectively. While, roasting 10 kg coffee beans requires 980 liters of gas at about 40 minutes.

Key words: Coffee, cocoa, cattle, waste, biogas, cooking and heating.

I. Introduction

Indonesia is the second largest exporter of cocoa after the Ivory Coast and the third largest exporter of coffee after Vietnam. Recent production of cocoa and coffee is approximately 400.000 and 420.000 tons respectively. These farms are faced with relatively similar environmental and energy issues [De Matos., et-al., 2001; Von Enden., et-al., 2002; Deepa., et-al., 2002; Ntiamoah & Afrane, 2008]. In fact, there are several scientific reviews describing that coffee and cocoa farms residues can be treated in the bio-digester to produce useful biogas and thereby reduce the pollutants [Lane, 1983; Chacon, 1984 and Bopaiah., et-al., 1988].

Several laboratory research works have been also done during the past two decades. Calzada., et-al., [1984] used a small scale of methanogenic bioreactors packed with polyurethane foams for converting acidified coffee pulp juice into a methane-rich biogas. Gas could be produced in the order of 3 v/v day with loads ranging from 9 to 22 kg VS/m^3 day. Farinet & Pommares., [1999] also reported that anaerobic digestion of the organic coffee waste was tested in a small scale unit set up in Mexico. The composition and low pH of coffee pulp usually resulted in excess acid production during anaerobic digestion using completely mixed reactors. The plug flow digester could however solve this problem of acidification which could produce a comparatively the same amount of biogas as produced by cattle dung digestion. The end compost produced from the digester could also be used as an organic fertilizer for coffee farms.

Murthy., et-al., [2004] underlined a technical solution for treatment of coffee effluents using large scale lagoon type digesters. The results showed that the digester provided not only a solution to waste disposal, but also an alternative fuel for electricity generation. Working differently, Bruno., et-al., [2008] evaluated the efficiency of two stages up flow anaerobic sludge blanquet [UASB] reactors, in a bench scale, treating a liquid effluent from the coffee pulping. The result showed that the recovery of methane gas varied from 69 to 89 %. In case of a cocoa waste utilization, Bopaiah., et-al., [1988] reported that biogas was produced using cocoa pod husks and a small amount of cattle manure as inoculum. But, biogas was produced only by the dry powdered pod husk.

As perennial crops, coffee and cocoa harvesting season take place intermittently. Hence, during off season, the digester should be kept running by co-digesting various feed stocks [Phalla, 2004]. These can be any biologically degradable residues available in the coffee and cocoa farms, such as cocoa pod husk, leaves and trunks. Some advantages of applying co-digestion inputs are to maintain closed natural resources cycles, to increase gas yield and to enhance additional income for farmers from converting any waste materials into added value products [Heinz.Peter Mang, 2009]. The current intensive cocoa and coffee production is to apply an integrated farming system [Richard, 2006]. The integration of crop and animal production system gives sustainability supply of biodegradable feed stocks. The animals help in efficient recycling of organic crop residues [Channabasavanna., et-al., 2009]. There is marked complementary in resource use in this system, with inputs from one sector being supplied to others [Van Der Vossen, 2005; Zhanserikova, 2008]

The paper is focused to review the practical experiences gained from a serial field trials of biogas production using a co-digestion of plant-based and animal manure resources which are available in the cocoa and coffee farms. The biogas is utilized mainly for household cooking/lighting and heating of cocoa and coffee products.

II. Materials and Methods

2.1. Feed stocks supply estimation

2.1.1. Plant and animal-based residues

The amount of residues is calculated based on the cropped area, planting density, the type of farm management and the crops variety [Lim, 1986a; Lim, 1986b]. Animal-based residue is estimated by multiplying number of animals and the quantity of waste.

2.2.2. Factory waste

Factory waste materials consist of two groups, i.e., solid and liquid in states. Solid waste can be estimated using a mass balance method. This involves measuring the crop and product ratio [CPR]. The total factory waste is estimated by multiplying the CPR value and the total crops production per hectare per year [Upreti., et-al., 1991].

The coffee processing is done based on a fully washed processing procedure [Figure 1]. Liquid waste is estimated by measuring loading rates of coffee processing in each of the two waste waters outlet per unit time. The loading rates are calculated by multiplying the measured concentration or average concentration for triplicate analyses by the average flow rate over the 24-hours sampling period. Loading rates are expressed as kilograms [tons] per day.

Figure 1. A schematic of fully washed method of coffee processing.

2.3. Biogas digester design

The digester design is based on the results gained from a laboratory scale digester tested by ICCRI and the experiences collected from various researchers working at the subject. An in-ground rectangular type digester is finally to be chosen for the field test and is constructed by using brick masonry materials. The gas holder made from steel plates is installed on the top of the tank [Figure 2]. Four digesters are installed at the ICCRI Experimental Station those can be run in parallel as duplicate analysis. The experiments have been started since 2007 during the whole year of cocoa and coffee harvesting seasons.

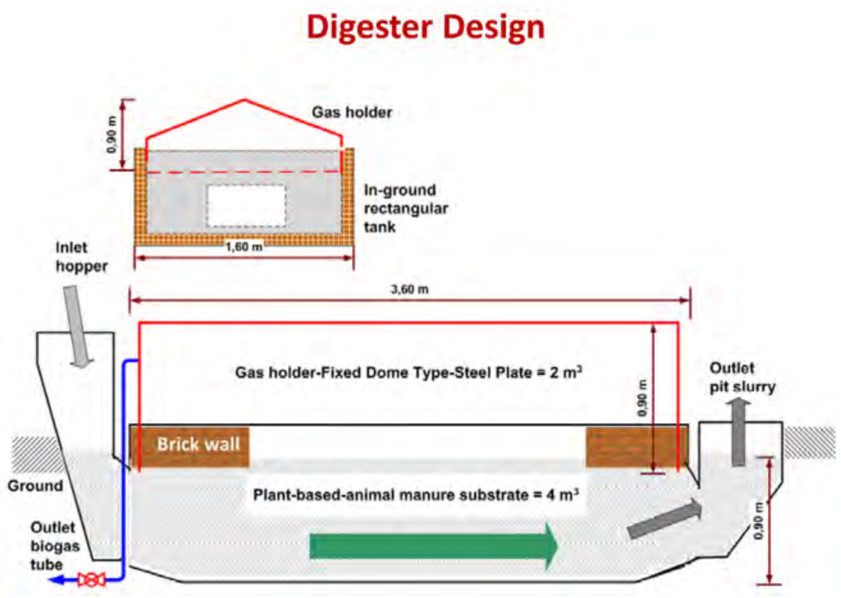

Figure 2. A schematic drawing of horizontal digester.

2.4. *Plant-based feed stocks preparation*

Pre-treatment of co-digestion input materials derived from plant-based materials are required which consist of size reduction of bulky materials, removal of undesirable materials and blending of different materials input. The final size of biomass after being chopped ranges from 3 to 4 mm.

2.5. *Experimental procedures*

Procedure of experiment 1.

Type of Input : mixture between animal manure and waste water from coffee processing. The inputs are loaded into two digesters for duplicate analyses, with the following procedure; four months prior to the coffee harvesting season, single fresh cow dung [after diluted with water at 1/1 by weight proportion] is fed to the digester, to initiate the anaerobic digestion process. When, the coffee harvesting starts, the effluents from the factory are initially neutralized with commercial lime in the equalization tank to reduce their acidity till their pH value achieve 6.5 to 7. Afterward, this neutral effluent is used to dilute fresh cattle dung at the ratio of 1/1 [by volume basis]. The dilution is done to obtain a homogenous mixture of two or more substrates with the final total solid content from 12 to 13 %. A 75 kg of substrate input is loaded into the digester at once through an input hopper and leave the substrate within the digester uninterruptedly for several weeks to make a methane gas production steadily [a batch type operation]. The digester is operated naturally under ambient tropical conditions.

Procedure of experiment 2

Type of Input : mixture between animal manure and cocoa pod husk from cocoa processing factory. The inputs are loaded into two digesters for duplicate analyses, with the following procedure, cocoa pod husk chips are soaked in water for 3 to 4 days and afterward mixed with a cattle manure substrate at a weight ratio 1/3. The dilution and digestion are done as described in the experiment 1.

Gas pressure is measured with a hand-crafted pressure gauge made of a 10 ㎠ section of plastic tube attached [in a U-shape] to a graduated rectangular plank.

2.6. Biogas Application

Biogas produced by the digester will be tested in a various of applications such as for household cooking and lighting and for agro processing such as roasting of coffee and cocoa. A simple biogas burner for cooking and heating is designed to match with the available cooking devices in the rural household area. The performance of stove for cooking is determined by calculating the heat gained by the water subjected for boiling and amount of fuel consumed during this process. The time taken for the various tasks is measured by a digital data logger. The cooked material is determined by organoleptic tastings.

III. Results and Discussions

3.1 Feed Stocks availability for biogas production

3.1.1. Farm residues

Biogas feed stocks out of coffee and cocoa plantations are derived from the pruning process of main crop and shade trees. With the average main crop population is 1,100 trees per hectare, the amount of plant based residue from the pruning process ranges from 20 to 30 ton/hectare/year. The integration of cattle and goat produces an animal-based material to an average 11 ton/hectare/year/ which is very useful for co-digestion process. Table 1 summarizes the amount on-farm residual estimation in cocoa and coffee farms and Table 2 shows the average value of C and Nitrogen ratio [C/N] each type of residual waste. Based on their C/N value, the plant-based and animal based residues can be mixed, hence, it is suitable as feed stocks for bio-digester.

Table 1. Biomass residue potential of coffee and cocoa farm [ton/hectare/year].

Residual Type	Coffee	Cacao
Plant-based		
Main crop trees	12 - 15	15 - 20
Shade trees	7 - 9	9 - 12
Animal-based		
3 Cattle	10 - 12	10 - 12
3 Goat	0,5 - 1,0	0,5 - 1,0

Table 2. The C/N ration each type of residual waste.

Type of residual waste	C/N value
Fresh wood trunk	1/110 - 125
Dried wood trunk	1/150 - 200
Fresh leaf	1/20 - 25
Dry leaf	1/50 - 70
Cattle dung	1/19 - 20

3.3.2. Factory wastes

A ripe cocoa pod consists of 25 % seed, 65 % of husk and the rest [10 %] is placenta in which 30 - 40 cocoa beans are tied up on it. The weight of the ripe pod ranges between 0.50 to 0.70 kg. A well manage cocoa plantation will produce pods ranging from 45.000 to 60.000 pods per hectare per year. The pod should be split into halves to remove the beans leaving the cocoa pod husk which is estimated to about 13 to 15 tons. A recent technology of cocoa processing requires a small amount of water. Thus, the environmental effects of the effluents discharged from cocoa processing factory does not occur. Basically, cocoa pod husk is the only solid waste derived from cocoa processing factory and is an excellent source of organic fertilizer after being simply composted for several weeks.

In case of coffee farm, the amount of water used in coffee processing is quite large and depends strongly on the type of processing. As shown in Figure 1, the amount of waste materials derived from coffee processing can be seen in Table 3. The waste estimation is based on the average coffee product ivy is approximately 1.125 kg/ha/yr. While the weight ratio between the bean [usable portion in cherry] and the cherry is about 20 %.

Table 3. Mass balance of coffee processing [in 1 hectare during coffee season]

	Input	Output	
		Usable product	Waste
Coffee cherries, kg	5625		
Water, L [10 L/kg cherries]	56250		
Total, kg	61875		
Coffee bean, kg		1125	
Husk, kg			281
Pulp content and skin, kg			2278
Mucilage, kg			900
Water loss, kg			1040
Waste water, kg			56250
Total, kg		61875	

Water used in processing coffee contains high levels of pollutants. There is a significant change in physical, chemical and biological properties of water before and after the processing [Table 4].

Table 4. Raw and waste water characteristic.

Quality	pH	BOD [mg/l]	COD [mg/l]	SS [mg/l]	TS [mg/l]
Influent raw water	6,8	250	500	500	800
Waste water	3,8	12.000	18.000	3.600	12.000

The main component is organic matter, stemming from pulping and mucilage removal. Pulping water consists of fermenting sugars from both pulp and mucilage components. Pulp and mucilage consists to a large extent of proteins, sugars and the mucilage in particular of pectins, i.e. polysaccharide carbohydrates. The majority of organic material in the wastewater causes high COD values as high as 18,000 mg/L. The BOD coming from biodegradable organic material can reach values of 12,000 mg/L. Other components in pulping water are acids and toxic chemicals like polyphenolics [tannins and caffeine]. The waste water from washing process contained sugars and organic acids causing the wastewater is very acidic. The total suspended solids in the effluents are also high.

After pulping, the beans are fermented in 12 to 36 hours to break down microbiologically the remaining mucilage on the beans surface. The fermentation of the sugars [disaccharide carbohydrates] into ethanol and CO_2 leads to acid conditions in the washing water. The ethanol is converted in acetic acids after reaction with oxygen, lowering the pH to levels of around 3.8 [Von Enden and Calvert, 2002]. The combination of waste water from pulping and washing process can be used as a bio-digester feed stock. In order to optimize the anaerobic processing of the wastewater pH values should be between 6.5 and 7.5, instead of the present values of pH = 4, which is highly acidic. This is obtained by adding commercial lime to the wastewater.

3.4. Biogas Production

Five months prior to the coffee harvesting season, single fresh cow dung [after diluted with water at 1/1 by weight proportion] is fed to the digester, to initiate the anaerobic digestion process. The digester is operated naturally under ambient tropical conditions at temperature range between 28 and 32℃. Thus, a number of mesophilic and thermophilic anaerobic bacteria is assumed to grow well in its optimum condition to promote higher biogas production. The gas production rate for the total solid [TS] concentration level of 12 % is recorded on a daily basis for a period of 45 to 50 days. The total biogas production expressed as ㎥ biogas/kg total solids [TS], ranges from 0.25 to 0.40 /day/㎥ digester volume [Figure 2]. Biogas production continues steadily till the coffee harvesting season is commenced.

At the beginning of harvesting season, the coffee factory starts producing waste water that can be used as an replacement material to animal manure as a digester feed stock. One of the main characteristics related to the composition of the coffee waste water substrate is a value of

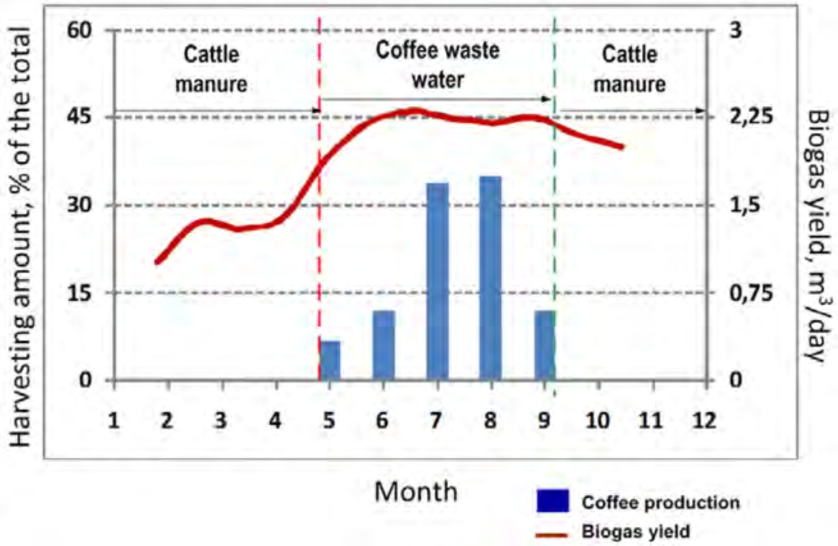

Figure 2. Biogas production of co-digestion cattle manure and coffee waste water.

chemical oxygen demand [COD], which is directly proportional to the total amount of organic compounds contained in the substrate [Calvert, K.C. 1997]. Thus, it is expected that coffee waste water after being treated with lime, can be feed into the digester as a single feed stock. The existence of cattle-manure as an digesting initiator however take an important role in accelerating of biogas production.

The use of co-substrates, such that usually improves the biogas yields from anaerobic digester due to positive synergisms established in the digestion medium and the supply of missing nutrients by the co-substrates [Mata-Alvarez et al., 2000]. Co-digestion can provide a better nutrient balance and therefore better digester performance and higher biogas yields. Animal manure usually contains high ammonia concentration that had an inhibitory effect on the glycolytic pathway. The same trend also appears in the biogas production using co-digestion between cattle manure and coffee processing waste [Braun., 2003, Neves., et-al., 2006].

The coffee waste water after being neutralized by lime will be a seething solid mass of micro-organisms and will float out more solids on the surface of the water. That solid is a highly methane-enriched biogas raw material [Rathinavelu & Graziosi, 2005]. No nutrient limitations and no substrate inhibition as reported by Field & Lettinga [1987], have been observed during the tests. The anaerobic degradability is higher than 70%. As a result, the total biogas production can reach to maximum of 0.55 m^3/day/m^3 digester volume, 40 days after the co-digestion input is operated.

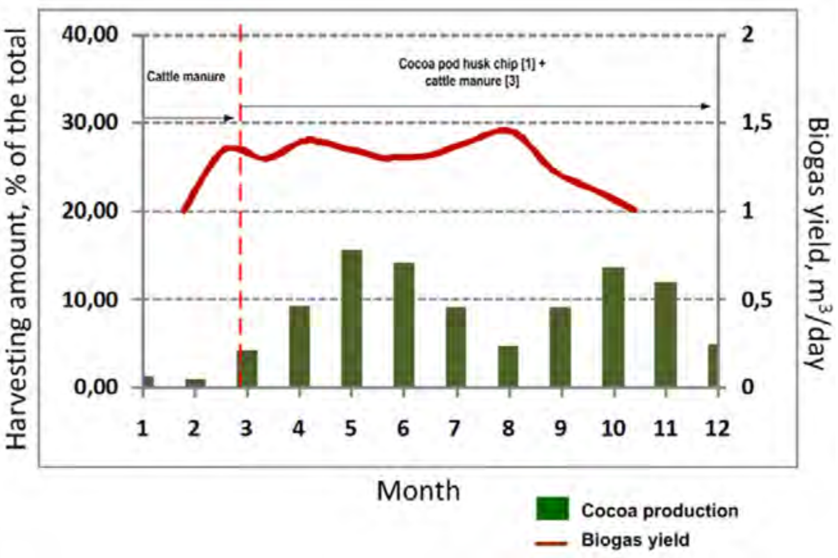

Figure 3. Biogas production of co-digestion cattle manure and cocoa pod husk chip.

In case of using cocoa pod husk chips as co-digesting material, the digester needs more time to achieve a steady biogas production and hence, produce less amount of biogas compared that of using coffee waste materials. After a 45 days retention time, the maximum attainable biogas production from co-digestion cattle manure-cocoa waste is only 0,33 ㎥/day/㎥ digester volume [Figure 3]. The velocity of degradation of the basic classes of compounds increases in the following order, cellulose, hemicellulose, proteins, fat and carbohydrates. Cocoa pod husk contains more than 35 % cellulosa and hemi-cellulosa. As a result, the digestion of cattle manure and coffee waste materials with their high carbohydrat and protein contents faster than cocoa waste materials [Aregheore, 2002].

Cocoa pod husk also contains tannin substance which gives inhibitory effect on the biogas production. Tannin can be removed partially by soaking cocoa pod husk chips in water for 3 to 4 days before being used a feed stock. The negative effect of tannin can also be minimized using higher proportion of cattle manure in a co-digestion cattle manure-cocoa pod husk chips substrate input [Bopaiah., et-al., 1988]. Due to its high C/N ratio, cocoa pod husk chips has to be mixed with cattle manure [C/N = 20] in all inputs during the whole year biogas production to bring the average ratio of the composite input to a desirable level.

In average the co-digestion cattle manure-coffee waste materials starts after 2 weeks. While, co-digestion of cattle manure and cocoa farm residue [chopped cocoa husk] requires 4 to 5 weeks. A large amount of methane is produced during the first week to fourth week and the remaining methane is released at a much slower rate at the following weeks. As the materials are kept longer inside the digester, the slurry will tend to settle out and form a hard scum on the surface. It will prevent release of the biogas and as a result the biogas production is decreasing. Stirring is done by pulling a harrow within the digester forward and backward direction using a plastic rope. When cocoa pod husk chips is used for a co-digesting material, the periodic maintenance of digester is more frequent to keep the digester functioning properly.

A parallel batch digesters operated in a group is therefore recommended for co-digesting cocoa pod husk chips-cattle manure. At least one is producing useful quantities of gas, whilst the other can be repaired or overhauled regularly.

3.5. Biogas Application

Biogas has a calorific value of approximately 23.5 MJ/m³. In principle, it can be used in the same way as any other combustible gas such as LPG or LNG for cooking and lighting. A biogas pressure of between 30 and 60 mm H_2O column is able to produce a sufficient heating source in a simple stove for boiling of water and cooking of rice. The biogas stove is able to produce heat is relatively fast. Within less than 5 minutes, the flame temperature rise sharply from ambient temperature to a constant temperature of 525℃ [Figure 4]. At the same time, the water temperature rise steadily approaching its boiling point at 100℃ which can be observed from its physical changes [air bubbling]. The water temperature rise begins to a constant value at 100℃ after the heating period reaches 35 minutes. At this point, the biogas consumption is approximately 170 liters of biogas. The same procedure is done to cook rice and the result is shown in Table 5. Continuous operation of the stove gives higher cooking efficiency and less biogas consumption. Thus, the farmer's house wife has to change the daily cooking habit, meaning that she should not operate the biogas stove for cooking intermittently as she gets used to cook the meal or to boil water using a kerosene or wood stove.

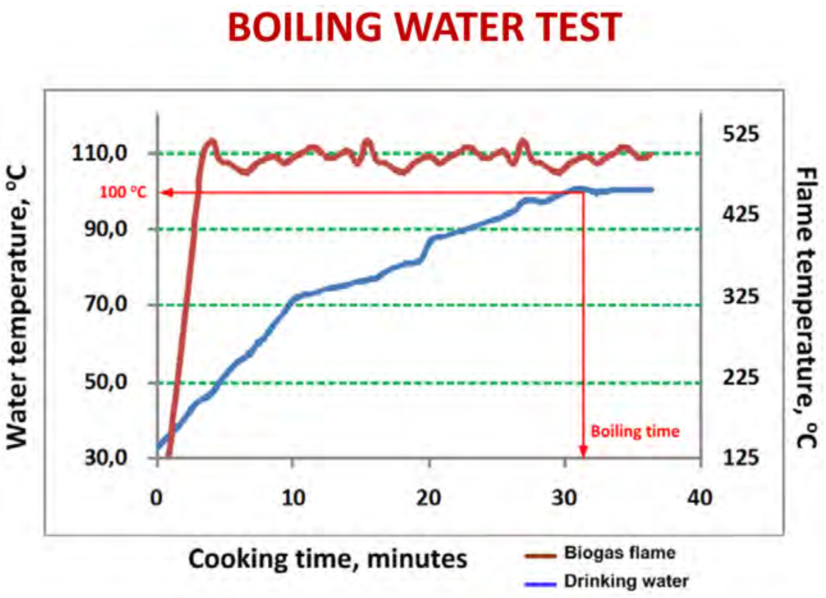

Figure 4. The temperature profile of 5 liters water heated by a biogas stove.

Methane gives a soft, white light when burned with an incandescent mantle. Lamps require a pressure of about 30 mm H_2O column. The lighting efficiency of biogas lamps is quite low, averaging between 4% and 5%. Nonetheless, a good biogas lamp can illuminate a room far better than a wick kerosene lamp, and produces a light intensity comparable to that which can be obtained with a pressure kerosene lamp or an electric light bulb in the power range of 25-75 W.

A small scale industrial used of biogas is demonstrated for coffee roasting. Roasting is the heat treatment which transforms the raw coffee beans into the aromatic brown nuggets that are ready for grounding. The beans are kept moving during the beans are heated up to temperatures of about 280 to 300℃. Figure 5 shows that the biogas stove can provide sufficient heat to roast the coffee beans. The specific flavor and aroma of the coffee has been developed, when the beans temperature reaches about 200℃ and the beans color turns a darker brown produces. Thus, the process is stopped at 50 minutes after the initial heating. The biogas consumption for roasting is approximately 960 liter.

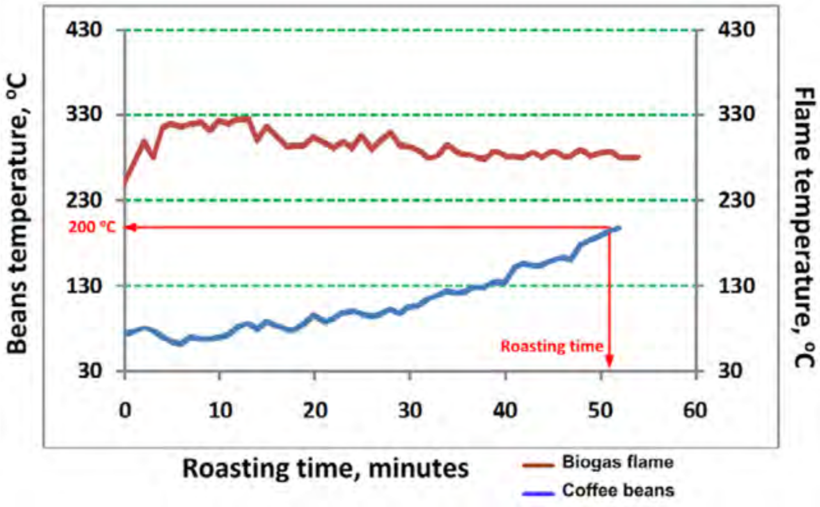

Figure 5. The temperature profile of 10 kg coffee beans roasted by a biogas stove.

Table 5. Various applications of biogas at household and small industrial scales.

Type of use	Time, min	Consumption, L	Pressure, mmH_2O
Boiling water, 1 L	13	40	30-60
Boiling water, 5 L	32	170	30-60
Cooking rice, 500 g	41	210	30-60
Lighting [. 60 W]	360	945	15-30
Roasting coffee, 10 kg	45	980	250-300

IV. Environmental and Economic Benefits

Conversion of cocoa and coffee farms residues to biogas can significantly decrease the potency of environmental problems associated with wastes. The field trials show that the COD and BOD content of the coffee processing effluents can be reduced significantly to an allowable level for direct disposal. In fact, the effluent of the digester is the slurry that can be used as compost materials [organic fertilizer] having the appearance of farm manure and has a value of plant nutrients [Table. 6].

Table 6. The average of slurry compositions

Slurry	Value
COD, mg/L	1.960
BOD, mg/L	0,35
N, %	1,90
P, %	0,75
K, %	0,45

Having the biogas reactor at a family level may take up alternative income-generating activities. The farmer can get as additional incomes from selling the compost and the cost saving from not any more buying kerosene or LPG for daily cooking [Table 7]. A field observation shows that a farmer family [1 parent and 2 children] consumes 1,50 to 2,0 liters of kerosene for daily cooking. This amount of kerosene can be replaced by 1,10 to 1,20㎥ of biogas.

Table 7. Economic benefit estimation for operating biogas digester.

	Day	Year
Kerosene, L	1,50	547,50
Energy cost saving, Rp	4.500 [US $ 0,50]	1.642.500 [US $ 164]
Compost, kg	15	5475
Selling price, Rp	13.500 [US $ 1,30]	4.927.500 [US $ 493]
Total added income	18.000 [US $ 1,80]	5.570.000 [US $ 557]

V. Conclusions

Anaerobic digesters have been installed and tested at the ICCRI Experimental Station as a field observation and demonstration for treatment of cocoa and coffee wastes and animal waste to produce biogas. The results show that,

1. The integrated cocoa and farming system is able to provide a sustainable feed stock for yearly around biogas production.
2. The rectangular type reactor can be used as co-digesting biogas reactor using cocoa and coffee factory waste materials.
3. At the same daily input of 75 kg and solid concentration of 12 to 13 %, co-digestion cattle manure-coffee processing waste produces more biogas [0,55 ㎥/day/㎥ digester] than that of from cattle manure-cocoa processing waste [0,33 ㎥/day/㎥ digester].
4. Coffee processing waste can be an aerobically digested as a sole carbon source without further addition of co-substrates [animal manure].
5. Cocoa processing waste cannot be used as a single input for the digester, there is a risk of producing a hard scum floating the substrate which hinders the methane production.
6. The heating value of biogas is about 23,50 kJ/㎥. It can boil 5 liters of water and cook 500 g of rice within 35 and 45 minutes which consume about 170 and 210 liters of gas respectively.
7. Biogas can also be utilized as an energy source for coffee roasting which consumes 980 liters per 10 kg coffee for about 40 minutes.
8. Conversion of cocoa and coffee farms residues to biogas can significantly decrease the potency of environmental problems associated with wastes.
9. Converting the waste to biogas may give double economic benefits to the users from selling the compost and energy cost saving from not any more buying kerosene or LPG for daily cooking.

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3

Treatment of Wastewater and Sludge in China, and its Perspective as Bio-Energy Sources Around Towns for Supplying Energy Needs

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Abstract

In China wastewater amounts are increasing steadily, and treatment ratio is increasing very fast in recent years. Because of climate change and global warming, more and more attentions are paid for renewable energy production. In this paper some data will be demonstrated for wastewater and sludge treatment in China and analyzes are done to investigate the potentials of renewable energy produced from wastewater and sludge, which has at least two positive aspects, i.e. environmental protection and renewable energy production. The energy can be supplied for peoples around towms.

Keywords: Municipal Wastewater; Sludge; Perspectives; Bio-Energy Source; Urban Areas

1. Introduction

At present, China is encountering severe water shortages, resulting from both a large population and water pollution caused by rapid economic development. Although China significantly improved its water and wastewater infrastructure, with annual water supply at 581.9 billion cubic meters in 2007, there are still annual water shortages of 40 billion cubic meters. Accelerated urbanization and high-speed economic growth in China continue to aggravate the water shortage problem. The official municipal wastewater treatment rate was 56 percent at the end of 2006, which is far from adequate given China's serious water pollution. According to "11th five-year" plan, the municipal wastewater treatment rate of major cities should reach 70% before 2010.

With the wastewater treatment rate increasing, more and more wastewater sludge produced which has become a serious problem to environment compared with water pollution. The treatment and beneficial use of sludge are attracting more attention nowadays. The view of municipal wastewater and sludge have shifted, from a waste to be treated and disposed of, to a resource that can be processed for recovery of energy, nutrients, and other constituents.

2. Situation of Wastewater and Sludge Treatment

2.1 Wastewater treatment

By the end of 2006, of the 661 cities in china, there were 383 cities which had 815 wastewater treatment plants, wastewater treatment rate increased from 34% in 2000 to 56%, and formed wastewater treatment technology route and management mechanism adjusting to the situation of China. Of which, wastewater treatment rate in 135 cities got to or was close to 70%, maximum treatment scale per plant was up to 1 million cubic meters per day.

Physical, chemical and biological methods are used to remove contaminants from wastewater. In order to achieve different levels of contaminant removal, individual wastewater treatment procedures are combined into a variety of systems, classified as primary, secondary, and tertiary wastewater treatment. More strict treatment of wastewater includes the removal of specific contaminants as well as the removal and control of nutrients. Natural systems are also used for the treatment of wastewater in land-based applications.

The following diagram shows the main methods which used in wastewater treatment plants.

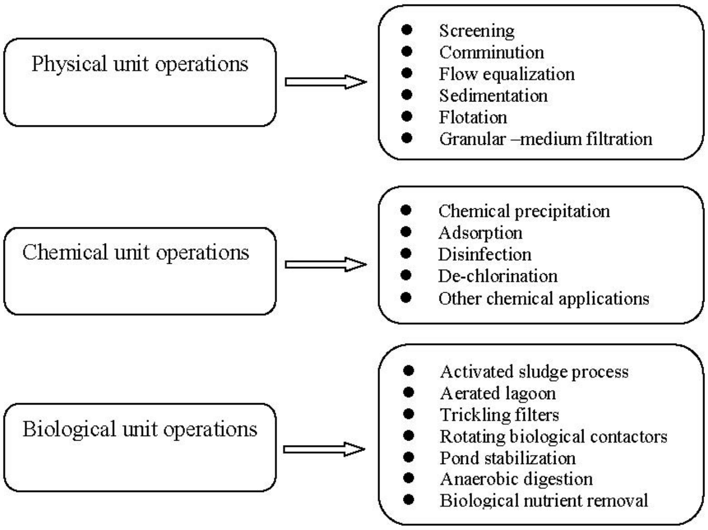

Figure 1 wastewater treatment unit operations and processes

China wastewater treatment industry is growing rapidly, total volume of wastewater treatment increases year by year, wastewater treatment rate in urban areas increases continuously, almost every process which is being used world widely can be seen in Chinese WWTPs, but China wastewater treatment industry is still in the primary development stage. The capacity of wastewater treatment can’t catch up with the rapid expansion of the water using scale, and construction of the matching facilities such as pipe networks, sludge treatment, etc. is lagging behind seriously.

2.2 Sludge treatment

Sludge is produced from the treatment of wastewater in on-site (e.g. septic tank) and off-site (e.g. activated sludge) systems. This is inherently so because a primary aim of wastewater treatment is removing solids from the wastewater. In addition, soluble organic substances are converted to bacterial cells, and the latter is removed from the wastewater.

The composition and characteristics of sludge vary widely. Furthermore, sludge characteristics change considerably with time. The generated sludge is usually in the form of a liquid or semisolid, containing 0.25 to 12 percent solids by weight, depending on the treatment operations and processes used. The amount of municipal sludge in china is approximately 3.0 million ton dry substance annually according to the recent statistics. The disposal of sludge has always been one of the major environmental problems of cities and other urbanized areas. If

Chinese government goals for 2010 are achieved with 60% treatment rate for major cities, there are a lot of works to be done in recent years.

In order to reduce its water and organic content and make it suitable for final disposal and reuse, sludge handling, treatment and disposal are complex, owing to the offensive constituents present, which vary with the source of wastewater and the treatment processes applied. The following diagram is the sludge processing and disposal flow.

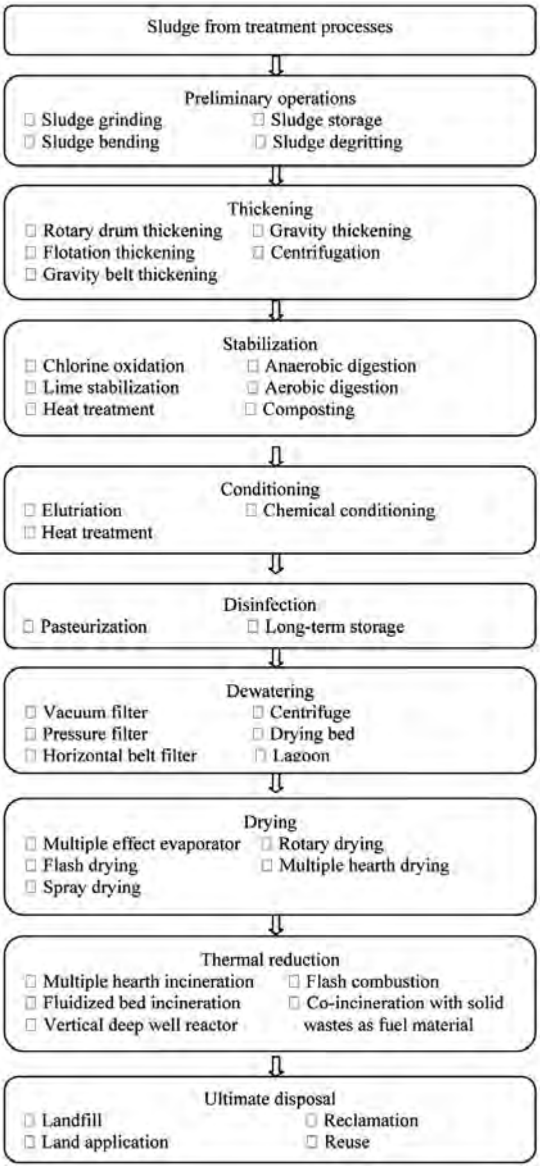

Figure 2 sludge processing and disposal flow diagram

There was a time when sludge was commonly disposed of in sanitary landfills and lagoons. However, the beneficial uses of sludge are attracting more attention nowadays. Treated and digested sludge may be used as a soil amendment and conditioner. Sludge may also be treated chemically for use as landfill cover or for landscaping or land reclamation projects. In figure 3 the percentages of different disposal methods are demonstrated in 2004, which shows that 56% of sludge are disposed by landfill.

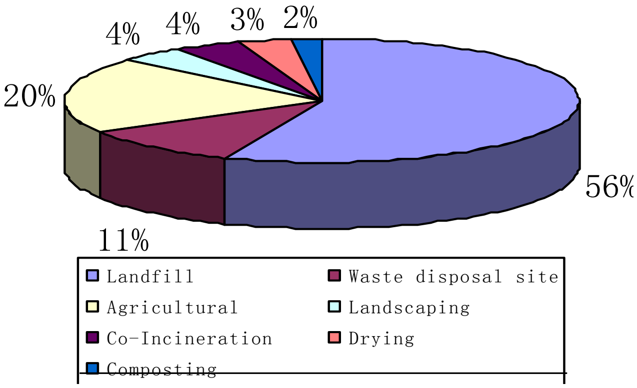

Figure 3 ways of disposal and utilization for sludge

2.3 *Bio-energy use of sludge*

Wastewater contains 10 times the energy needed to treat it, and it is technically feasible to recover energy from sludge. As renewable energy, it can be directly used in wastewater treatment, reducing the facility’s dependency on conventional electricity. The greater the quantity of energy produced by the sludge management industry, the more the industry can help reduce emissions of greenhouse gases. Using solids as a resource rather than a waste may help stressed public budgets as well.

In the field of sludge reclamation and reuse technologies, increased attention is being devoted to the production of sludge that is clean, has less volume and can be safely reused. Developments in this area have been slower than in the field of wastewater treatment, but a number of new technologies have emerged, including high-solids centrifuges, egg-shaped digesters and powerful heat dryers. Other developments include temperature-phased anaerobic digestion and auto-thermal aerobic digestion processes, which destroy volatile solids more effectively and yield enhanced production of class A biosolids.

Anaerobic digestion is a bacterial decomposition process that stabilizes organic wastes and produces a mixture of methane and carbon dioxide gas (biogas). Due to the characteristics of China's urban wastewater sludge, sludge anaerobic digestion has less gas production than in Europa, about 6~12㎥ Biogas/㎥ sludge, methane (CH_4) concentration is lower in the biogas, or about 45%~55.9%. Wastewater sludge has relative high thermal value, which makes it self-sustaining combustion. The thermal value of methane is the same as natural gas, therefore biogas is valuable as a renewable energy source. In table 1 the thermal values of different kinds of sludge in two WWTPs in China are shown.

Table-1 Sludge thermal value of china municipal wastewater treatment plants

Sludge source	Sludge type	Volatile solid (%)	Dry basis thermal value (MJ/kg)	Ash-free basis thermal value (MJ/kg)
WWPTS of Jizhuangzi Tianjin	Primary	45.2	10.72	23.7
	Second	55.2	13.30	24.0
	Disgested	44.6	9.89	22.2
WWPTS of Jinshan Shanghai	Mixed	84.5	20.43	24.2

According to development status for energy conversion from sludge, there are different methods such as gasification, co-incineration, biogas production, incineration etc. Until now most popular technology about sludge management to energy conversion is anaerobic fermentation technology for biogas production.

Converting bio-solids or sludge to energy is feasible and desirable, from a treatment perspective. The challenge is finding a process that is also affordable, cost-effective, and acceptable to the public, which depends on local condition, economic development level, demands for energy, etc. While the current technology is promising, none of the processes can fully extract all the energy available in wastewater and sludge. New technological developments, or improvements of current technologies, are necessary to take advantage of the maximum energy available in wastewater and sludge.

3. Perspective as Bio-Energy Sources

China's extraordinary economic growth and heavy reliance on increasingly expensive and limited oil source, the vast environmental toll that is one of the most apparent costs of economic success, persistent rural poverty in China and periodic power shortages all have impressed upon Chinese government that renewable energy must be a important part of it's economy if china is to both complete its economic transformation and achieve "energy security".

Chinese government has expressed a strong interest in cleaner coal-based technologies like coal liquefaction and gasification, but the government appears to put official hope in renewable energy, setting a target of 12% of its power generation capacity coming from renewables by 2020-- up from a mere 3% in 2003. In the long-term, China has set an objective of having 30% or more of its total energy requirements satisfied by renewable sources by 2050 (Figure 4). The government's interest in reducing China's use of coal and petroleum products extends beyond environmental and health concerns; it sees both the strategic value of mitigating its reliance on foreign oil and the economic advantages of being on the technological leading edge of energy production.

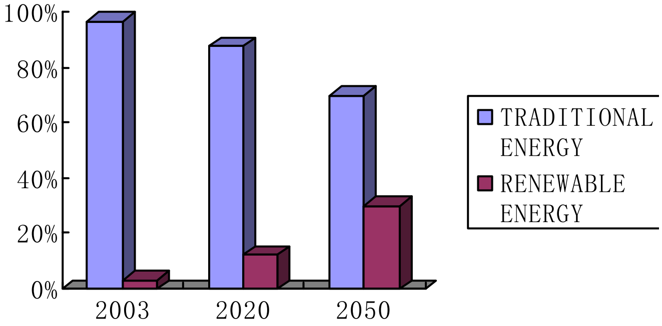

Figure 4 Compare of energy supply with traditional and renewable energy

Supposing the biogas production amount can be calculated based on the experiences, i.e. each person can produce 20 liter biogas /person*d from his/her wastewater, which equals 7.3 ㎥ biogas/person*year. Excluding the self-energy consumption for anaerobic reaction, each person can produce 18 KWh /person*year from his/her wastewater. In China it means that the domestic wastewater alone can produce about $95*10^8$ ㎥ biogas/year, or $234*10^8$ KWh/year. Of course, for decentralized wastewater collection systems, it is not economically feasible that biogas is used for power generation. For different scale systems biogas can be used in different ways, for small scale wastewater system, biogas can be directly used as burning gas; for medium and large scale wastewater system, biogas can be used through CHP to produce power and heat; for medium and large scale wastewater system, biogas can also be separated into methane gas and CO_2, then methane gas can be transported into natural gas pipe network as biofuel.

4. Related Regulation about Renewable Energy

In order to promote the development of renewable energy, China has passed some relevant laws and regulations of renewable energy, such as “Renewable Energy Law of People’s Republic of China”, “Energy Conservation Law of the People's Republic of China”, etc. during the past several years. In February 2005, China passed a groundbreaking law, “Renewable Energy Law of People’s Republic of China”. Implementation of the law started on January 1, 2006. The law provides a feed-in tariff for some technologies and establishes grid feed-in requirements and standard procedures. It establishes cost-sharing mechanisms so the incremental cost will be shared among utility consumers. It also creates new financing mechanisms and supports rural uses of renewable energy. The law also provides for a long-term development plan, R&D, geographic resource surveys, technology standards, and building codes for integrating solar hot water into new construction.

Renewable energy is helping China complete its economic transformation and achieve "energy security". China has moved along the path of renewable energy development rapidly. Technology development and increased amounts of investment in renewable energy technologies and installations has increased markedly throughout the 2000s in China, and investment in renewables is now part of China's economic stimulus strategy. China’s central government would release preferential tax policies for the renewable energy industry.

5. Conclusions

China government has been paying more and more attention to the issue of public health and environmental problems. The treatment rates of wastewater and sludge are increasing steadily. Sustainable wastewater treatment, with a reduced carbon footprint, is now becoming a goal of technical exploration and experimentation. While the current technology is promising, none of the processes can fully extract all the energy available in wastewater. New technological developments, or improvements of current technologies, are necessary to take advantage of the maximum energy available in wastewater and sludge.

To be attractive, technologies for energy and resource recovery must meet social, economic, and environmental objectives, as well as being affordable and cost effective. For instance, chemical use may be required in certain processes, but it may not always be the best option in terms of health protection and life cycle impacts (energy use and emissions during production and transportation). In addition, technologies with high potential for pollutant emissions, either upstream or onsite, will have less public acceptance.

Energy conversion from wastewater and sludge is very complex technology depending on the economic factors. It is important to find more effective technologies which treat wastewater effectively while avoiding production of poisonous and harmful substances on environment.

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4

Biogas Recovery from Piggery Wastewater by Anaerobic Digestion

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Abstract

The purpose of this study is to investigate the performances of organic removal and methane recovery from high-strength piggery wastewater by using a full scale two-phase anaerobic system. The full scale two-phase anaerobic process consisted of an acidogenic ABR (Anaerobic Baffled Reactor) and a methanogenic UASB (Upflow Anaerobic Sludge Blanket) reactor. The volumes of acidogenic and methanogenic reactors were designed to be 28.3 ㎥ and 75.3 ㎥, respectively. The two-phase anaerobic system showed 60-82% of COD removal efficiency with influent COD concentration in the range of 7,150 to 16,270 mg L^{-1} and its averaged value was 10,280 mg/L after screening. After steady-state, the effluent COD concentration from the methanogenic reactor was 2,740 ± 330 mg L^{-1} with an averaged removal efficiency of 71.4%

at an operating temperature ranged from 19 to 32℃. The effluent SCOD concentration was in the range of 2,000-3,000 mg L^{-1} at steady state while volatile fatty concentration was not detected in the effluent. The COD removal efficiency in the acidogenic reactor was below 5%. The acidogenic reactor played key roles in reducing a shock-loading, when accidental shock loads were occurred, and in acidifying influent organics.

Keywords : ABR; methane recovery; piggery wastewater; Two-phase anaerobic process; UASB

Introduction

Due to the increase of meat consumption, the number of livestock heads and the size of livestock farms become larger in South Korea. Accordingly, the production of swine wastewater has been drastically increased during the past decade and currently amounts to 150,000 ton per day in South Korea (Kang et al., 2003). Swine wastewater is widely known to be a high-strength wastewater with a pollutant organic load which is much higher than domestic sewage. Therefore, minimizing the impact of swine wastewater on the environment is the single most pressing challenge facing the agriculture industry.

One of the promising technologies to control piggery wastewater is anaerobic treatment processes because these can produce valuable methane gas and fertilizer for domestic and agriculture use. Generally, anaerobic processes is operated at 35-37℃ regardless of temperature of raw wastewater. If these processes can achieve good performances in the wide range of operating temperature, it will be cost-effective. Some researchers tried to develop a system which operated successfully at 10-15℃ (Kenndy et al., 1982; Koster et al., 1985; Kettunen et al., 1997). However, there are only a few reports of treating piggery wastes by anaerobic system under the low operating temperature due to high concentration of inhibitors such as hydrogen sulfide and salts in the high-strength piggery wastewater (Sanchez et al., 2001; Stevens and Schulte, 1979). The purpose of this study is to investigate the performances of organic removal and methane recovery using a full scale two-phase anaerobic system under a wide range of operating temperature.

Material and methods

Configuration of anaerobic system

The full scale two-phase anaerobic process consisted of an acidogenic ABR and methanogenic UASB reactors as shown in Figure 1. The volumes of acidogenic and methanogenic reactors were designed to be 28.3 ㎥ and 75.3 ㎥, respectively. The acidogenic reactor played key roles of converting higher molecular organics to volatile fatty acids and reducing hydrogen sulfide content in the biogas by drawing off the biogas in the acidogenic reactor to air. Recirculation tanks for both reactors were installed to provide constant up-flow velocity which was maintained at 0.8 m/h. The recirculation played an important role in reducing organic loading in the influent, especially in the case of shock-loading.

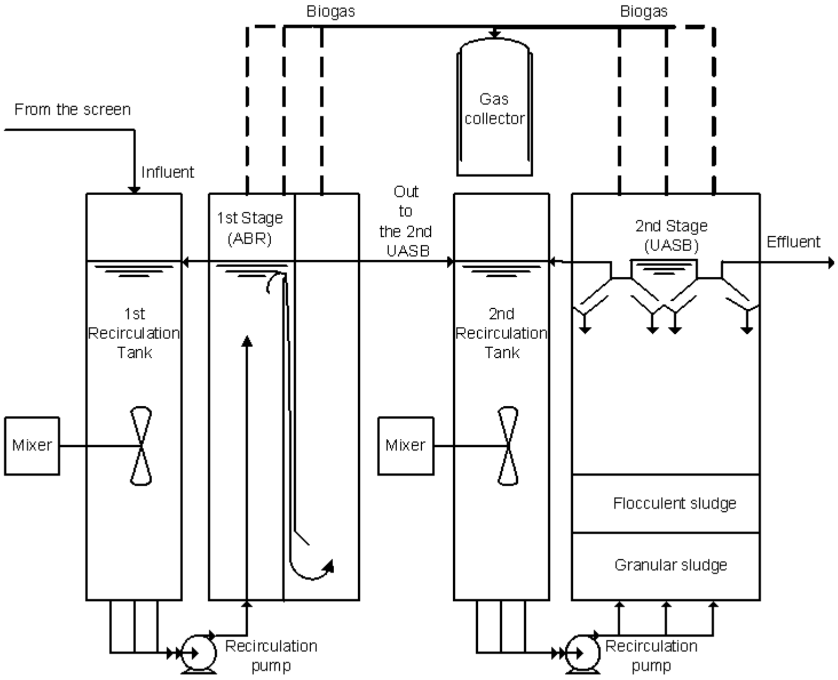

Figure 1 Schematic diagram of full-scale two-stage anaerobic process.

The characteristics of piggery wastewater are shown in Table 1. The average TCOD and TBOD concentrations of the piggery wastewater were 10,280 mg L^{-1} and 5,168 mg L^{-1}, respectively. The reason for low concentration of soluble phosphate was struvite formation in the storage tank.

Thirty tons of seeding sludge was taken from a full scale UASB reactor treating distillery wastewater. The influent was screened by a 1mm sieve screen prior to flowing into the acidogenic reactor. The process operated as a fed-batch type: The daily average flow rate was 3 m^3 ranged from 2 to 4 m^3. The influent was pumped into the reactor between one to three hours. Once 10-20 m^3 of raw wastewater was pumped into the reactor due to mistake of operator. When average flow rate was in the range of 3-4 m^3, the corresponding volumetric organic loading rate (ORL) was 0.4-0.6 kg COD m^{-3} d^{-1} and increased to 2.4 kg COD m^{-3} d^{-1} at overloading. The operating temperatures of the reactors were maintained above 20℃ using a boiler.

Table 1 Characteristics of wastewater used in the full-scale experiment (SD: standard deviation).

Parameters	Average	SD	Range	Number of analysis
pH	7.9	0.32	7.5-8.7	32
Alkalinity (mg $CaCO_3$ L^{-1})	8,066	1,330	5,820-10,780	30
TSS (mg L^{-1})	1,382	1,258	290-5,550	32
VSS (mg L^{-1})	1,031	775	230-3,550	32
TCOD (mg L^{-1})	10,282	2,526	7,145-16,270	32
SCOD (mg L^{-1})	8,367	1,947	5,834-13,129	32
TBOD (mg L^{-1})	5,168	1,147	3,227-7,350	16
SBOD (mg L^{-1})	4,752	1,800	982-6,750	12
TVFA (mg HAc L^{-1})	2,392	1,009	1,048-4,777	18
TKN (mg L^{-1})	2,114	502	1,202-2,909	32
NH_4^+-N (mg L^{-1}))	1,903	534	630-2,803	32
T-P (mg L^{-1})	37	21	4-70	27

After April, 2004, samples were taken more than twice a week, while sampling was conducted once a month from November, 2003 to March, 2004. Samples were analyzed quickly as they arrived in laboratory from field. Soluble samples were prepared by filtration with GF/C filter after centrifugation for 30 minutes at 3,000 rpm. Gas compositions was analyzed with gas chromatography (HP 5880) equipped with a thermal conductivity detector (TCD) and 1.8 m (6 ft) x 2 mm (ID) stainless steel column packed with Porapak Q (80/100 mesh). The temperatures of the column, the injector, and the detector were 50, 100, and 110℃, respectively, with introducing helium as a carrier gas at a constant flow rate of 30 mL min^{-1}. For the analysis of volatile fatty acids, filtered samples were acidified to pH 2.0 and then directly injected into a gas chromatography (HP Agilent 6890) equipped with FID (Flame Ionization Detector) and HP-INNOwax Polyethylene Glycol Capillary (30.0 mm x 250 μ m x 0.25 μ m nominal). The temperatures of the column, the injector, and the detector were 110, 220, and 240℃, respectively. Analysis of other parameters such as COD, BOD, SS, T-P were carried out in accordance with Standard Methods (1995). Volume of gas produced in the full-scale reactor was measured by counting the number of draw-offs of big balloon having a capacity of 2,000 L. When the level of gas reached the maximum value, the solenoid valve opened and exhausted the produced biogas to air, automatically. Methane and carbon dioxide contents in the field were measured by infrared gas analyzer (GA 94A).

Results and discussion

Organic removal

As shown in Figure 2(A) and (B), influent COD concentration was measured in the range of 7,150-16,270 mg L^{-1} after screening (average concentration is 10,280 mg/L). After 100 days of operation, the effluent COD concentration from the methanogenic reactor was 2,740±330 mg L^{-1} showing 60-82% of COD removal efficiency (average COD removal efficiency was 71.4±8.1%) while operating temperature was maintained in the range of 19-32℃. The effluent SCOD concentration was 2,000-3,000 mg L^{-1} at steady state while volatile fatty concentration was not detected in the effluent. It means that about 20 to 30% of COD concentration in the raw piggery wastewater were non-biodegradable organics in anaerobic conditions. De Lemos Chernicharo and Borges (1977) reported that the average organic removal was 68% in treating sewage by a UASB reactor. When lab-scale UASB reactor was operated to treat piggery wastewater, the organic removal efficiency was 50-70% (Cintoli et al., 1995). Compared to other researches, two-phase anaerobic system showed a higher COD removal efficiency, although the operating temperature was lower than the previous cases: it was maintained in the range of 19-32℃ throughout the experimental period. Effluent BOD concentration was measured *Ca.* 1,000 mg L^{-1} with average influent concentration of 5,170 mg L^{-1}. COD removal efficiency in the acidogenic reactor remained below 5%. However, acidogenic reactor played key role in reducing a shock-loading when accidental over loading was occurred, hydrolyzing and acidifying influent organics.

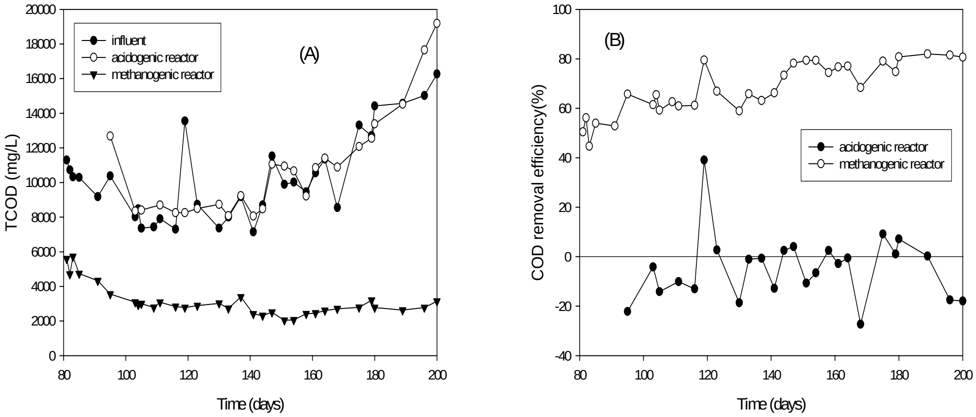

Figure 2 Variation of TCOD concentration (A) and removal efficiency (B) in two-phase anaerobic process.

Methane recovery

Operating temperature of two-phase anaerobic reactor was monitored with a standard thermometer and ranged 19-32℃ as shown in Figure 3(A). After April, the boiler was stopped to save energy to heat the reactor since the water temperature increased to 20℃. Biogas produced was highly dependent on the influent flow rate as shown in Figure 3(B). After 120 days of continuous operation, the biogas produced stably. The amount of daily gas production increased to 10㎥ in July and August (summer season) due to an increase of influent organic loading and operating temperature. When the measured methane production was compared to the theoretical methane production computed from the removed organics in the two-phase anaerobic digester, the methane recovered in this system ranged from 69 to 78% of theoretical production as shown in Table 2. Theoretical and measured daily methane productions were calculated using the following equations.

- Theoretical methane production(m^3 CH_4 d^{-1}, compensated for temperature) $= \dfrac{X\times Y\times Z\times A}{100} \times \dfrac{(273 + \text{avg. temp.})}{273}$ (1)
- Measured methane production (m^3 CH_4 d^{-1}, compensated for temperature) $=$ Total gas volume produced (m^3d^{-1}) $\times$ measured methane content (2)

Where, X: 0.35 m^3 CH_4 kg COD^{-1}, Y: Influent COD (kg m^{-3}), Z: Flow rate (m^3 d^{-1}), A: COD removal efficiency (%)

Assumption: (1) Methane production in the acidogenic reactor was ignored.
(2) Methane content in the methanogenic reactor was 90%.

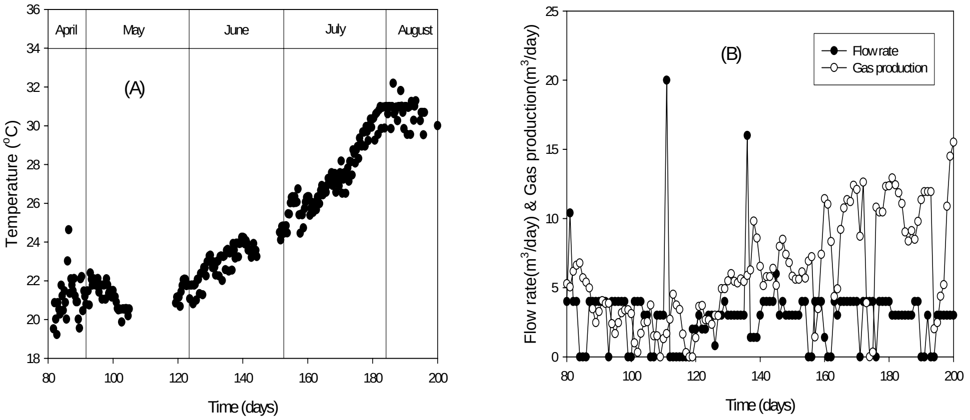

Figure 3 Variation of temperature (A) and flow rate & daily gas production (B) in the two-phase anaerobic system.

Table 2 Calculation of methane recovery in different operating conditions.

Parameter Month	Influent COD (kg m^{-3})	COD removal (%)	Flow rate (m^3 d^{-1})	Temp. (℃)	TMP1) (m^3 d^{-1})	MGP2) (m^3 d^{-1})	MMP3) (m^3 d^{-1})	CH_4 recovery (%)
June	8,830 ± 1,540	69.3 ± 7.8	3.0	24.0	7.0	5.7 ± 0.5	5.1	73
July	11,295 ± 2,030	76.3 ± 3.9	4.0	27.5	13.3	11.5 ± 1.1	10.4	78
August	15,290 ± 880	81.4 ± 0.9	3.0	30.7	14.5	11.1 ± 2.2	10.0	69

1) TMP: Theoretical methane production based on the COD removal at STP condition
2) MGP: Measured gas production at STP condition in the full-scale methanogenic reactor
3) MMP: Measured methane production at STP condition in the full-scale methanogenic reactor

The reason for low recovery in August compared to June and July was relatively higher methane production in the acidogenic reactor due to increased operating temperature as shown in Figure 3(A). The loss of methane might be due to leakages from GSS (Gas Solid Separator) device and concrete structure.

Other operating parameters

The average influent alkalinity was 8,070 mg/L, while this in the final effluent increased to 14,000 mg L^{-1}. At the same time, the effluent pH also increased to 8.2. Due to high concentration of alkalinity and high pH in the effluent from the methanogenic reactor, more than 80% of methane in the biogas was produced consistently (Figure 4(A). Figure 4(B) shows changes of TSS concentration in the influent and effluent from the acidogenic and methanogenic reactors. The average influent TSS concentration was 1,380 mg L^{-1}, whereas it from the methanogenic reactor remained in the range of 400-500 mg L^{-1} up to 100 days of operation, and decreased to 200-250 mg L^{-1} during 100 to 150 days of operation. After 150 days, the effluent TSS concentration in the acidogenic reactor started to increase due to accumulation of sludge in the acidogenic reactor, furthermore, the effluent TSS concentration gradually increased to 500 mg L^{-1}. It means that sludge withdrawal is required in the acidogenic reactor.

H_2S concentration in biogas should be maintained below 10 ppm in order to use it as a fuel. However, H_2S concentration in the biogas produced from the methanogenic reactor was in the range of 2,000 to 4,000 ppm. While, H_2S concentration in the acidogenic reactor ranged from 5,000 to 12,000 ppm depending upon the strength of influent. The chemical scrubber was applied to remove H_2S properly.

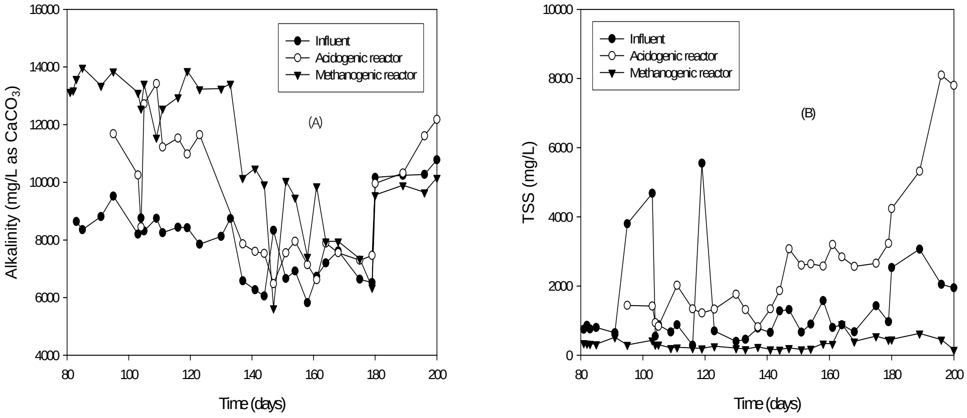

Figure 4 Variation of pH and alkalinity (A) and TSS concentration (B) in the two-phase anaerobic process.

The BMP test for the estimation of practical methane production

As shown in Table 3, the biological methane potential at 20℃ was tested to estimate practical methane production in June. Many difficulties in measuring an exact methane production in the filed can be overcame by a simple BMP test operating at different temperatures, characteristics of influent and biomass. As shown in Table 3, raw piggery wastewater was injected into serum bottles from 0 to 40 mL into the 100 mL of test volume after adding mineral salts medium and seeding micro-organisms. Seeding organism was taken from the methanogenic reactor in the full scale two-phase anaerobic reactor. Biological methane potential test was performed according to the procedure described by Shin et al.(1995). All test bottles were incubated for 30 days at 200 rpm and 20℃. Gas volume produced was monitored by a syringe. Methane production was calculated from the produced gas and methane content in the biogas, and it is proportional to the amount of raw piggery wastewater injected. The ratio of VSS/TSS after batch test was found to be 0.55 while initial VSS/TSS ratio was 0.45-0.50. Total gas and methane production at 20℃ were computed to STP condition (0℃, 1atm). CO_2 content in the biogas was higher in the beginning of incubation due to acidogenic activity, but it gradually decreased to less than 10%. The measured pH in the initial and final samples was 8.2 and 7.8, respectively. As a result, 20 ㎥ of methane was produced for each ㎥ of piggery wastewater. Methane content in the biogas was found to be over 90 %.

Table 3 Summary of the biological methane potential tests for methanogenic reactor.

	Blank	M-1	M-2	M-3	M-4
Volume of piggery waste, %	0	10	20	30	40
[1)]Total gas production, mL	-	22.6	42.0	64.7	91.0
[2)]Methane production, mL	-	21.2	40.0	59.7	84.0
Methane content, %		93.8	95.2	92.2	92.3
pH-in	8.2	8.2	8.2	8.2	8.2
pH-out	7.9	8.0	8.0	8.0	8.0
Alkalinity-in, mg L^{-1}	6,540	7,890	9,070	9,920	10,460
Alkalinity-out, mg L^{-1}	4,300	5,470	6,125	7,250	7,870
SCOD-in, mg L^{-1}	299	948	1,637	2,389	3,274
SCOD-out, mg L^{-1}	443	568	793	1,066	1,994
[3)]MLVSS-in, mg L^{-1}	4,400	4,700	4,700	5,900	5,700
MLVSS-out, mg L^{-1}	5,000	3,350	3,250	3,050	3,250
VSS/TSS-in	0.46	0.47	0.48	0.45	0.50
VSS/TSS-out	0.62	0.55	0.55	0.54	0.55

[1), 2)]: Total gas and methane production is on the basis of STP condition (0℃, 1atm).
[3)]: MLVSS: Mixed liquor volatile suspended solids.

Conclusions

Full scale two-phase anaerobic system was studied for recovery of high purity methane from piggery wastewater and the results were summarized as follows:

1) With the influent COD concentration ranging between 7,150 and 16,270 mg L^{-1}, COD removal efficiency was in the range of 60-82%.

2) The temperature of the anaerobic digester in the winter season was prevented from decreasing to less than 20℃ by using boiler and was maintained in the range of 19 to 32℃ depending upon climatic conditions. With increasing operating temperature, the COD removal efficiency increased to 71.4 ± 8.1%, as the effluent COD concentration was 2,740 ± 330 mg L^{-1}.

3) The acidogenic reactor played a key role in acidifying influent organics, with COD removal efficiency of less than 5%.

4) Due to high alkalinity and pH, methane content in the biogas was found to be more than 80% which is useful to be used as a fuel directly.

5) The actual methane recovery from removed organics was about 70% of the estimated production, in the full scale operation.

Acknowledgement

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5

Biogas Development in Viet Nam - Opportunities and Challenges

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1. Livestock production in Viet Nam

Vietnam is an agriculture country with the population of 86 million habitants. More than 75% of population in the country is living in the rural area and their living depends on agriculture production. The main food crop of Vietnam is paddy rice production. Rice cultivation integrate with animal husbandry is a traditional agriculture production system of the country. From 1990, rice production was not only met the demanding of the population of nation but also for export. At present Vietnam is the third biggest country in the world for rice exporting. Total rice export was about 4 million tons in 2004 and estimated about 4.5 millions tone of rice export in 2005. Livestock production plays an importance in agriculture production and contributed about 23.0% of total annual agriculture products.

More than 15 years with the open policies and development of economy forward the open marketing system (Doi moi), the annual average economic growing rate of Vietnam was about 7-8%; the average income per capita per year is also increased significantly.

The annual human population growing rate is 1.7%/year during the period from 1990-2001. Due to the improving of the economic income and better living condition so the demand of foodstuff and animal products consumption of the population are increased and the requirement of meat and milk are also increasing day by day.

In-order to meet the demand of the population growing rate and the higher living condition of the people; livestock production of Vietnam has been developed significantly in both head size and their products.

Paddy rice cultivation and livestock production is the traditional integrate production system of Vietnam agriculture. The main and common animal breeds of Vietnam are pig, poultry, cattle, buffalo, goat and sheep. Total of animal population is indicated in the Table 1.

Table 1 Livestock population from 1990-2005 (head).

Year	Cattle and buffaloes	Dairy cattle	Pigs	Poultry	Goat & Sheep
1990	5,970,000	11,000	12,260,000	103,800,000	372,300
1991	6,016,000	12,100	12,183,000	105,258,000	312,475
1992	6,077,200	13,080	13,881,000	117,875,000	312,297
1993	6,293,800	15,000	14,873,000	126,399,000	353,200
1994	6,437,700	16,500	15,569,000	131,668,000	427,862
1995	6,600,000	18,700	16,310,000	140,000,000	550,474
1996	6,750,000	22,563	16,920,000	151,400,000	512,812
1997	6,850,000	24,501	17,640,000	160,600,000	514,982
1998	6,940,000	26,645	18,130,000	166,400,000	514,347
1999	7,020,000	29,401	18,890,000	179,300,000	516,000
2000	7,030,000	34,982	20,190,000	196,200,000	543,847
2001	7,100,000	41,241	21,700,000	218,800,000	569,452
2002	7,200,000	58,500	23,169,000	233,278,000	621,913
2003	7,228,000	79,225	25,451,000	254,057,000	780,354
2004	7,771,000	95,794	26,143,000	218,152,000	1,021,196
2005*	8.462.855	104.120	27.434.895	219.000.000	1.314.189

Note: * 1st.August 2005

After more than ten years (1990-2005), pig and poultry population are increase more two times, meanwhile dairy cattle population is increase more than 10 times.

- The growing rate of the cattle buffalo herd in the period of 1990-2000 is 1.78%/year, from 2001 to 2005 is 2.3%/year, the average growing rate in the period from 1990 to 2005 is 2.15%.
- For pig production, the growing rate of pig herd from 1990-2000, 2001-2004 and 1990-2004 are 6.47%, 5.12% and 8.09% respectively.
- The growing rate of the poultry in the period of 1990-2000 is 8.9%/year, in the period of 2001 to 2004 is 0.07%/ year and the average growing rate in the period of 1990-2005 is 7.78%.

Livestock production: Livestock plays an importance role in agriculture production systems of Vietnam and contributed about 22.5% in agriculture production of the country.

Animal products is increasing fast 9-10% every year its contribute to the income of the farmer and to meets the high living standard requirement of the people.

2. Situation, potential, forecast and issues of biogas development in Viet Nam

2.1. Biogas production in Viet Nam

Biogas has been researched and applied in Viet Nam since beginning of decade 60, espeacially after year 1975 with the national programme on new and renewable energy (Program 52C), biogas research and application has been promoted in Institute, University and Department of Natural Resources and Environment (DONRE). The research focus on designing of household biogas plant with volume from 1-50 m^3.

In this period, many biogas projects has been implemented with number of projects as following:

- Project "*Application of Biogas and Energy Efficiency Saving Stoves*" with support of GEF in Binh Son district, Quang Ngai (2001-2003). The main objective of project is to construct biogas plants and efficientcy saving stoves in 3 communes of Binh Son to save energy and wood and protect environment. Participated household in the program has been supported 80% budget, the remaining 20%
- Project "*Biogas development for reducing green house effect*" financed by Solar power Center of Australia implemented at Phu Dong-Gia Lam district-Hanoi (2000) with objective to construct 100 biogas plants for treating of livestock waste, protecting environment and

reducing green house effect caused by livestock waste; financial support for biogas plants is 100%

- Project “*Development of energy efficiency stoves and biogas stoves*” with the objective to save energy and protect environment implemented at Gia Vien district-Ninh Binh province. Households were supported 1 million VND/biogas plant and were loaned 2-3 million VND with low interest for biogas construction.
- Project “*Develop renewable energy for North Central provinces*” of Netherland Development Organization (2001-2003). The project has installed solar cell, small hydroelectricity and wind electric motor for communes who not have electricity in Thua Thien Hue, Quang Tri and Quang Binh province, and constructed biological plants to be used for cooking and lighting to save energy at these three provinces. Construction of biogas in this period that were received all financial support from project.
- Project “*Livestock Waste management in East Asian Project*” of GEF/WB. The project has developed number of biogas plant at household and commune level. In addition, the project has focused on development of policy to encourage the development of biogas in Viet Nam.
- Project “*Clean water and environment sanitation for Ha Tay province* (1999-2003)”. The project has combined installation of biogas plant with improvement of livestock breeding facilities system, bath room, WC for rural community with state and local budget support. In period 5 years duration of project, all province built 7,000 biogas plants in which Dan Phuong district has largest number with 3,650 biogas plants. Biogas plants classification in Dan Phuong district was presented in below Table

Table 2 Biogas plants at Dan Phuong(1)

Number of biogas plants classified by volume			Amount construction works by types		
Volume	Amount	Rate %	style	Amuont	rate %
$4 \div 6\ m^3$	1,045	28,62	Plastic bag	18	0,50
$6 \div 8\ m^3$	1,313	36,00	Composite ball	190	5,20
$8 \div 10\ m^3$	857	23,48	Style of old DRAC	958	26,25
$> 10\ m^3$	435	11,90	NL5 Style	2472	67,75
Total	3650	100	VACVINA Style	12	0,30
			Total	3650	100

(1) Sumamary Report of Project “ Mobilize the participation of community to construct biogas plants in Dan Phuong, Ha Tay”

According to assessment report, after 4 years in operation, total biogas plant is still in operation accounts for 99,2 %. Biogas plants are not in operation caused by technical errors such as incorrect construction of biogas (2 biogas plants), gas leaking (20 biogas plants), inlet gas stuck (6 biogas plants), outlet gas stuck (3 biogas plants).

- Project “*Biogas programme in Quang Ngai*” was supported by Plan Organization (2005-2006). Program has target of construction 76 biogas plants at 2 communes (Nghia Dien and Nghia My) to protect environment and supply cooking fuel. Applied technology in project is biogas plants with fixed dome designed by Institute of Energy (style NL-5 and NL-6). The first phase of project has constructed biogas plants with volume 3-5 m^3. Financial support account for 90% from project and 90% from local support.

  After 10 years of development (1995-2005), according to the report of Agriculture Encouraging Centers in 61 provinces, all country has constructed 100.000 biogas plants with different volume. In which, the biggest amount is biogas plants with fixed dome designed by Institute of Energy (70%), then biogas plants designed by SAREC project which constructed in the North by Viet Nam Gardening Association (VACVINA) and constructed in the South by Ho Chi Minh Agriculture-Forestry University. Provinces have biggest amount of biogas plants are Ha Tay, Tien Giang, Dac Lac, Dong Nai, Hai Duong…

In livestock breeding sector, large biogas plants with volume of 50-100 m^3 has been constructed in provinces with concentrated livestock breeding. In South area, livestock breeding is strongly developed because of advantages of climate condition and food. Therefore, biogas technology also has a lot of advantages when it apply in this area. Many biogas plants has been piloted for supplying heat or generating electricity in Binh Duong, Dong Nai, Ho Chi Minh city, Tien Giang with support of Ho Chi Minh Agriculture-Forestry University, Can Tho university and some international projects. The volume of biogas plants are in the range of hundreds m^3, mainly for heating purpose. At present, HCM Agriculture-Forestry University has applied successfully Covered Anaerobic Lagoon with simple construction and operation technique and low investment cost which is appropriate for tropical condition in South area. This style has been developed in many countries in Asian such as Thailand, Philippine and Indonesia. Total number of this style is 5 biogas plants in Binh Duong and Dong Nai provinces.

In the North, number of biogas plants and volume of biogas plants is smaller compared with the South area. Thailand Anaerobic Lagoon has been installed at Ha Tinh Mineral Company. Covered Anaerobic Lagoon also has been installed in livestock breeding farm in Yen Binh Farm (Luong Son, Hoa Binh) with volume of 1.500 m^3 under support of Industrial biogas project. This project also piloted biogas plant with composite dome with volume of 150 m^3 at livestock breeding farm in Dan Phuong district, Ha Noi.

In Industrial sector, biogas technology was applied in some beer factories, alcohol processing factories and food and agriculture product processing factories. However, these technologies were designed and transferred by foreign companies. I) Join-venture Dong Nam A beer company in Hanoi has constructed one biogas plant with UASB style for treatment of waste water from beer cooking technology. Waste water volume of the factory is 600 m^3 per day. The biogas plant has constructed for 4 years, it is controlled automatically by one computer software and still operated well to present to ensure waste water discharge after treatment meet discharge standard; I) Alcohol factory of Lam son sugar-cane company in Thanh Hoa province has constructed biogas plants with Indian technology with volume 16,000 m^3, treating 900m^3 waste water per day; III) One biogas plant with Thailand UASB style with volume of 5,000 m^3 has been installed at Quang Ngai Agriculture and Food Product Join-stock company for treatment of waste water from cassava starch processing factory.

The development of biogas in Viet Nam is still subsidized. Expenses for research and development were supported by state budget or international financed projects. Speed of biogas construction is highly depended on financial support. The provinces with high number of biogas plants such as Ha Tay is the province with 4 financial support projects (Rural Clean Water and Sanitation Program implemented from 1995; Project of Protecting Ba Vi National Park and Buffer Zone (2002-2005); Biogas program for the animal husbandry sector in Viet Nam (from 2006) and Project on Encouraging Agriculture (from 1999). Rate of financial support for biogas plant also significantly contribute to speed of application of biogas (financial support accounts for 70-100% of price for construction of biogas plant in period 1995-1998, 40-60% in period 1999-2003)

2.2. Potential for biogas development in Viet Nam

2.2.1 Inputs for biogas production

Viet Nam is agricultural country with more than 80% population live in rural areas. The products of agriculture-forestry-fishery contribute 20.89% to GDP in which agriculture includes three main sectors: cultivation, breeding and agriculture services1).

Inputs for biogas production in Viet Nam are variety, especially by-products from livestock breeding and agricultural production. Livestock breeding in Viet Nam is in the progress of development. Contribution of livestock has increased from 17.9% in 1990 to 22% in 2004. Livestock growth and number of livestock in 2000-2005 are presented in Table 3 and Figure 3

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1) Statistic yearbook 2005

Table 3 Livestock Growth in 2000-2005

Unit: Million

Livestock		2001	2002	2003	2004	2005
Pig	Number	21.8	23.1	24.9	26.1	27.4
	Growth Rate (%)	0	6.0	7.8	4.8	5.0
Cow	Number	3.89	4.06	4.39	4.91	5.54
	Growth Rate (%)	0	4.4	8.1	11.8	12.8
Buffalo	Number	2.81	2.81	2.83	2.87	2.29
	Growth Rate (%)	0	0.0	0.7	1.4	-20.2

Source : Consolidated Report of Deparment of Livestock, 2006

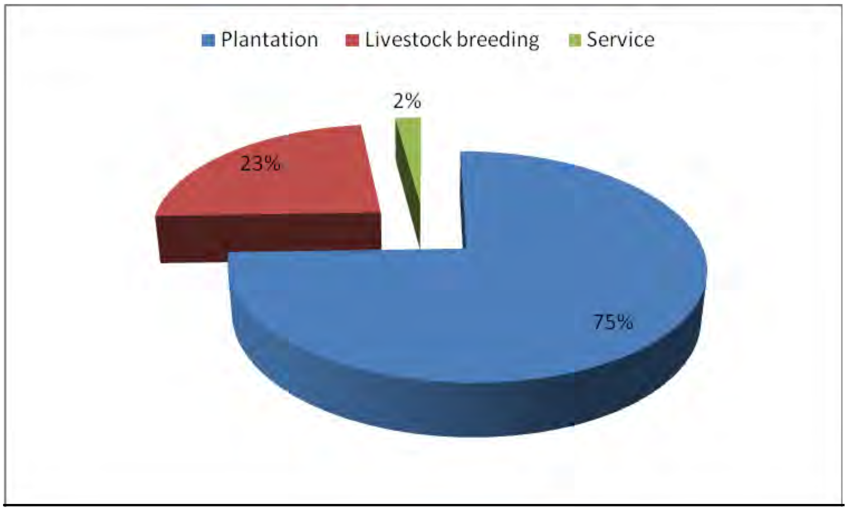

Figure 1 Agriculture structure by sector

Livestock breeding rate is quite stable. MARD has promulgated number of regulation on changing agricultural structure, regulation on environmental protection and incentive polices for development of centralized livestock breeding to control disease.

According to report of Department of Livestock in 2001-2005 and direction on 2006-2015, the total farm in the whole country is 17.721 farms as describe in Table II. However, inputs which can be used for biogas production are mainly from livestock waste from farms of buffalo, cow and pig with total number of 14.127 farms.

Table 4 Number of farms in whole country

Order	Areas	Pig farm	Poultry farm	Cow farm	Buffalo farm	Goat farm	Total
	Whole country	7475	2837	6405	247	757	17721
A	**North**	**3069**	**1274**	**1547**	**222**	**201**	**6313**
1	Northeast	534	76	150	38	46	844
2	Northwest	113	43	295	79	24	554
3	Red River Delta	1927	900	290	1	39	3157
4	North Central	495	255	812	104	92	1758
B	**South area**	**4,406**	**1,563**	**4,858**	**25**	**556**	**11,408**
6	South Central	351	414	620	2	4	1391
7	High land	422	128	919	0	11	1,480
8	Southeast	2,604	522	2683	20	537	6,366
9	Mekong River Delta	1,029	499	636	3	4	2171

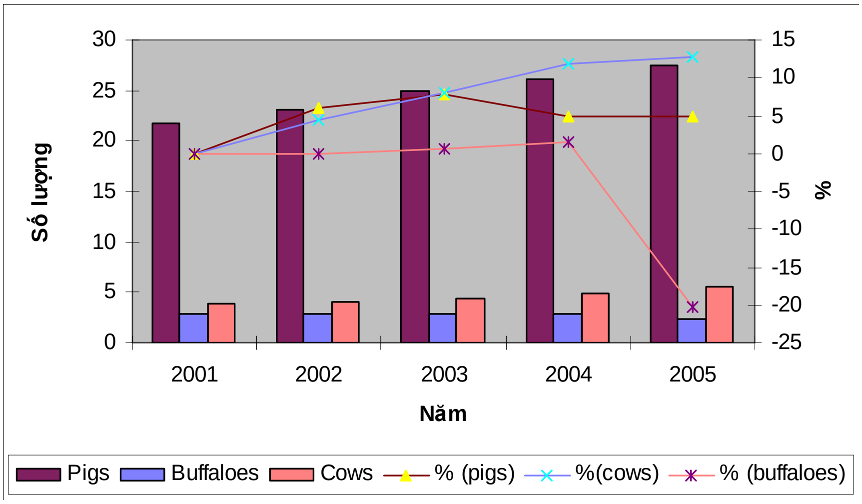

Figure 3 Livestock growth in 2001 - 2005

Moreover, inputs for biogas production also can be exployed from agricultural subsidies such as leaves, organic waste from agro-production progress, household waste, etc. This source is varied and high potential in Viet Nam. Following calculated figures based on annual report of MARD, State of Environmental Report of MONRE and annual report of GSO.

Table 5 Domestic Waste Generation in Viet Nam

Type of waste	Whole country	Urban	Rural
Total domestic waste generated per year (ton/year)	12.800.000	6.400.000	6.400.000
Rate of domestic waste generation per head (kg/person/day)		0,8	0,3

Domestic waste generation rate has increased trend. Statistic number in 2002 shows that the average rate of domestic waste generation is 0.6-0.9 kg/person/day in large urban areas and 0.4-0.5 kg/person/day in small urban areas.

Domestic waste accounts for 60-70% urban waste and has increased trend with average number 10-16%.

2.2.2. Potential for biogas production.

According to the report of MARD, livestock breeding is in progress of development according to direction of agricultural sector. However, growth rate of livestock is different for different areas of the country. The development of livestock breeding in the South is higher than in the North. Potential for biogas production from livestock waste is calculated as following[2]:

Table 6 Potential of biogas production from livestock waste

TT	Type of animal	Annual waste (ton/head/year)	Biogas development capacity (m^3/ton)	Animal head (million head)	Biogas capacity (million m3/year)
1	Buffalo	4,6	30	2,2	402,96
2	Cow	4,0	30	5,40	648,0
3	Dairy cow	7,0	35	0,104	25,48
4	Pig	1	50	27,40	1370,0
	Total				2446,44

Potential for biogas production from agricultural waste and solid waste is calculated basedd on figure of Statictic Year book and State of Environmental Report of MONRE. By-products from agriculture are calculated based on rate between main products and by-products. Main

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[2] Summary report of livestock breeding in the period 2001-2005 and development direction from 2006-2015 of Department of Livestock breeding, Ministry of Agriculture and Rural Development

sources are rice straw, stem of corn, sweet potato, potato and vegetable crops. Figure of main products are based on Statistic Year book.

Figure of solid waste is based on State of Environmental report 2005. According to the report, the total urban solid waste is 15 million tons in which domestic waste is 12.8 million tons. Domestic waste has high organic content, accounting for 50-60%, average pH is 6.5-7, humidity is 60-67% and density is 0.38-0.416 ton/m^3. One ton of organic waste can produced 200-4000 m^3 biogas with methane content of 50%. If we take average figure is 300 m^3 biogas/ton organic waste, the biogas generated from annual solid waste will be 1275 million m^3. Figure··· presents potential for biogas production from different sources.

Table 7 Total theoretical potential for biogas production

Sources	Potential (million m^3)	Rate (%)
Livestock waste	2,446.44	21,05
Bi-products from agriculture	7,902.9	68,00
Solid waste	1,275.0	10,95
TOTAL	11,624,34	100,0

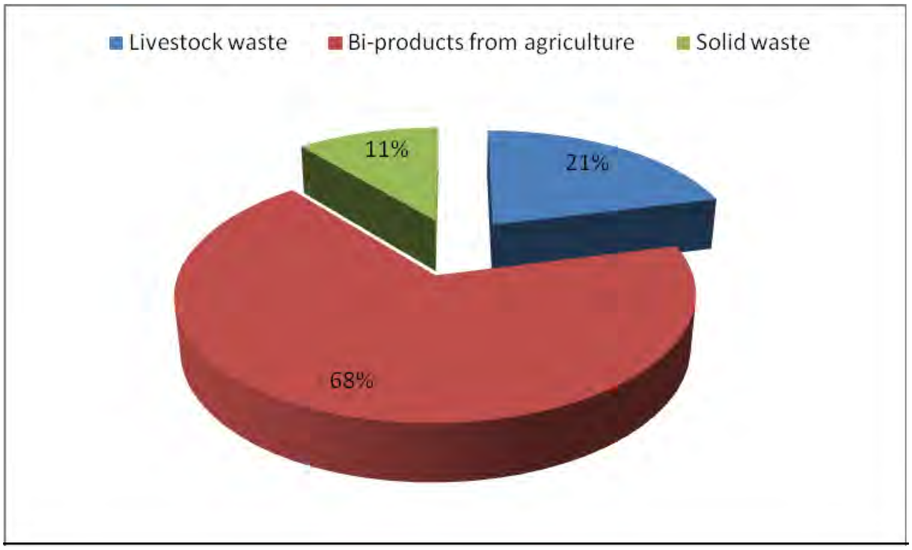

Figure 4 Biogas production potential from different sources

From theoretical calculation, Potential for biogas production is mainly from by-products from agriculture, accounting for 68% and livestock waste accounts for 21.05% and solid waste account for 1095%. However, in practice, livestockwaste is main resources for biogas production since it is easy to collect and require simple technology for treatment at household or farm level. Therefore, livestock is more appropriate for household utilization while solid waste would be more appropriate for large scale level, espeaciall off-grid electricity geneartion or on-grid electricity generation.

3. Current situation of biogas utilization

Biogas consists of many gases in which CH_4 account for 60-70% of volume (Table..). Biogas is utilized as fuel for household consumption and production. Biogas utilization is presented in Figure 6.

Table 8 Composition of Biogas

TT	Gas type	Rate %
1	Methane (CH_4)	60-70
2	Dioxit cacbon (CO_2)	30-35
3	Nitrogen (N2)	0-20
4	Oxygen (O2)	0-5
5	Sulfuahydro (H2S)	0-2
6	Other	0-0.1

3.1 Utilization of biogas for cooking

Utilization of biogas for cooking is most popular in Viet Nam. Biogas stoves is produced in the country or exported from China.

The single biogas stoves produced in the country consumes 0.22-0.40 m^3 biogas/hour; the double imported biogas stoves consumes 0.30-0.7 m^3 biogas/hours. The demand of biogas for each person in family of Viet Nam is around 0.15-0.30 m^3 biogas/person/days. Therefore, with the family of six people, the minimum required biogas is 1.8 m^3 biogas/day which requires biogas plant with volume of 5 m^3 equal to 6-10 pigs or 2 buffalo.

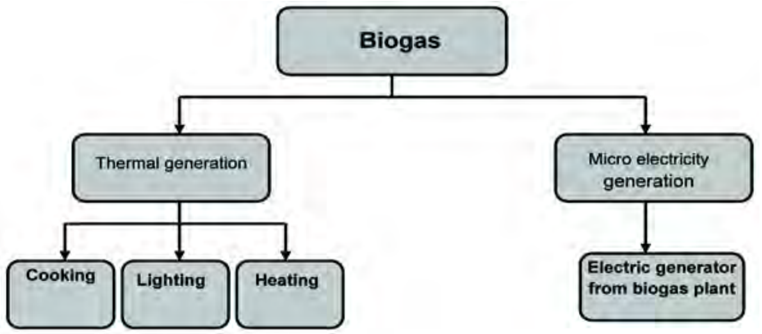

Figure 5 Main utilization of biogas

Biogas also used for lighting. However, the number of household use biogas for lighting is not high, only account for 2% of total household who has biogas plant[3]. One of reason for low percentage of biogas utilization for this purpose due to the demand for lighting in areas with electricity is not high. In addition, the spare parts for lamp while damaged are not popular in the market.

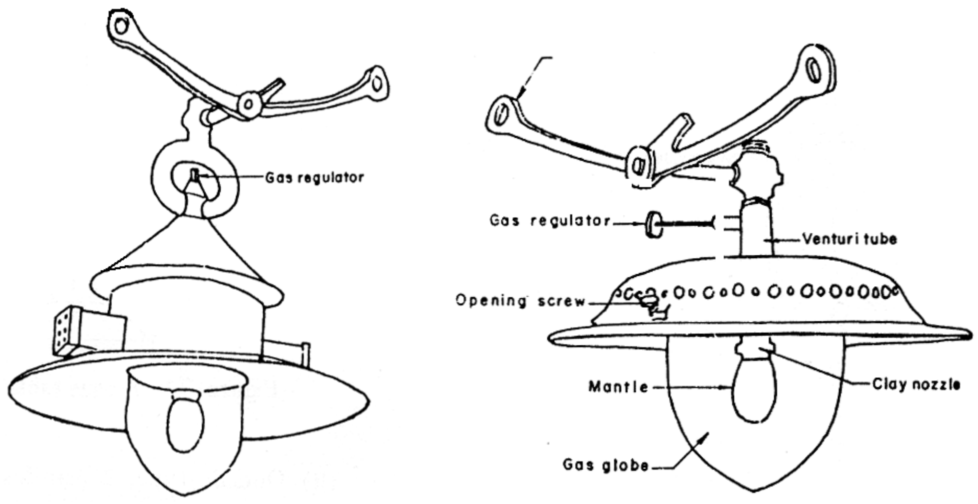

Figure 6 Biogas Lamp

Another purpose of using biogas for thermal is water heating with imported heater from China. The percentage of biogas utilization for this purpose is very low, less than 1%.

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[3] Survey on biogas utilization 2005

3.2 Utilization of biogas for electricity generation

Utilization of biogas for electricity generation is applied in recent year, especially for large farm with high number of livestock and centralized waste treatment areas. Institute of Energy, Ha Noi University of Technology, Ho Chi Minh University of Technology and Da Nang University has successful researched biogas generator with capacity of 0.5-3 kW.

4. Potentials and forecast for biogas demand in Vietnam.

Market for biogas utilization in Viet Nam is very potential. According to the forecast, the potentials of biogas production from all of organic waste sources including livestock waste is about nearly 5 billion cubic biogas/year. Exploiting effectively of this energy source will contribute to increase remarkably the density of reuse energy in national energy balance. At present, the percentage of biogas utilization for heat supply occupies about one-fifth of collected biogas output. Therefore, the potentials of biogas utilization for electrical generating are much. It is assumed that 0.6 cubic biogas produces 1kWh, 4 billion cubic biogas will produce 6.67kWh. Biogas utilizations for electrical generating are being in the test stage with capacity from 1 to several kW and it hasn’t got a real effectiveness and stop in household scope mainly. If it is used for other purposes, production source and output of biogas must be in larger scope.

With over 17,000 existing farms comprising over 100 heads of cattle and some farms with scope of over 10,000 heads of cattle being in planning of MARD, biogas source in large scope would supply electric for production activities in the farm. At present, production activities of farm are various such as pumping for watering the plants according to the processing of spray and aerosols, operation of oxygen aerator for aquatic breeding lake, lighting, cooling and heating for breeding area of porker, sow and piggy. Biogas demand of many modern farms having food production area and frozen storehouse, slaughter hall··· is relative large. Biogas is produced in scope of centralization will supply both heating and electricity for energy demands of farm and residents in this area.

Industries in Vietnam which have got high organic carrying power including sugar industry, cassava processing factories, fruit, export canned food, beer and refreshment industries, domestic and urban solid waste landfills are suitable industries to apply anaerobic treatment processing and biogas production. These factories have got high biogas output which can reach thousands of cubic biogas per day, and biogas is used for operation of industrial boilers for example in Lam Son Sugar Factory. It will prepare to install a factory to treat organic solid waste and product electricity by gas collecting from solid waste with capacity of 10MW in Go Cat urban solid waste landfill of Ho Chi Minh city. One of the most differences and barriers of investors in the field of electric generating by reuse energy in general and biogas in particular is the price of electric production. Average lowest electric price of reuse energy for 1kWh is small hydroelectricity, sources of living mass and biogas with amount of USD 6-6.5 cent while EVN only buys with the price of USD 4.5 cent/kWh. The difference in European countries will be supported by the Government in the regulations or law on reuse energy. Supported policies are useful tool to encourage producing electricity from reuse energy.

The economy of Vietnam in recent years has developed with high speed and average per capital income still increases together with rapid speed of urbanization and civilization, the demand for food, nutrition and energy utilization will increase rapidly. This is an opportunity and power to impulse the development of biogas utilization, especially in rural area where is assessed as the largest consumption household of Vietnam. Now, the rate of living mass utilization in rural area occupies with 90% and remaining of 10% is other commercial energy sources including electricity, coal and LPG··· Selection of energy sources for domestic purposes as well as production mainly depends on household’s income, and the percentage of cost for energy and total cost still depends on this factor.

Table 9 Household Income and Cost for energy according to region

Area	Population growth (%)	Average income / person ('000 dong)	Energy consumption (% investment cost)
Northern Mountain and Midland	17.9	3,900	3.9
Red River Delta including Hanoi	19.6	5,132	3.7
Northern Central Part	13.8	12,165	3.9
Southern Central Part	10.7	15,010	3.7
Highlands	3.7	16,988	4.2
South-East Part including Ho Chi Minh city	12.8	39,287	3.6
Cuu Long Delta River	21.5	16,624	3.8
Rural area		13,175	n.a
Hanoi and HoChiMinh city		52,944	n.a
Urban area		45,245	n.a
Total	100.0	17,709	

Source: World Bank (2002)

With long-term development strategies and the attention of the Government, Vietnamese energy system is changing vigorously in spite of many challenges and barriers. It required that we have to modernize technology, complete legal framework and macroscopic management methods, take form the energy market and develop human resource for the development in the future.

5. Challenges for biogas development in viet nam

5.1 Disadvantages and challenges in utilization of biogas in Vietnam

The utilization area of biogas in Vietnam is very potential, even in domestic use. There are 80% of total Vietnamese population living in rural area with over 2 million households having technical potentials of biogas in household scope (according to the assessment of the project for biogas program for breeding industry and some research agencies) and nearly 20,000 centralized breeding farms.

Fuel for domestic purposes in rural area is wood occupying with approximate 70%. Utilization of LPG is popular but it only concentrates in urban area and city because of high cost. Coal is a main fuel source in rural area. However, for environmental opinion, coal still is a fossil fuel causing much air pollution. The remarkable advantage of this fuel is price in accordance with resident’s ability.

As above analysis, main problems cause barriers and disadvantages in biogas utilization in Vietnam as follow:

1. The equipment for biogas utilization and problems from supplier: the system comprises: cooker, lamp and other equipments such as heat supply system, electric generator or brood machine which is operated by biogas. The good quality of biogas equipments will contribute strengthening the effectiveness of the work and impulse the development of biogas utilization.
   At present, the most advantage of this part as follow: there isn’t the manufacturer for specialized equipment so that technicians or building workers will improve themselves available equipments in the market such as cooker for LPG or smuggled goods from China. Some kinds of single cooker are produced by hand without technical processing. The advantage and disadvantage of biogas equipment suppliers as follow: i) The advantage: mostly technicians have got the experiences and fixed knowledge on equipment of biogas utilization; ii) The disadvantage: the equipment is produced single by hand so

it is not comprehensive, no control of the quality and uncontrolled price. Besides that, the profession of suppliers hasn’t been presented such as there isn’t any factory or workshop taking responsible for producing equipments of biogas utilization in Vietnam and there isn’t a formal distribution system of this equipment with quality and productivity control system.

Opportunities and challenges for suppliers are that at present, there are many LPG cooker assembly plants in both the North and the South of Vietnam with modern production line and strictly quality management system to keep their trade name and prestige. Beside that, the user is interested in comfortable quality more than the requirements of design, quality and price. Climate changes influenced by environmental pollution are being more and more seriously. Therefore, the government at various levels will bring out many closer regulations for user, even the requirements of quality and landscape of the systems including the work and equipment for biogas utilization.

2. User and problems from their demand. The residents have known the benefits of biogas utilization. The potentials of utilization are very large, especially in production activities due to increase the income and improve the living condition of their families. The awareness of residents on environmental protection is improved more and more together with development tendency of civilization and modern socio will influence directly with biogas utilization. The most challenge of user is the problem of investment cost and technical consulting services as well as after-sales services.

   The loan demand of residents is very large but they have to face with many difficulties such as loan structure of commercial banks, enclosing with the difficulties in dealing with administrative procedures in local authority where borrower needs have the confirmation. Technical consulting and after-sales services and alternative fittings when their equipment is damaged. Because this system isn’t developed outspread and non profession, residents meet many difficulties in finding the necessary support when the work meet the trouble and its equipment is damaged. They have to themselves find alternative solutions when it is not enough cost for replacing serious damaged equipments. Problems on maintenance are week points of supplier to user.

5.2. Difficulties and Challenges for development of biogas in Viet Nam

Biogas technology has developed in Viet Nam for more than 40 years. Therefore, the technology has been stable and standardized in designing, constructing and operating stage in standards promulgated by MARD in 2003. There are many designs and types which can be selected for installation.

However, biogas plant is still in small scale and there is still lack of centralized biogas since the technology for large scale biogas is not stable, high cost and the equipments for installation are not synchronized. Promotion and marketing of biogas technology is still limited and awareness of livestock breeding households is quite limited.

There are about 100,000 biogas plants with different types have been constructed, accounting for 5-6% total households who have livestock breeding. International support and state budget are used for research and implementation. Most of biogas plants are subsidized with high percentage (70-100% subsidy for period 1995-1998; 40-60% subsidy for period 1999-2003). Therefore, the construction of biogas depends on size of project and total investment for projects and programmes.

In management and monitoring aspects, there is still lack of national focal point for coordinating and monitoring biogas plants. As a results, there is still lack of collaboration between research organizations. Many researches has been applied without verification before application in wide scale, leading to ineffectiveness of biogas plant. Number of biogas is damaged after short time of construction. Organizations and research institutes or international projects work independently without sharing information with each other. There are still lack of maintenance services after construction of biogas plant. The users do not well understand the procedure for operation of the plant. Therefore, the operation of plant is ineffective. In addition, financial support for biogas plants account for high percentages is other challenge for development of market for biogas plants.

In summary, biogas market is still in initial stage. Construction of biogas is supported partly by government or international projects/programmes. It is unsustainable direction in open market. Biogas technology for food processing industry, domestic waste and livestock waste in concentrated farm is not effective and comprehensive, especially technical services for biogas construction to ensure the plants meet the standards at all stage: design standards, construction standards and maintenance standards,

Distribution system of equipments for biogas utilization is scattered and uprofessial. Some equipment such as lamp and pressure-gauge is self-made, leading to low quality and not synchronized of the equipments.

In general, equipments for biogas utilization are scattered and high price. Quality of biogas equipments is still low with short duration.

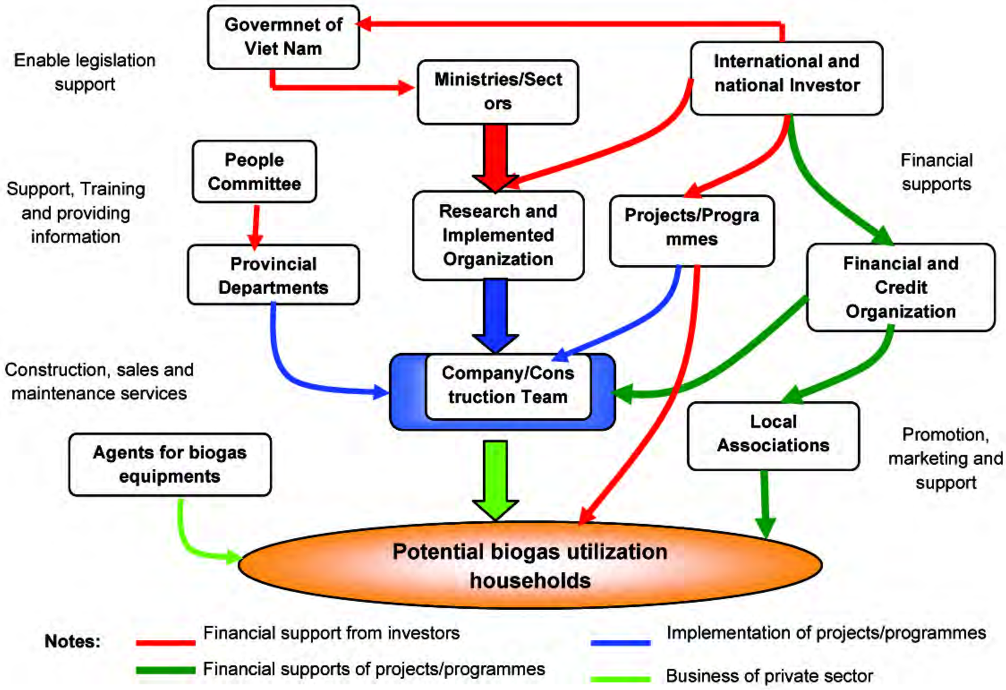

Figure 7 Relation of organizations and individual in biogas market

Biogas commercialization has to follow market principles, meaning that revenue from biogas business must be higher than investment expenditure. It means that service suppliers such as construction team should be organized as company or SMEs. In addition, subsidies for biogas construction should be removed gradually. The financial support should be utilized for research and pilot application of new technology. Strategy and policies for biogas development should be developed. Role of financial organization and banks is important for biogas development in term of supporting investment on biogas plants.

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6

Biogas System from Swine Waste in Thailand

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Abstract

The average pig production in Thailand for last ten years was about 6-9 millions/year. Pig farms could be categorized by size (small, medium and large) or types of barn (closing housing, open housing and backyard farms). Biogas systems are widely used among the pig farms because the farms can save their operating cost by using the produced biogas to replace the traditional energy. Covered Lagoon and Channel Digester are choices for large and medium farms who could afford for the investment cost. While the Fixed Dome were promoted to the small scale pig farms but currently, the bag digesters are introducing to this segment.

1. Situation of Biogas System from Swine Waste in Thailand

Under the energy and economics crisis Thailand, bio-fuel is considered to be an important national policy. Biogas is one form of the renewable energy will become alternatives to traditional sources of energy.

First biogas system was introduced in Thailand about 40-50 years ago for farm waste management particularly in swine farms. This was to serve the environment protection rather than energy purpose, but they were not so much recognized among the farmers. Until 1995, Energy Policy and Planning Office (EPPO), Ministry of Energy introduced biogas for power generation promotion in livestock farms project an focused on the medium and large scale swine farms. The project will continues until 2012.

The fixed dome system was promoted to the small livestock farms, mainly swine farms by the Department of Agriculture Extension (DOAE), Ministry of Agriculture and Cooperatives (MOAC) during 1998-2004. Bag digester also introduced to the small farms by Department of Alternative Energy and Efficient (DEDE) during 2008-2009.

2. Swine Farming Situation

2.1 Swine Population

The statistics of swine number in Thailand recorded from 1998-2008 (Information and Statistics Group, Department of Livestock Development, 2008) showed that number of swine tends to vary around 6-9 millions/year. This is depended on market demand, outbreak, production cost and economic crisis.

Almost pig productions in Thailand are served for domestic consumption. Very small and inconsistent amounts are exported. According to the study of the Office of Agricultural Economics in 2001, pork consumption in Thailand is 12 kilograms / person / year. Pork consumption in the whole country is slightly increased such as from 9.59 million tons in 2002 to 9.86 million tons in 2003. It is expected to reach 10.6 million tons in 2005 (Office of Agricultural Economics, 2005; Kittiwongse Sombuntham, 2005)

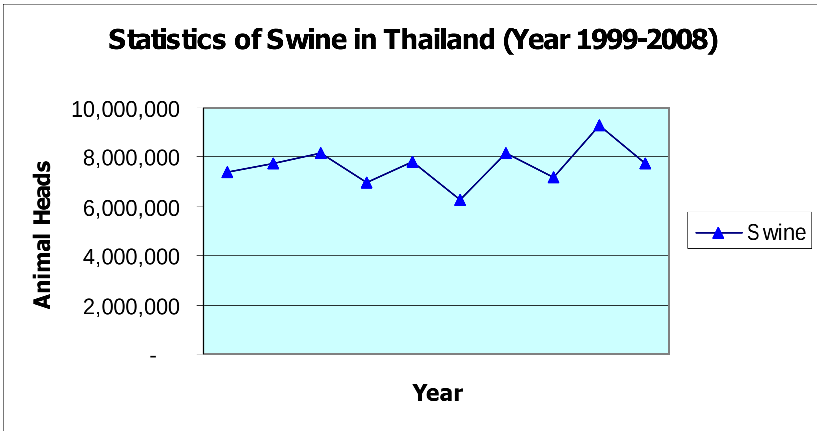

Fig 1. Swine Population Statistics in Thailand (Source : Data from Department of Livestock Development (DLD) Statistics Record)

2.2 Geographic Location

According to Office of Agricultural Economics' statistics record (OAE), swine farms are most crowded in the central amounting 59.2 % of the whole country. Top 5 provinces that have highest number of swine farms are Ratchaburi, Nakorn Pathom, Chacheongsao, Chonburi, and Nakorn Ratchasima while Southern provinces are least production only 7.7% of the whole country. Swine population density for all country and by province, are shown in Figure 2.

2.3 Type of Farm

In Thailand, generally, there are three types of farm that operated by farmers. They are close housing (with evaporative cooling) farms, open housing farms and backyard farms. Close housing farms also called developed swine farms, almost developed swine farms are medium and large scale with good management and adopted modern technology. Open housing farms or developing farms are conventional farms, open barn to the open air for energy saving purpose. Various farm scales from small to large operated by open housing systems. Backyard farms, mostly are small and non-commercialized farms, located at the countryside or remote area.

2.4 Classification of Swine Farm by Size

Ministry of Natural Resources and Environment (MONRE) announced to define the swine farm size for control the discharged standard. Classification of swine farm by size is shown in Table 1.

Table 1. Classification of Swine Farm by Size in Thailand

Swine Farm Size (Livestock Unit)	Approx. Swine Number	Size Class
> 6 to < 60	> 50 to < 500	Small Scale
> 60 to < 600	> 500 to < 5,000	Medium Scale
> 600	> 5,000	Large Scale

Note: 1 livestock unit of swine = 500 kgs live weight

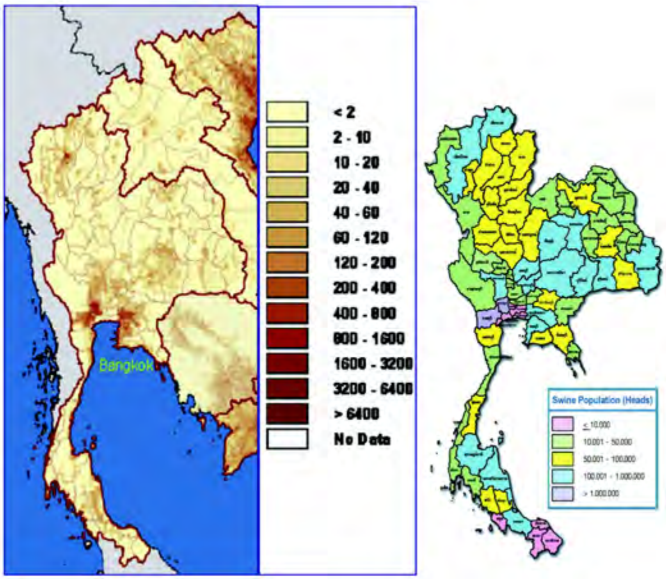

Fig 2. Swine Density in Thailand (Sources : FAO LEAD Project and OAE)

3. Swine Waste and Management Practices

Pollution generated from swine farm activities are categorized by waste characteristics as followed; 1) Liquid waste i.e. from urine, barn cleaning wastewater (almost farmers do their barns cleaning once a day), and others washing wastewater. 2) Solids waste i.e. manure, hypodermic syringe, feed packaging, medicine bottle, water bottle, afterbirth and dead body. 3)

Offensive odor from gases i.e. from digested waste such as ammonia, methane, hydrogen sulfide.

In large scale farms, wastewater treatment by the biogas systems are popular and widely used. Covered lagoon and Channel Digester are selected choices for these farms. For medium scale farms, the possibility to use the biogas systems, depended on their financial situation and land constrained problem. In case, they have sufficient land, open ponds/lagoons may be their choices if they do not want to invest. Small scale farms, DOAE and EPPO used to promote the fixed dome system. Currently, DEDE has launched for the package system (bag digester) to this segment. However, some farmers sell fresh manure to the crop farm as plant fertilizer. Some also used the dry manure for fishing feed.

4. Biogas Systems in Thailand

Currently, almost well managed swine farms had constructed the biogas systems for their wastewater treatment. This is not only for the environment purpose but the produced biogas can be used as a renewable energy. There are several biogas systems used in swine farms, each system has different characteristics and designs.

4.1 Fixed Dome System

Fixed dome is a small biogas system for livestock wastewater treatment. Because the investment cost is low therefore, suitable for small farms. Department of Agricultural Extension (DOAE) and Energy Policy and Planning Office (EPPO), Ministry of Energy had promoted to 1,150 farms nationwide with partial finance support. It was designed with significant components such as wastewater filling chamber, digester unit, effluent tank and sludge drying beds.

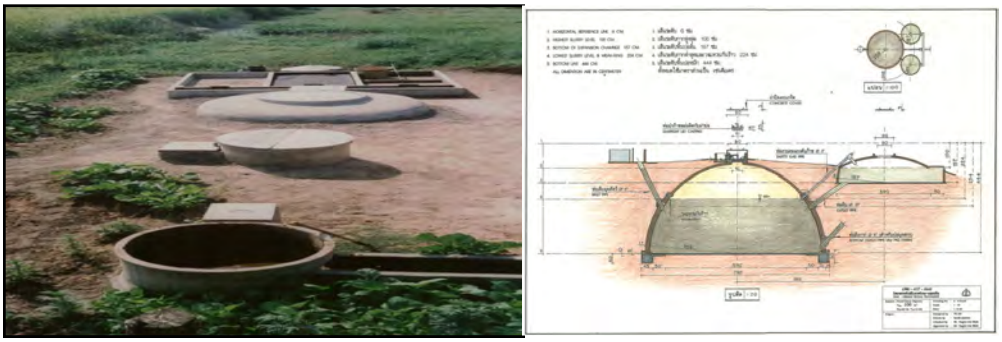

Fig 3. Fixed Dome System

The objective of the fixed dome extension was to support the farmers to manage their livestock waste especially, from swine farms for biogas production. Besides the adverse effect from wastewater to environment was reduced, the produced biogas was utilized as a renewable energy to replace the liquid petroleum gas (LPG).

Table 2. Fixed Dome System Construction Record

Item	Phase, Year	No. of Farms	Digester Volume, m^3	CH4 Produced, m^3/year	CH4 Produced, tCO_2e/year	Treatment for Swine, heads
1	1, Year 1998-2000	263	6,056	637,350	8,967	27,965
2	2, Year 2001-2004	887	45,464	4,773,720	67,166	220,405

Case Study for Fixed Dome System (Source : Department of Agriculture Extension, DOAE)

Donkeaw Farm is a small pig farm who feeds 250 sows and 500 piglets, located at Chiangmai province (Northern of Thailand). Wastewater from barn cleaning about 20 m^3/day with BOD 10,000 mg/l was discharged to the open ponds where functioned as storage and anaerobic pond.

Problem :

Bad smell from fermented process and many flies made the uncomfortable life to the farm's neighbors around the farm. This leaded to an accusation from the local administrative office regarding to bad smell and flies problem.

Solution :

In order to avoid from farm relocation, farmer decided to construct the fixed dome system under the support from DOAE. Two units of 100 m^3 was selected and constructed.

Results :

1) Health issue - Bad smell and flies were gradually decreased and finally, no more compliant 2) Economic issue - Produced biogas about 90 m^3 per day was piped to all neighbor houses (102 units) for cooking gas. Each family can save for 70 USD per year 3) Social issue - Good relationship between farm and neighbor.

Recently, DOAE had no longer promotion for the fixed dome system.

Fig 4. Pig Barn at Fixed Dome Site Case Study Site

Fig 5. Constructed Fixed Dome at Case Study Site

Fig 6. Farmer's Neighbor used the Biogas from Fixed Dome for Cooking
(Source : www. thaibiogas.net)

4.2 Package Biogas System (Bag Digester)

(Source : Department of Alternative Energy Development and Efficiency, DEDE)

Package Biogas (Bag Digester) had been developed by DEDE for small livestock farms. Concept for Developed system was emphasized on 1) ease for construction, installation, and operation 2) good performance and promptness for extension and 3) acceptable price for farmers. Selected system was Bag Digester, made from PVC sheet with 1.00 mm thickness and prefabricated at the workshop. There are two models; 1) treating capacity of 10 m^3 wastewater/day or 500 fattening swine, called DEDE1 and 2) treating capacity of 2 m^3 wastewater/day or 100 fattening swine, called DEDE2.

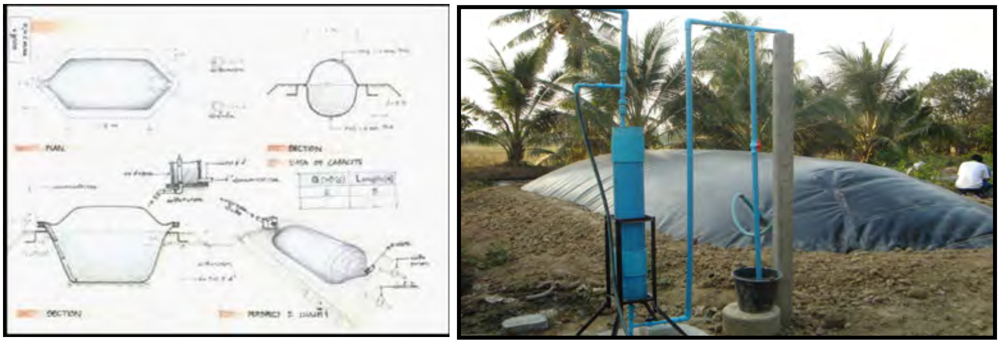

Fig 7. Package (Bag Digester) Biogas System

Case Study for Package Biogas (Bag Digester) System

DEDE had promoted the DEDE1 and DEDE 2 systems to nationwide for small livestock farms. This project extended to swine, dairy cow, beef cow, horse, and layer chicken farms. Eighteen units of DEDE2 and twenty five units of DEDE1 had implemented from year 2008 to 2009. Typically, system was composed of wastewater collecting tank, bar screen, bag digester, post treatment ponds and sludge drying beds.

Table 3. Wastewater Characteristics* for Package Biogas (Bag Digester) System

Parameter	Influent, mg/l	Effluent after DEDE2, mg/l (Treatment Efficiency, %)	Effluent after Post Treatment Ponds, mg/l (Treatment Efficiency, %)	Total Treatment Efficiency, %
pH (no unit)	7.0	7.2	7.9	-
BOD_5	767	127 (83.4)	66 (48.0)	91.4
TCOD	4,258	1,445 (66.1)	298 (79.4)	93.0
TKN	288	439 (-)	173 (60.6)	39.9
TSS	1,599	537 (66.4)	115 (78.6)	92.8

*Data from the prototype model

Table 4. Package Biogas (Bag Digester) System Efficiency *

Parameter	Treatment Efficiency after DEDE1, %	Treatment Efficiency after DEDE2, %
TCOD	72-88	78-82
BOD_5	76-92	83-91

* Unpublished data from Thai Environment and Energy Development

Benefit to farm :

1) Produced biogas for DEDE 2 and DEDE1 range from 16-22 m^3/day and 1.1-3.2 m^3/day, respectively. Average methane content is 60%.

2) Dry sludge (2.7% N, 3.2% P, 0.25% K) used as organic fertilizer

4.3 Covered Lagoon System (CL)

Covered Lagoon System is an earth pond covered with HDPE or PVC plastic sheet. This biogas system required most construction area because the designed wastewater retention time is long up to 60 days. It is preferred among more than 500 pig heads or medium to large swine farms because low construction cost, quick startup and less concrete structure, compared to other systems.

Fig 8. Covered Lagoon in Thailand

First Covered Lagoon came to Thailand in year 1996 by large scale agro-industry firm for the swine farm wastewater treatment. Then the system have been promoted mainly by the private sector and widely known among the farmers. There are many plants constructed in

Thailand but unfortunately, they have no an official record about the number of constructions. It is estimated that there are 150 to 170 medium- to large-scale swine farms nationwide with CLs. More than 70 percent of those CLs are designed and constructed by a local large agro-industry firm. The remaining are designed and constructed by farm owners. Site surveys have revealed that the overall system efficiency is 60 to 70 percent and the hydraulic retention time (HRT) was between 30-60 days.

4.4 Channel Digester System (CD)

Channel digester is a biogas system that collects produced biogas in PVC plastic dome. System had been developed since 1995 by Biogas Technology Center at Chiangmai University (Hereafter name changed to Energy Research and Development Institute, ERDI) under the Project "Biogas System Promotion in Medium and Large Scale Livestock Farms". The project had been financial supported by Energy Policy and Planning Office (EPPO), Ministry of Energy. Aim of the Project is to promote the biogas system in medium and large scale livestock farms (mainly in pig farms), to produce and use the biogas as the renewable energy.

Fig 9. Channel Digester System

Currently, ERDI have launched the project phase 4 (2008-2011) and target to construct the digester system to treat 2 million swine manure with expected methane production and capture is 763,000 tCO_2e/year.

EPPO also plan during year 2008-2012, to scale down the Channel Digester System to serve the small scale farms. Target is for 400,000 swine heads.

Table 5. Channel Digester System Construction Record

Item	Phase, Year	No. of Farms	Digester Volume, m^3	CH4 Produced, m^3/year	CH4 Produced, tCO_2e/year	Treatment for Swine, heads
1	1, year 1995-1998	6	10,000	1,600,000	22,512	60,000
2	2, year 1997-2003	14	46,000	10,000,000	140,700	276,000
3	3, year 2002-2008	249	280,000	50,566,000	711,463	1,864,000
						2,200,000

Case Study for Channel Digester System (Source : Thai Environmental Remediation Co., Ltd. reported to Energy Research and Development)

Pisit Farm is a medium pig farm with 3,000 fattening pigs, located at Rayong province (Eastern of Thailand). Daily discharged wastewater from farm is about 72 m^3/day with BOD 4,500 mg/l. Wastewater system was comprised of collecting tank, sand trap, channel digester (HRT = 8 days) and two series of earth pond for post treatment (Total HRT = 60 days).

Fig 10. Channel Digester System in Case Study Site

Table 6. Wastewater Characteristics for Channel Digester System at Case Study Farm

Parameter	Influent, mg/l	Effluent after Channel Digester, mg/l	Effluent after Post Treatment Pond, mg/l	Discharged Standard, mg/l
pH (no unit)	7.0	7.2	7.1	5.5-9.0
BOD_5	4,544	530	13	100
TCOD	17,046	3,359	50	400
TKN	1,196	1,021	23.3	200
TSS	8,110	2,610	22	200

Table 7. Channel Digester System Efficiency at Case Study Farm

Parameter	Channel Digester, %	Post Treatment Pond, %	Overall Efficiency, %
BOD_5	88.3	97.5	99.7
TCOD	80.3	98.5	99.7
TKN	14.6	97.7	98.1
TSS	67.8	99.2	99.7

Benefit to farm :

1) Electricity produced from biogas generator 285 kWh/day from 238 m^3 biogas

2) Dry sludge for organic fertilizer ingredient 150 kg/day

Summary

1) Biogas systems were constructed in the pig farms for two main purposes; 1) Environmental protection and 2) Economic from replacement traditional energy by produced biogas.

2) Covered Lagoon and Channel Digester are the most favorite among large and medium farms, they are still continued selected to construct.

3) Promotion for further extension of Fixed Dome and Bag Digester for small pig farms, are required.

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Session

IV

1. Production of Bio-crude and Bio-phenols from Agricultural Residues or by-Products through Direct Liquefaction
2. Biodiesel Promotion in Thailand
3. Study on Crude Oil Productions and Supercritical Clean and Green fuels on Application of Liquefaction Technology with Agricultural Biomass
4. Outlook of Palm Biodiesel in Malaysia

1

Production of Bio-crude and Bio-phenols from Agricultural Residues or by-Products through Direct Liquefaction

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Abstract

Direct liquefaction of cornstalk as a typical agricultural residue and two model biomass compounds (pure lignin and pure cellulose as references) has been conducted in hot compressed water, phenol and phenol-water co-solvent at temperatures ranging from 250℃ to 450℃ for the production of bio-crude (phenolic/neutral oil). When hot-compressed water was used as the direct liquefaction medium, significant quantities of phenolic compounds such as 4-ethyl-2-methoxy-phenol, 2,6-dimethoxy-phenol, were present in the resulting phenolic/neutral oils from the lignocellulosic waste and pure lignin. The relative concentration of phenolic compounds in the lignin-derived oil was as high as about 80%. Addition of $Ba(OH)_2$ and Rb_2CO_3 catalysts were found to significantly increase the phenolic/neutral oil yields for all feedstocks except lignin. Cornstalk powders were more effectively liquefied in a hot-compressed phenol-water medium (1:4 wt/wt) and pure phenol at 350℃, where the liquid yield attained a maximum at about 70 wt% and 80 wt%, respectively. Molecular weights and polydispersivity of the oils obtained with water or phenol-water medium were greater than those obtained with phenol, while the molecular weights of the bio-crude products generally reduced with increasing the liquefaction temperature. The cornstalk-derived phenolic oils proved to be useful phenol substitutes for the production of bio-based resol-type phenol-formaldehyde resins that were thermally curable with good thermal resistance.

Keywords: Cornstalk, bio-crude, direct liquefaction; water, phenol, phenol-water co-solvent.

1. Introduction

Biomass, currently providing approximately 14% of the world’s energy needs, has a total annual production of 2.74×10^{19} Btu, about 8 times the total annual world energy consumption. It thus represents an immense and renewable source for the production of bio-fuels (e.g., bio-oils, ethanol, syngas) and valuable chemicals (bio-phenols, organic acids, etc.). The U.S. Department of Agriculture (USDA) estimated that the U.S. could produce 1.3 billion tons of dry biomass annually in a sustainable manner using its agricultural (72% of the total) and forest (28% of the total) resources (Perlack, et al., 2005).

Lignocellulosic material can be converted into liquid fuels and chemicals by two primary routes, i.e., bio-conversion via the sugar platform, and thermo-chemical conversion via the syngas platform through gasification followed by catalytic synthesis or via the bio-oil/bio-crude platform through fast pyrolysis/direct-liquefaction followed by upgrading. Compared with bio-conversion technologies, thermo-chemical conversion approaches may be more advantageous with respect to costs and technological maturity, Direct liquefaction of biomass in a hot-compressed (or sub-/supercritical) solvent (water or organics) has proven to be an effective methodology to convert recalcitrant and low-grade lignocellulosic waste material into low molecular weight products as liquid fuels and valuable chemicals (Lee and Ohkita, 2003).

Hot-compressed (sub-/supercritical) fluids possess improved transport properties and enhanced miscibility with the liquid/vapour products from the processes, providing a favourable reaction environment for biomass conversion. For instance, water near its critical point (CP; 374 ºC, 22.1 MPa) is commonly referred as hydrothermal or hot-compressed water. In the hot-compressed water at conditions near the CP, the hydrogen-bond network of water, and the water becomes a weakly-polar solvent with low dielectric constant (ε) value, which can thus dissolve many non-polar organics and light inorganic gases such as hydrogen and oxygen. When hot-compressed and near-critical water is employed as a reaction medium, homogeneous reaction conditions may be obtained, thus enhancing the reaction rates by eliminating the mass transfer resistance between different phases.

Biomass direct liquefaction is performed under an inert or preferable reducing atmosphere at a moderate temperature (200-400℃) but high pressure (5-25 MPa). In a liquefaction process under high pressure, the macro-molecule compounds of the feedstock decompose into fragments of light molecules directly in the presence of a hot-compressed (water, alcohol, alkanes, phenols, and tetralin, etc.), promoted by a suitable catalyst. A pioneer work of biomass direct liquefaction technology was reported by Appell et al. (1971) at the Pittsburgh Energy Technology Center (PETC), where a variety of lignocellulosic materials were efficiently converted to oily products in water at an elevated temperature in the presence of CO and Na_2CO_3 as the catalyst. The PETC's biomass direct liquefaction technology was further advanced by the research group led by Elliott at Pacific Northwest Laboratory in USA (Elliott, 1980; Schirmer et al., 1984). Recent development of this direct liquefaction includes efficient liquefaction of woody biomass in near-/super-critical water and organic solvents (alcohol, alkanes, phenols, and tetralin, etc.) with a suitable catalyst (e.g., K_2CO_3, KOH, $FeSO_4$, FeS), obtaining a total liquid yield of 40-60 wt% (Yamazaki et al., 2006; Xu and Etcheverry, 2008). Recently, some researchers have successfully converted lignin into chemicals in supercritical water. Yokoyama et al. (1998) attempted to decompose organosolv lignin in sub- and supercritical water at 350-420℃ at 40 MPa, where a high oil yield (up to 40%) and a low char yield (less than 30%) was reported. The formation of char suggested that re-polymerization would occur at the same time, reducing the yield of chemicals from lignin. In this regard, phenol was used as a capping agent to prevent the lignin-degraded intermediates from forming char (Saisu et al., 2003).

On the other hand, phenol is a simple organic chemical that is widely used in many industries. It is typically produced by the cumene process where the petroleum-derived benzene is reacted with propylene, and oxidized by air in the presence of catalysts. Phenol is most often used to produce adhesives and binding agents in the production of coated abrasives, insulation and grinding wheel binders, paper laminates and foundry resins. Phenol is also widely used for production of phenolic resins for the production of engineered wood products such as hardboard, plywood, laminated veneer lumber (LVL) and oriented strand board (OSB). The production of phenol-formaldehyde resins consumes about 35-40% of the phenol production in the USA. The production of phenolic compounds from non-petroleum sources, biomass, for the manufacture of renewable phenolic resins is therefore attracting increasing interest (Effendi, et al., 2008). Agricultural residues or by-products (wheat straw, corn stover, rice husk, etc.) are lignocellulosic materials comprised primarily of cellulose (40%), hemicellulose (20-25%) and lignin (10-20%). Lignin is a biopolymer in which hydroxyphenylpropane units such as trans-p-coumaryl alcohol, coniferyl alcohol and sinapyl alcohol are connected with ether and carbon-carbon bonds in a helical structure (Alder, 1977; Johnson, et al., 1988). Therefore, phenolic chemicals can be obtained in the bio-crude products from direct liquefaction of lignocellulosic materials (Amen-chen, et al., 2001).

The amount of potential agricultural residues in Canada has been estimated at 29.3 Mt oven dried (OD) biomass per year, among which 17.8 Mt OD biomass/year may be available for energy and chemical production (Wood and Layzell, 2003). This represents a vast source of phenolic feedstock for the production of bio-oil and bio-based chemicals (such as bio-phenols) and bio-phenolic resins. The objective of this study is to liquefy agricultural resides in hot compressed water, phenol and water-phenol media, to produce bio-crude and bio-phenols. For comparison, lignin and cellulose were also liquefied in hot compressed water, Effects of composition of the liquefaction medium, temperature, reaction time and catalyst on the yields and properties of the liquid products were investigated.

2. Materials and Methods

2.1 Materials

The cornstalks for this study were obtained from a local farm. The tops and any immature cobs were removed from the stalks. The raw materials were dried at 105℃ in air over several days and subsequently milled to a particle size of less than 20 mesh (0.8 mm). This ground materials were drial was dried further in an oven at 105℃ for 24 h before use. For comparison, organosolv lignin and cellulose were used in some tests. The organosolv lignin and cellulose feedstocks were obtained from Sigma-Aldrich, and they were used as received without any further treatment. A.C.S. reagent-grade solvent and chemicals (phenol, ethyl acetate, diethyl ether, acetone, Rb_2CO_3 and barium hydroxide octahydrate ($Ba(OH)_2 \cdot 8H_2O$)), supplied by Fisher or Sigma-Aldrich were used. Table 1 gives the textural and elemental analyses of the biomass feedstcoks as well as the inorganic compositions the ashes from the cornstalk.

Table 1. Textural and elemental analyses of the biomass feedstcoks and major inorganic elements in the ash from the cornstalk.

	Textural analysis, wt% (d.b.[a])				Ultimate analysis, wt% (d.a.f.[b])				
Feedstock	Ash[c]	Lignin[d]	Cellulsoe	Hemi-cellulose	C	H	N	S	O[e]
Cornstalk	6.8	24.7	26.7	21.0	48.2	5.0	2.3	0.1	44.4
Lignin	0.5	99.5	-	-	68.8	5.4	0	0.02	25.8
Cellulose	0.27	-	100	-	44.6	6.0	0	0	49.4

Major inorganic elements in the ashes, wt% (d.b.)[f]										
	Na	K	Mg	Ca	P	Fe	S	Al	Si	Mn
Cornstalks	0.24	13.69	4.38	5.33	2.60	0.67	0.53	0.45	0.40	0.05

[a] On a dry basis; [b] On a dry and ash-free basis; [c] Ashed at 575℃ in air for 8 hours;
[d] The samples were extracted with acetone for the extractive-free test specimens, cellulose/hemicellulsoe were determined according to TAPPI test method T249cm-85, and the acid-soluble and acid-insoluble lignin were determined according to the TAPPI test method T222 om-88.
[e] By difference; [f] by ICP-AES

2.2 Liquefaction of Cornstalk, Lignin and Cellulose in HW

The experiments were carried out in a micro-reactor made of stainless steel (SS 316L), consisting of capped 5/8 inch Swagelok bulkhead unions, with an effective volume of 14 ml. In a typical run, 1.5 g of biomass was weighted into the reactor, followed by adding catalyst (if needed) at a ratio of 10% (w/w) of the biomass sample, and then 6 mL of distilled water was added. In all runs, the biomass concentration in the reaction mixture was fixed at 20% (w/w).The reactor with suspension of biomass, catalyst and distilled water was sonicated for 20 min in an ultrasonic bath before being securely sealed. The air inside the reactor was displaced with high purity nitrogen by repetitive operation of vacuuming and N_2-charging. Finally, the reactor was pressurized to 2.0 MPa using high purity hydrogen. Supported on a mechanical shaker set at 100 rpm, the reactor was then rapidly heated in a fluidized sand bath to the specified temperature for 60 min reaction. After reaction, the reactor was removed from the sand bath and submerged in a water bath to stop the reaction. Two duplicate runs were performed for each feedstock to ensure the repeatability of the results, and the maximum error between the product yield results from the duplicate runs was ensured within ±5% of the corresponding yield.

Once the reactor was cooled to room temperature, the gas produced was collected in a sample bag. Gas volume was measured by displacement in water and composition was analyzed by GC-TCD. The solid/liquid products were rinsed completely from the micro-reactor with acetone. The solid and liquid products were then filtered under vacuum through a pre-weighed Whatman No. 5 paper filter. The solids recovered in the filter consisted of char and ash. The filter paper and solids were dried in an oven at 105℃ overnight before weighing. The filtrate was evaporated under vacuum at 55℃ to remove the acetone. After evaporation, the pH of the residual water was measured. This residual water was diluted by the addition of 50 mL of distilled water. The pH of the resulting solution was measured before adjustment to a pH of 7-8 with 5% NaOH solution. This was followed by the addition of 50 mL of diethyl ether to extract the phenolic and neutral fractions from the liquid products in a separatory funnel. The ether solution was then evaporated under vacuum at an initial temperature of 35℃ to remove the ether. The yields of phenolic/neutral oil, gaseous products and char (solid residues), all expressed in wt%, were calculated relative to dry biomass feedstock. The yields of acid/aqueous products were simply obtained by difference. The biomass conversion was calculated by (100% - Yield of Char).

2.3 Liquefaction of Cornstalk in Hot-compressed Phenol-Water Co-solvent

The apparatus used for the liquefaction was a 75 ml Parr high pressure reactor (Parr Instrument, N4740), made of Hastelloy alloy, with maximum working pressure of 6000 psi at 600℃. In a typical run, 5g dried cornstalk powder, 5g phenol and 20g distilled water were added, and then the reactor was sealed. The liquefaction medium could be the water-phenol mixture, pure phenol or pure water, but the initial concentration of the added biomass in each test was fixed at 16.7 wt%. The air inside the reactor was displaced with ultrahigh purity nitrogen by repetitive operation of vacuuming and N_2-charging, and the reactor was pressurized to 2.0MPa with nitrogen. The reactor was heated to the desired temperature at 10℃/min. After the specified reaction time (i.e., 5min in this work) has elapsed, the reaction was stopped by quenching with cooling water. Once the reactor was cooled to room temperature, the gas inside was vented and collected into a gas collecting vessel for analysis. The reactor was rinsed thoroughly with about 60 ml ethyl acetate. The resulting suspension was filtered under reduced pressure through a preweighed Whatman No. 5 filter paper to obtain filtrate. The solid residue along with the filter paper was dried overnight in the oven at 105℃ before weighing. The filtrate was separated to an upper organic oily phase and a lower aqueous phase using a separatory funnel. The organic phase was collected and evaporated at 50℃ at reduced pressure in order to remove the ethyl acetate, and the resulted oil product was black, viscous and odorous. Ideally, the yield of oily product could be determined based on the mass of the resulted oil product after the above evaporation operation minus the mass of phenol added before the liquefaction test (assuming no loss in phenol's mass during the test). It should however be noted that the interaction between ethyl acetate, phenol and the liquid products would cause a difficulty for complete removal of the ethyl acetate solvent from the liquid products, which rendered challenge to quantify the oily products. Accordingly, in the present work the mass of total liquid products (consisting of oily and aqueous products), instead of the mass of oily liquid products, was calculated simply by difference: (mass of total liquid products) = (mass of dried biomass loaded) - (mass of gas products) - (mass of solid residue). The yields of gas products ("Gas" for short), solid residue ("Solid" for short) and total liquid products ("Liquid" for short) were all calculated to the dry matters of the added biomass (i.e., on a dry basis). Most of the experimental runs were repeated twice or three times, and the maximum errors in the liquefaction products yields between the runs under the same conditions fell within 5% of the yield. For simplicity, in this work only the average data were presented in the figures hereinafter.

2.4 Product characterization

The elemental compositions (C, H, N and S) of the cornstalk, lignin, and cellulose were determined with a CEC (SCP) 240-XA elemental analyzer and a Leco CNS-2000 Analyzer. The gaseous products from the liquefaction processes were analyzed using an Agilent 3000 Micro-GC equipped with dual columns (Molecular Sieve and PLOT-Q) and thermal conductivity detectors. The GC system employed in this work enabled analysis of gas species up to C_3, including O_2, N_2, H_2, CO. CO_2, CH_4, C_2H_4, C_2H_6, C_3H_8, C_3H_6. The bio-oil and liquid products were analyzed by GC-MS [Varian 1200 Quadrupole GC/MS (EI), Varian CP-3800 GC equipped with VF-5 ms column (5% phenyl 95% dimethylpolysiloxane, 30 m×0.25 mm×0.25 μm); temperature program: 40℃ (hold 2 min) → 190℃ (12℃/min) → 290℃ (8 ℃/min, hold 20 min)]. Compounds in the bio-oil/liquid products were identified by means of the NIST 98 MS library with the 2002 update. The molecular weights and their distribution of some bio-oils were determined by Waters Breeze GPC (1525 binary HPLC pump; RI detector at 30℃, UV detector at 270nm; Waters Styrange HR1 column at 40℃) using THF as eluant at a flowing rate of 1 ml/min, and Polystyrene standards were used to get the calibration curve. X-ray diffraction

(XRD) measurements were carried out by using Ni-filtered Cu-Kα radiation with a Philips PW 1050-3710 Diffractometer, to examine the evolution of the crystalline forms in the biomass samples during the liquefaction processes. Experiments to synthesize phenol formaldehyde resins using the cornstalk-derived bio-phenols were also performed. For characterization of the bio based phenolic resins, thermogravimetric analysis (TGA) and differential scanning calorimetry (DSC) were employed.

3. Results and Discussion

3.1 Liquefaction of Cornstalk, Lignin and Cellulose in HW

3.1.1 Effects of temperature

The effects of temperature on biomass conversion for the three feedstocks (cornstalk, cellulose and lignin) are shown in Fig. 1a. It can be seen from the Figure that the conversion of lignin was above 95% at 250℃, but its conversion decreased markedly to below 70% as temperature increased to 350℃, which was likely due to the enhanced formation of chars by condensation and dehydration of the liquid intermediates/products, as evidenced by the declining phenolic oil yields vs. temperature (Fig. 1b) and more obviously by the increase in char yield at a higher temperature (the data were not shown). This result is consistent with many previous studies on biomass liquefaction with hot-compressed water (Allen, et al., 1996; Kabyemela, et al., 1998), where it was demonstrated that condensation reactions of the biomass-degraded intermediates to yield more insoluble polymers and char could be enhanced at a higher temperature. At lower temperatures (<300℃), the conversions of both the cornstalks and cellulose were found to be much lower than those of lignin, suggesting that de-composition/de-polymerization of lignin occurs more readily than that of cellulose/hemi-cellulose. It has been well demonstrated by many previous studies that when biomass was heated in hot compressed water, solvolysis of hemicellulose and lignin began to occur at > 19 0℃, and all of the hemicellulose and much of the lignin dissolved in the water at 220℃ (Allen et al., 1996), forming the intermediates or aqueous and oily products. Solvolysis and pyrolysis of the remaining lignocellulosic solids took place at higher temperatures (Antal et al., 1990; Bobleter, 1994). The conversions of cornstalks and cellulose climbed with increasing temperature and exhibited a maximum at about 300℃, while a higher temperature yielded slightly decreased conversion, most likely owing to the same reason as that with lignin discussed above.

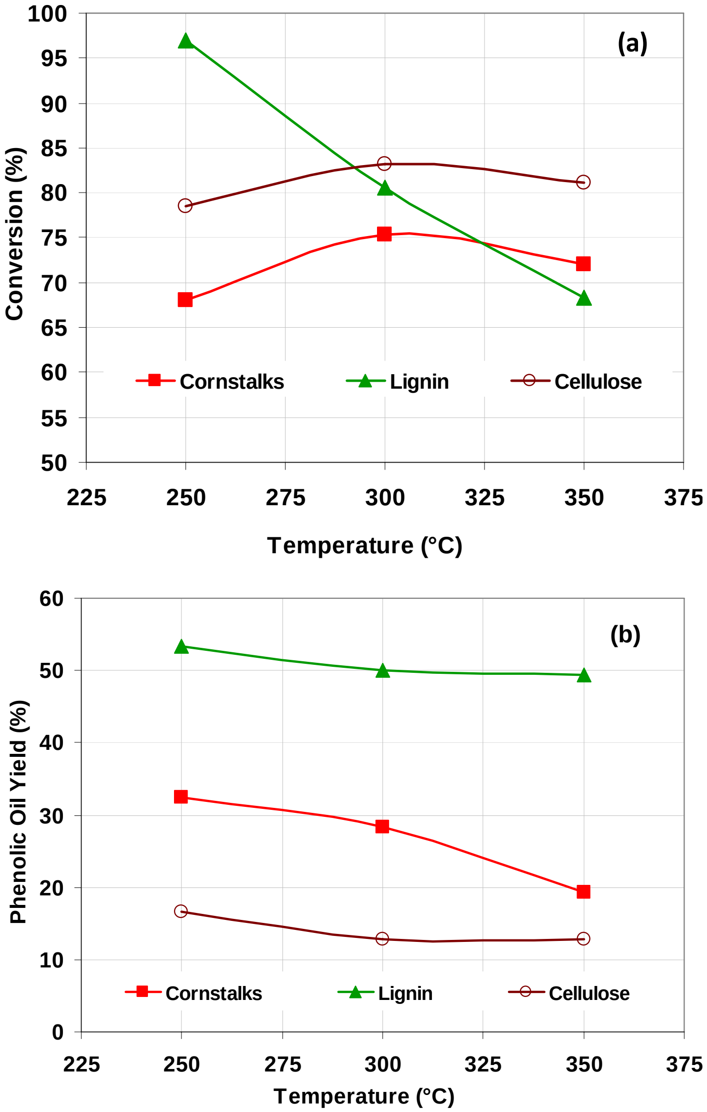

Fig. 1. Effects of temperature on biomass conversion (a) and phenolic/neutral oil yields (b).

The yields of phenolic/neutrals oils (called phenolics or bio-crude in this work for simplicity) are shown in Fig. 1b. For all types of the feedstock, there was a general decrease in phenolic oil yield with increasing temperature. This declining trend may be accounted for by the enhanced condensation reactions of the oil products to form more char, as discussed before, and more likely by the promoted cracking reactions of the oil products to form gaseous products, as evidenced by a significantly increased yield of gas products at a higher temperature. From Fig. 1b, it is clear that the liquefaction of lignin produced markedly higher yields of phnolic/neutral oil or bio-crude (>50 wt%), compared with the bio-crude yields from cornstalk (20~33 wt%) and cellulose (13-17 wt%). The differences in bio-crude yields may be easily explained by the differences of the lignin contents in the feedstocks, being ~100 wt% for pure lignin, about 25 wt% for the cornstalk and approximately none for cellulose. Lignin, as a biopolymer of hydroxyphenylpropane units, has been generally believed as the dominant precursor for the phenolic oils (Alder, 1977; Johnson, et al.; Amen-chen, et al., 2001).

3.1.2 Effects of catalysts

The effects of catalysts on phenolic/neutral oil yield are shown in Fig. 2. These experiments were conducted under conditions of 300℃ for 60 minutes. In the presence of a catalyst (either $Ba(OH)_2$ or Rb_2CO_3), the yield of phenolic/neutral oil from cellulose and the cornstalk was increased. The greatest catalytic effect was observed with cellulose where the phenolic/neutral oil yields more than doubled. The use of the catalysts resulted in a significant increase in gas at the expense of acid/aqueous products for both cellulose and cornstalk except for lignin. As an example, effects of catalysts on product distributions for cornstalk are illustrated in Fig. 3. The unexpected suppression of bio-crude yield for lignin by the addition of a catalyst might result from catalyzed condensation reactions of the phenolic/neutral oil products or intermediates, which was actually evidenced by the drastically increased formation of char from the tests of lignin in the presence of each catalyst. The char yield from lignin increased drastically from 19 wt% without catalyst to 45 wt% with $Ba(OH)_2$ and 33 wt% with Rb_2CO_3.

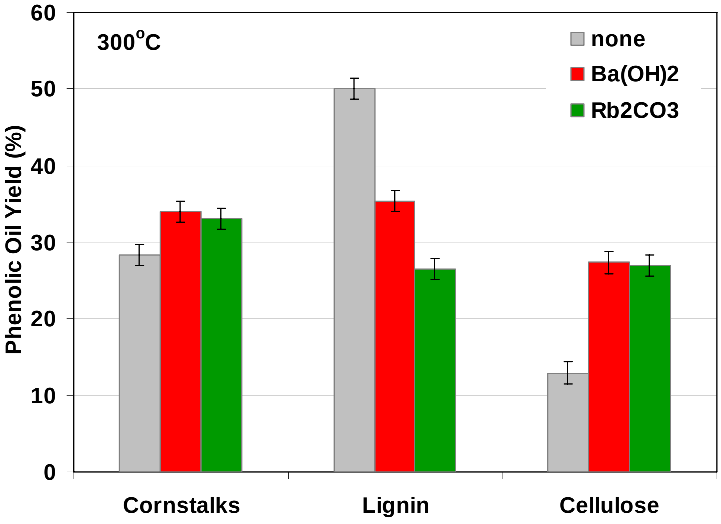

Fig. 2. Effects of catalysts on phenolic/neutral oil yields.

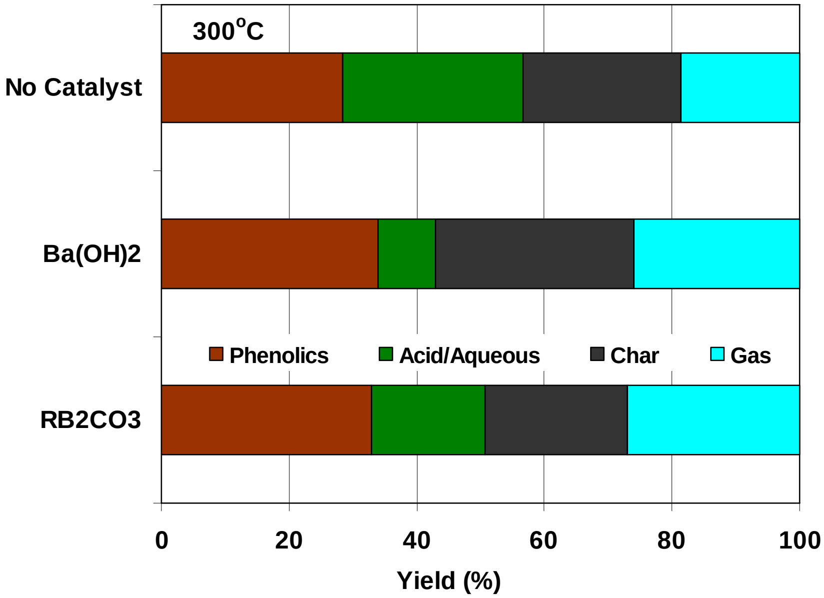

Fig. 3. Effects of catalysts on product distributions for cornstalk.

3.1.3 Bio-crude Product characterizations

GC/MS was used to identify the chemical composition of the phenolic/neutral oils produced by liquefaction of the biomass feedstocks. The major components of the phenolic oils derived from cornstalks at 300℃ are listed in Table 2, where the area percentages of each compound (defined by the percentage area for each peak in the chromatogram in relation to the total area) are also shown in the Table. Phenolic compounds make up approximately 55% of the phenolic/neutral oil produced with esters of complex organic acids making up another 15% of the total. As expected, the bio-crude derived from lignin was the most concentrated with phenolic compounds. Substituted phenols and phenolic compounds comprise almost 74% of the phenolic oil collected from the liquefaction of lignin. In the bio-crude from cornstalk and lignin, the major phenolic compounds detected were 4-ethyl-2-methoxy-phenol, 2,6-dimethoxy-phenol, apparently the degraded products from lignin. Lignin could be de-polymerized/cracked into its building blocks or derivative compounds by cracking and hydrolysis reaction easily at the ether linkages (e.g. β -O-4 and α -O-4) or condensed linkages (e.g. 5-5 and β -1) to form low molecular weight liquid compounds (Wahyudiono and Motonobu, 2008). The cellulose sample produced the noisiest chromatogram due to the complexity of oil compositions. It may not be surprising that almost no phenolic compounds were detected in the oil from the liquefaction of cellulose, and the major components of the cellulose-derived oil appear to be esters of complex organic acids and long chain hydrocarbons, likely formed by hydrolysis/dehydration of the cellulose and derivatives.

Table 2. Major compounds in phenolic/neutral oil produced by liquefaction of cornstalk at 300℃ for 60 min in hot-compressed water

RT (min)	Compound Name	Area %
5.281	Phenol	3.96
6.564	Phenol, 2-methoxy-	9.91
6.678	Mequinol (*p*-methoxyphenol)	2.99
7.494	Phenol, 3-ethyl-	1.90
8.860	Phenol, 4-ethyl-2-methoxy-	20.75
9.739	Phenol, 2,6-dimethoxy-	1.99
9.791	Benzenemethanol, 3-hydroxy-5-methoxy	2.66
9.883	2,4-dimethoxyphenol	2.48
11.399	5-Hydroxy-8,8-dimethyl-3,3a,4,5,6,7,8,8b-octahydroindenol-[1,2-b] furan-2-one	1.71
11.442	4,6-di-tert-Butyl-m-cresol	2.19
11.557	5-tert-butylpyrogallol	5.83
11.71	Acetic acid, 10-dimethoxymethyl	2.50
11.881	6,9-octadecanoic acid, methyl ester	1.81
11.959	2-Naphthalenol, 1-[(2-hydroxy-4-nitrophenyl]azo)-	1.89
12.268	1,4-benzenecarboxylic acid, methyl ester	2.13
12.454	2,4-hexadienedioic acid, 3,4-diethyl-dimethyl ester	4.55
13.712	Phenol, 2-(1,1-dimethyl-2-propenyl)-3,6-dimethyl	1.81
27.876	Octadecane, 3-ethyl-5-(2-ethylbutyl)	1.95
29.423	Butylaldehyde, 4-benzyloxy-4-(2,2-dimethyl-4-dioxolanyl)-	1.92
29.63	1,2-Benzenedicarboxylic acid, diisooctyl ester	4.55
Total Area %		85.17

3.2 Liquefaction of Cornstalk in Hot-compressed Phenol-Water Co-solvent

3.2.1 Effects of Types of Liquefaction Solvent

With the solvents of phenol, water and phenol-water (1:4 w/w) co-solvent, cornstalk was liquefied in an autoclave reactor (75 ml) at various temperatures ranging from 300℃ to 450℃ for 5 min at a biomass-to-solvent ratio of 1/5 wt/wt (or biomass concentration of 1/6 wt/wt). The yield of liquid products was found to peak at around 350℃ for all both phenol alone and the phenol-water co-solvent. With the hot-compressed water alone, a higher temperature monotonically produced a greater yield of liquid products, implying that enhanced hydrolysis and pyrolysis reactions might dominate over the condensation/cracking of the intermediates to form char at temperatures between 300℃ and 450℃. Compared with water, phenol and phenol-water co-solvent were found to be much more efficient in liquefaction cornstalk into liquid products, with very low char formation. A comparison of the Liquid yields at 350℃ with different liquefaction media is shown Fig. 4. The Liquid yield for the liquefaction in water was 60 wt%, was much lower than those in organic solvents, i.e., 70 wt% in phenol-water (1:4 w/w) co-solvent and 80 wt% in pure phenol. Liquefaction of coenstalk in hot-compressed phenol also produced the lowest char yield (10 wt%), compared with 15 wt% in phenol-water co-solvent and 30 wt% in water. The organic solvent such as phenol could readily dissolve the liquefaction intermediates and liquid products, which would greatly accelerate the de-polymerization reactions and meanwhile reduce the condensation reactions of the degraded intermediates, resulting in a lower yield of solid residue and a higher yield of liquid products. More importantly, phenol could act as a capping agent to prevent the lignin-degraded intermediates from forming char (Saisu et al., 2003). Although phenol exhibited the best performance among the solvents tested for the liquefaction of cornstalk, phenol-water mixture would be more promising with respects to cost of solvent and environmental concerns (water may qualify to be one of the greenest solvents).

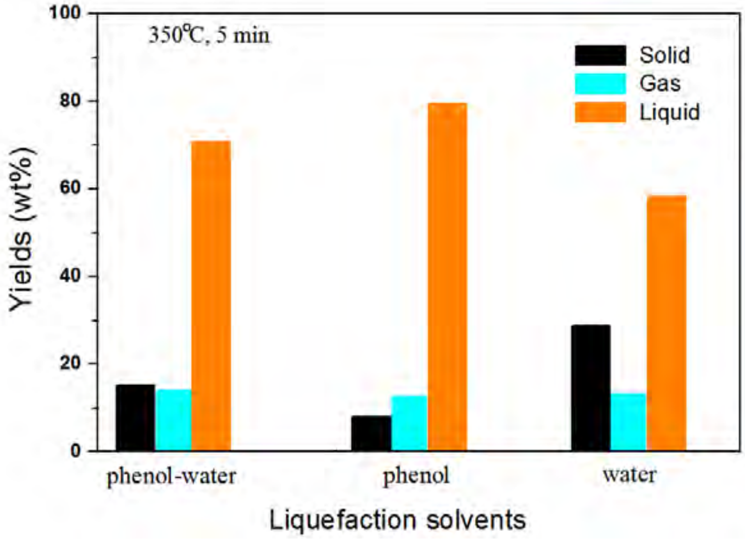

Fig. 4. Product yields in liquefaction of cornstalk powder at 350℃ for 5 min using different solvents

As an application of the phneolic bio-crude or bio-phneols, resol type bio-based phenol formaldehyde resins could be readily synthesized from the liquefied cornstalk using phenol-water co-solvent. The resinification/ploymerization process was conducted at 80℃ for 2 hour using sodium hydroxide as catalyst. The bio-resol resins obtained had an adjustable viscosity and a broad molecular distribution. The bio-resole resins were thermally curable with good thermal resistance (higher than 300℃). The residual carbons of the cured bio-phenolic resins at elevated temperatures were determined by TGA to be *ca* 57% at 700℃. This is still inferior to the commercial phenol-formaldehyde resins due to the lower reactivity of the bio-phneols than the petroleum-based phenol. More research work is needed to either improve the reactivity of bio-crude (bio-phneols) for the resin synthesis application, or to upgrade the oil into green diesel for bio-fuels.

3.2.2 Liquid Product characterizations

The GC-MS analysis results for the bio-oil product from the liquefied cornstalk at 350℃ in the phenol-water (1:4 wt/wt) co-solvent showed that the bio-oil consisted mainly of phenolic compounds, their derivatives, and a small amount of long-chain oxygenated hydrocarbons, mostly derived from lignin. A small amount of carboxyl acids and carbohydrates (commonly degraded from hemicelluloses and cellulose) was also detected in the bio-crude. GPC analyses were conducted in order to study the molecular weights and distribution of the cornstalk-derived bio-crude, as the molecular weight was considered as a critical property that could influence the physical/chemical properties of the oil products (viscosity, density, chemical stability and reactivity, etc.). The molecular weights and distribution of a bio-crude were more critical in applying the bio-crude to the synthesis of phenolic resins (Mansouri and Salvadó, 2006). The GPC results showed the bio-oils exhibited broad molecular weight distributions and contained a lot of high molecule weight compounds as partially degraded oligomers. Table 3 provides a summary of the GPC results for the bio-crude products from different liquefaction media and at various liquefaction temperatures. As a general observation, the molecular weights and polydispersivity of the oils obtained with water or phenol-water medium were greater than those obtained with phenol. These results might also be accounted for by the fact that phenol could act as a capping agent to stabilize the liquid intermediates from forming larger oligomers. As the operating temperature increased, the molecular weights of the bio-crude products generally reduced. For example, with the phenol-water (1:4 wt/wt) medium, the bio-crude obtained from cornstalk at 350℃ has an average M_w of 977 and M_n of 530, compared with an M_w of 670 and M_n of 425 for the bio-crude obtained at 450℃.

Table 3 Summary of GPC results for the cornstalk-derived bio-oils

Liquefaction conditions[a]	M_n	M_w	Polydispersity
Biomass:phenol:water=1:1:4; 450℃	425	670	2.06
Biomass:phenol:water=1:1:4; 350℃	530	977	1.84
Biomass:phenol:water=1:1:4; 300℃	645	1205	1.87
Biomass:water=1:5; 350℃	483	880	1.83
Biomass:phenol=1:5; 350℃	439	713	1.62

[a] Reaction time was 5 min for all the tests.

4. Conclusions

In this study, lignocellulosic agricultural residue, i.e., cornstalk, and two model biomass compounds (pure lignin and pure cellulose as references) were directly liquefied in hot-compressed water at temperatures from 250℃ to 350℃ for the production of bio-crude (phenolic/neutral oils). Generally, for all the feedstocks tested, an increased reaction temperature resulted in a decrease in phenolic/neutral oil yield. The 60 min liquefaction operations at 250℃ produced the phenolic/neutral oil at a yield of about 53%, 32% and 17% for lignin, cornstalk and cellulose, respectively. As evidenced by GC-MS measurements, significant quantities of phenolic compounds (such as 4-ethyl-2-methoxy-phenol, 2,6-dimethoxy-phenol) were obtained by the direct liquefaction of the cornstalk and pure lignin, and the relative concentration of phenolic compounds in the lignin-derived oil was as high as about 80%. It was further shown that the yields of phenolic/neutral oil could be significantly enhanced by the addition of $Ba(OH)_2$ and Rb_2CO_3 catalysts for all feedstocks except lignin.

Cornstalk powders were also comparatively liquefied in hot-compressed phenol, water and phenol-water (1:4 wt/wt) co-solvent, at 300-450℃. When liquefying cornstalk in the phenol alone or the phenol-water co-solvent, 350℃ appeared to be the optimal liquefaction temperature at which the yield of liquid products peaked, attaining 70 wt% in the phenol-water (1:4 w/w) co-solvent and 80 wt% in pure phenol, suggesting phenol could act as a capping agent to stabilize the liquid intermediates from forming larger oligomers. Moreover, molecular weights and polydispersivity of the oils obtained with water or phenol-water medium were greater than those obtained with phenol. The molecular weights of the bio-crude products generally reduced with increasing the liquefaction temperature. With the phenol-water co-solvent the obtained bio-crude at 350℃ has an average M_w of 977 and M_n of 530, compared with an M_w of 670 and

M_n of 425 for the bio-crude obtained at 450℃. The obtained phenolic oils proved to be useful phenol substitutes for the production of green phenol-formaldehyde resins that were thermally curable with good thermal resistance (higher than 300℃).

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2

Biodiesel Promotion in Thailand

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Abstract

This paper presents biodiesel activities in Thailand during the last 5 years. The country has promoted the use of renewable energy by using several strategies. Short and long energy planning is discussed. Activities related to biodiesel such as policy, regulations, research works, current situation, future direction are presented.

Key words: Biodiesel, Promotion, Thailand, Palm Oil, Renewable Energy

1. Introduction

Thailand is growing more and more dependence on imported fossil fuels. Annual fossil fuel import accounts for more than 25,000 million US$. This raises the concern of energy security of the country. Uncertainty of the oil price in the world markets is mainly effect to retail price of oils in the country. To partially resolve such problems, seeking for new and more renewable energy resources has been counted as high priority. Main aims are to reduce the dependency on fossil fuels and to ensure energy self sufficiency. Many strategies have been set and implemented such as a strong policy from the government, supporting grant for research work and demonstration projects, partial support in renewable energy projects in private sector, add the adder in renewable energy production, lower tax, and etc.

Historically, His Majesty the King has done experimentation and implementation for more than two decades such as ethanol-gasoline and crude palm oil-diesel. His work is the primary knowledge for the latter bio-fuel research works e.g. crude palm oil (CPO)-blended diesel for 5% was used in a farm tractor, ethanol from local crops like sugar cane and cassava and etc.

Country location is in the tropical zone, where many energy crops can be grown. Bio-fuels such as ethanol, biodiesel and biomass are on the focus. Energy crops are oil palm, sugar cane, cassava, coconut, caster, soybean, sunflower seed, rice husks, and jathopha.

For palm oil production, Malaysia and Indonesia are among the leaders. Thailand is in the 3rd rank. Palm oil produced in the country is originally for food. Surplus palm oil from food, however, is now used as raw material of biodiesel production. Other raw materials for biodiesel making are used cooking oil and jathopha.

2. Policy, Research Works and Promotion Strategy

2.1 Policy

The 15 year-Alternative Energy Plan (2008-2022) is currently implemented. The goal for renewable energy is 20% of the total energy consumption, which is equivalence to 22,819 ktoe. Biodiesel has been included in the plan. The projection of the total biodiesel production is about 4.5 million liters per day by 2022, compared to the current production is about 1.3 million liters per day.

Petroleum diesel (100% diesel) has been replaced with B2-blended diesel since April 2008. Blending ratio will be increased to B5 in 2011. This also benefits to less air pollution. Other strategy, using price structure, is to reduce tax of bio-based fuel. The price of B5 is always lower than diesel price. The price difference is about 0.80-1.50 Baht per liter.

2.2 Biodiesel Regulation

Biodiesel standard has been compiled from ASTM standard. Two standards were announced by Department of Energy Business, Ministry of Energy: B100 commercial biodiesel and B100 farm-used biodiesel. The commercial standard is applied for the testing of pure biodiesel (B100). The farm-used standard is more flexible as compare to the commercial standard. For example, viscosity value in the farm-used standard is 1.9-8.0 *cSt@*40℃, while the value in the commercial is 3.5-5.0 *cSt@*40℃. The farm-used standard is applied for biodiesel that is used in a one stroke diesel engine. The engine is widely used as agricultural machines such as a water pumping engine, a small tractor, a modified truck and etc. The standard allows small scale biodiesel production which is mostly using used cooking oil as feedstock.

2.3 Research Works

Several researchers in university laboratories have been working on small scale biodiesel production using used cooking oil and CPO. The system is range from 100-2,000 liters. The system cost is about 5,000 to 20,000 US$. They are designed suitably for a farmer, a community or a small food factory whose have used cooking oil, which is waste from food making process.

The university activities during the last 5 years show in Table 1.

Table 1 Biodiesel related activities in Thai universities

University\Activities	Activities
Chiang Mai University[1]	• Survey of used cooking oil, results shown in Table 2. The amount of UVO in the country is 74 million liters per year. About 50% of total used cooking oil can be presently collected. • Design of 150 and 1,000 liter batch systems, shown in Figure 1 • Training for more than 1,000 people, follows up shows that more than 200 systems were built. Pictures show in Figure 2 • Study of oil palm plantation in Northern area • Oil from micro algae
Kasetsart University[2]	• Study of biodiesel from jatropha e.g. plantation, harvesting, oil extraction, testing for biodiesel properties, engine testing, and utilization of agricultural wastes from the plantation.

University\Activities	Activities
Prince of Songkla University	• Design of small and large continuous process systems for palm oil (CPO) • Demonstration of small scale biodiesel production business
Others	• Research work related to optimum production, higher biodiesel yield techniques, difference types and lower consumption of catalyzes which is used in the chemical reaction, and etc.

1. Grant from EPPO Energy Conservation Promotion Fund and Energy Policy and Planning Office, Ministry of Energy [2004-2005].
2. Grant from Petroleum Authority of Thailand (PTT).

Table 2 Results from the survey of used cooking oil in Thailand

Sector	Amount million liters per year
1. Food related business	22.5
2. Food industry	3.4
3. Fresh market	1.3
4. Household	47.2
Total	74.4

3.4 Commercial Production

At present, fourteen companies have registered as biodiesel producers [2]. The total production capacity is 4,455,800 liters per day. Three main raw materials are used for biodiesel productions in commercial scale: used cooking oil, CPO, and palm stearine. Commercial production using used cooking oil leads by Bangchak Petroleum Public Ltd.

Figure 1 150 and 1,000 liter biodiesel making systems [3]

Figure 2 Community participation in making and using biodiesel from used cooking oil [3]

Short term biodiesel projection is shown in Table 3. New oil palm plantation area is about 800,000 thousand acres by 2012. Diesel (B2 & B5) consumption is now at 55 million liters per day. The consumption will be increased to about 63 million liters per day by 2012.

Table 3 shows oil palm plantation area, CPO and biodiesel productions [DEDE, 2009]

	2007	2008	2009	2010	2011	2012
Oil palm area, million acres	1.18	1.38	1.58	1.78	1.98	2.18
CPO production, million tons/yr	0.045	0.35	0.35	0.35	0.84	0.87
B100 production, million liters/day	.131	1.2	1.33	1.38	3.02	3.14
Amount of B2 & B5, liters/yr	8.2	54.6	54.6	54.6	60.3	62.7

1. Excess palm oil from food.

4. Discussions and Conclusions

- Alternative energy promotion requires strongly policy and some grant supported on the early phase of the demonstration and implementation.
- In order to promote alternative fuel successfully the public relation work is one of the key factor. It is necessary to introduce and get people family with the new alternative fuel before introduce such fuel in the market.
- Time frame for introducing bio-based fuel is about 10 years.
- The limitation of bio-based fuels is amount of raw material which is directly related plantation area.

- Interference of food chain and energy chain in agriculture products have to be carefully considered especially in long run. The price structure of food will be highly depended on the price of energy, if the two chains could not be separated and managed.

5. Acknowledgement

The author is grateful to Energy Conservation Promotion Fund and Energy Policy and Planning Office (EPPO), Ministry of Energy, Thailand for supporting the author research work, which was undertaken at Energy Research and Development Institute (ERDI), Chiang Mai University, Thailand.

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3

Study on Crude Oil Productions and Supercritical Clean and Green Fuels on Application of Liquefaction Technology with Agricultural Biomass

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Abstract

Aqueous thermal liquefaction of rice, barley, wheat, and rapeseed straws was investigated to compare the amount of heavy oil with catalysts such as K_2CO_3, NaOH and KOH in the reaction temperature at 320℃ for 10 minutes. The reaction was carried out in a 5,000ml liquefaction system with dispenser and external electrical furnace. Raw materials (160g), 2,000ml of distilled water and 10% (wt/wt) of catalyst to plant residue were fed into the reactor. It was observed that the maximum heavy oil yield was about 29% from the feeding stock, barley straw, with addition of KOH. The caloric values of crude oil from different crop residues were ranged from 55% to 66% relative to the raw materials depend on crop residue. It was appeared that its maximum calorific value from wheat straw was approximately 6190 kcal/kg. Furthermore, in case study of co-solvent with ethanol and bulk-glycerol, it observed that more than 80% of rice hull was decomposed and liquefied in its solvent at 315-326℃ for 30 min. For the development of applicable bio-fuel from rice hull, its feasibility is necessary to be carried out for co-solvent soluble portions.

Keywords: Liquefaction, heavy oil, crop residues, caloric value

Introduction

Biomass is a renewable energy resources derived from all the organic materials produced by human and natural activities. It is a complex mixture of organic materials such as carbohydrates, fats and proteins. The main components of the plant biomass are carbohydrates and lignin which can vary with biomass type. The carbohydrates are mainly cellulose and hemi-cellulose fibers which gave strength to the plant structure, and lignin which holds the fibers together. Therefore, biomasses as plant residues of rapeseed, rice, barely and wheat could be good raw materials for alternative fuel resources. The plant residues are contained at 40~50% of cellulose, 25~35% of hemi-cellulose and 15~20% of lignin. Yield of rice straw is 4,776 million tones per year from 955 thousands ha, and its barely straw is 262 million tones from 58 thousands ha of cultivation areas (Ministry of Agriculture and Forestry, 2007) in Korea.

Therefore, several studies of bio-fuels have been conducted in order to establish the bio-energy production system based on hydro-thermal and supercritical fluid liquefaction technologies as an environmental friendly treatment (Fig. 1.)

Biomass contributes about 14% of today’s world energy supply, while in many developing countries, its contribution ranges from 40% to 50%. Biomass, as an energy sources, has two striking characteristics; first, biomass is not only renewable organic resources, but also is one of the most abundant resources. Second, biomass fixes carbon dioxide in the atmosphere by photosynthesis. However, biomass is not suitable to be used as energy directly with its high moisture content and low colorific value. Therefore, several studies have been carried out to convert biomass into high energy density liquid with liquefaction (Putun *et al*., 2004; Zhong and Wei, 2004; Minowa *et al*., 1998; Maldas and Shiraishi, 1997; Selhan *et al*., 2004; Yan *et al*., 1999; Takao *et al.*, 1997; Qian *et al.*, 2007; Qu *et al*., 2003). In case of liquefaction, biomass is decomposed into small molecules in water with or without solvent and catalyst.

These small molecules are unstable and reactive, and can re-polymerize into oily compounds with wide range of molecular weight distribution (Demirbas, 2000). The liquefaction of biomass has been investigated in the presence of solutions of alkalies (Demirbas, 1994), formate of alkaline metals (Tarabanko and Gullbis, 1989), propanol and butanol (Ogi and Tokoyama, 1993) and glycerine (Demirbas, 1998), and direct liquefaction (Minowa *et al*., 1994). However, biomass causes not only environmental problem, but also waste resources. Therefore, the development of biomass utilization processes is an urgent and important topic in Korea.

Objectives of this study were to estimate the calorific values of different feeding stocks and their crude oils and to evaluate the yield of liquefaction production with different crop residues and catalysts and co-solvents.

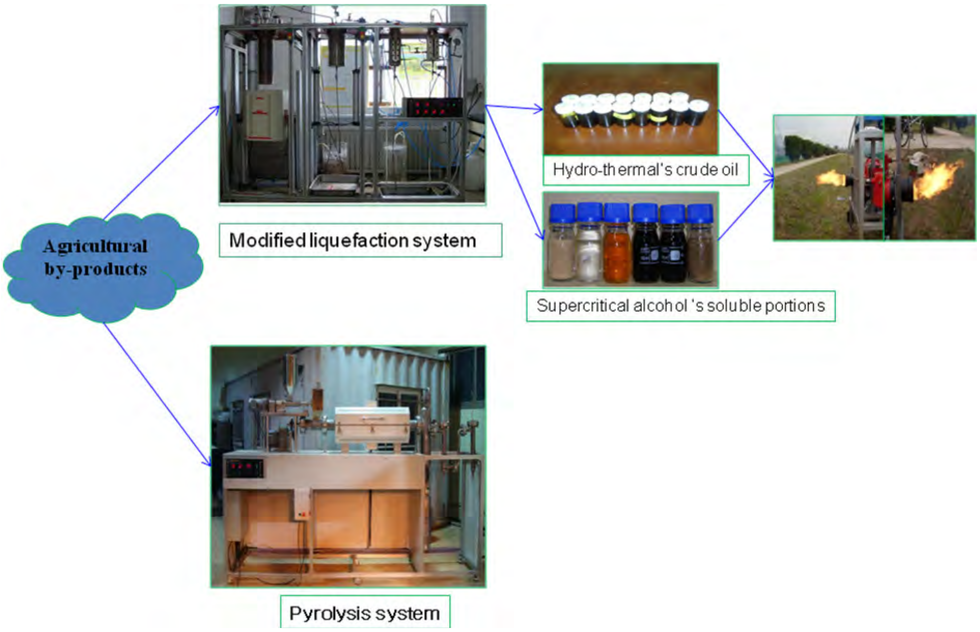

Fig. 1. Paradigm of bio-fuel production system with hydro-thermal and supercritical fluid liquefaction technologies by using agricultural bio-mass.

Materials and Experimental Methods

Materials

The feeding stocks of rice, barley, wheat, rapeseed straws and rice hull were ground and then screened; particle size of plant residues grinded was used in this work through 2mm mesh.

Sodium hydroxide (>98.0%) and potassium hydroxide (>85.0%) were purchased from DAEJUNG Chemicals.

Liquefaction Processes

The reaction was carried out in a 5 L of Inconel reactor with agitator and cooling system in the devised liquefaction system. The reaction tank was heated with an external electrical furnace, and its temperature was maximized up to 500℃. 160g of raw materials as rice, barley, wheat and rapeseed straws, 2 L of distilled water and 10% of catalysts such as K_2CO_3, NaOH and KOH were fed into the reactor. After air was displaced into nitrogen gas, the reaction tank was heated up to the 320℃, and the temperature was kept for 10 min of reaction time at approximately 144bar of reaction pressure. Then the reaction tank was cooled to room temperatures with air from compressor and cooling system with standing for overnight. In the liquefaction system runs for supercritical clean and green bio-fuel production, 150g of rice hull was weighed into the reactor, followed by adding 1.8L of ethanol and 1.2L of co-solvent. Its co-solvents were used as ethanol : bulk-glycerol (60 : 40) and ethanol : glycerol (60 : 40). The ranges of reaction temperatures and pressure were 315~323 ℃ and 22.7~24.6 MPa for ethanol : bulk-glycerol (60 : 40) and 320~326 ℃ and 22.2~23.7 MKa for ethanol : glycerol (60 : 40), respectively (Fig. 3). Under these conditions, the reaction time was 30 minutes in this case study.

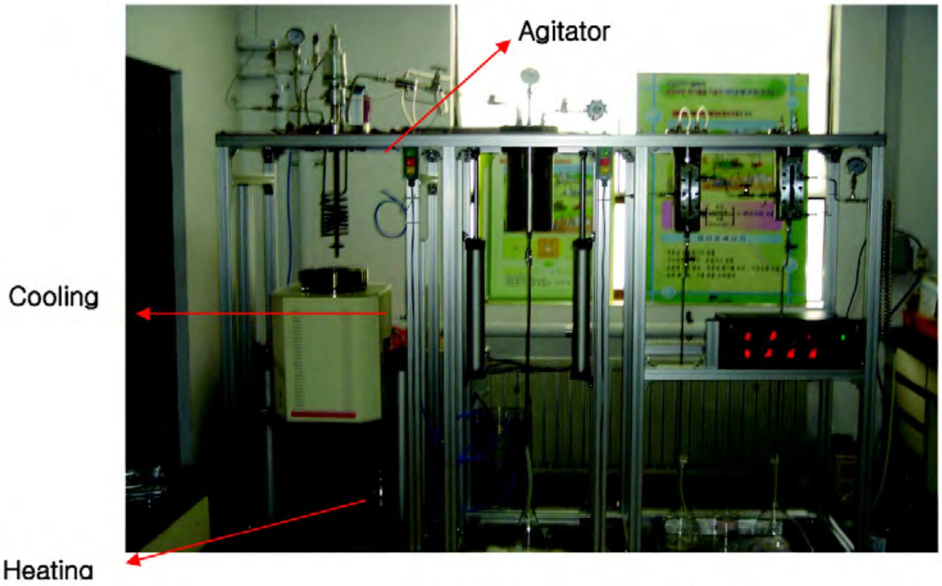

Fig. 2. Devised liquefaction system for producing the crude oil.

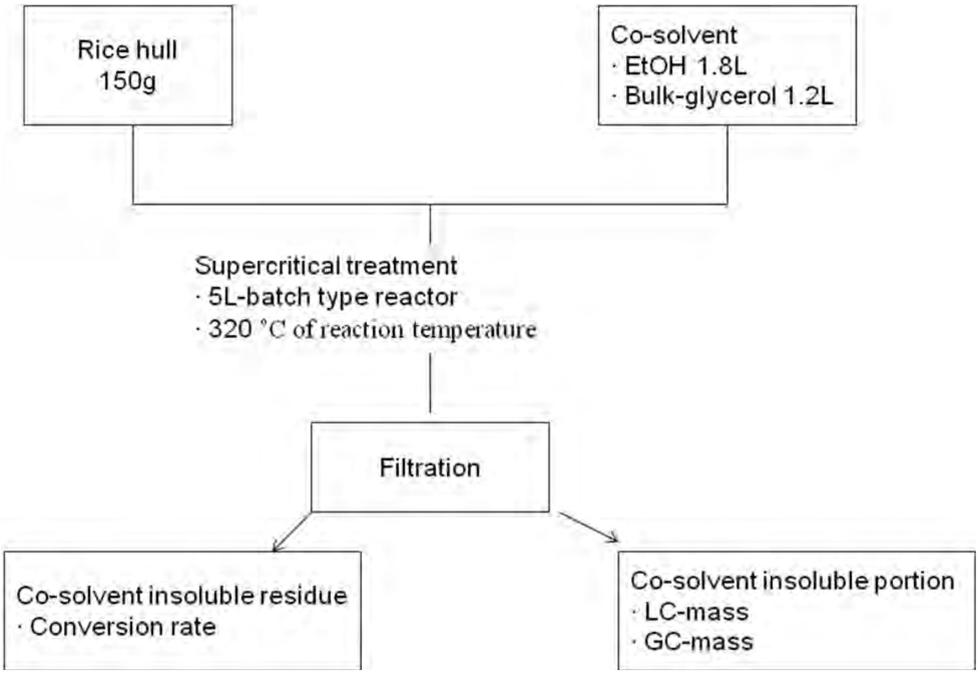

Fig. 3. Overall scheme of supercritical clean and green fuel production on liquefaction with rice hull.

Separation After each run, the nitrogen gas was venerated and the contents of reaction tank poured into the vessel which separation procedure was shown in Fig. 4. The aqueous phase was filtered to separate the water insoluble fraction. The residues on the filter was dried at 70℃ over two days, and they are so called "Organic Dissolved' (OD). The water insoluble fraction and wall of reaction tank were washed with acetone three times. The acetone insoluble material on the filter was dried at 70℃ over two days, and weighed for ash. The acetone solution was concentrated with rotary evaporator, and then evaporated the residual acetone at 70 ℃ hot plate over two days. The residue is so called and weighed the crude oil.

Analysis and Calculation The calorific values of crop residues and their crude oils were measured by using the Calorific Meter (C5000). For supercritical soluble portions from liquefaction with rice hull, its analysis was conducted by LC-mass. The amounts of liquefaction products were estimated by following equations;

Yield of crude oil = (mass acetone soluble/ mass biomass added)*100 ·························· (1)

Yield of OD (organic dissolved) = (mass water soluble/ mass biomass added)* 100 ····· (2)

Yield of residue = (mass acetone insoluble/ mass biomass added)*100 ·························· (3)

Total yield = (1) + (2) ·· (4)

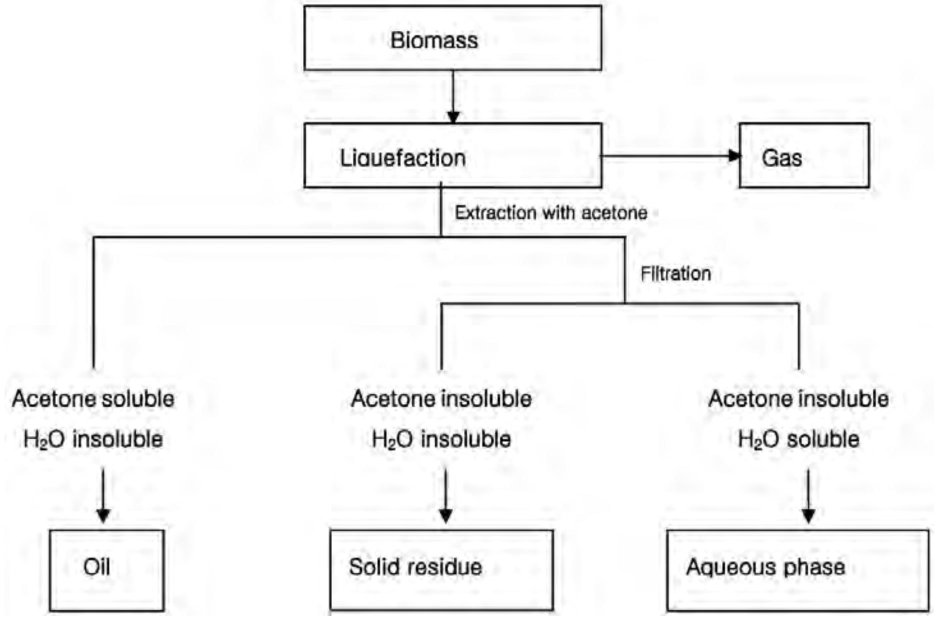

Fig. 4. Separation scheme of liquefaction products

Results and Discussions

Yields of plant residues with different crops were described in Table 1. Yield of rice straw was most abundant as 1.9 million tones, and then its garlic was 146 thousand tones per year. Total yield of main crop residues in Korea was 2.2million tones per year. However, main grain crops for food are rice, barely, wheat, and rapeseed is for oily crop in Korea. The reason that is used for feeding stocks for crude oil production was main food and oily crops in Korea.

Table 1. Yields of plant residues with different crops

Crops	Fresh Yield(ton/year)	Dry Yield (ton/year)	Plant Residues (ton/year)	Total Biomass (ton/year)
Rice	5,089,230	5,044,620	1,934,682	12,764,001
Hot pepper	410,281	110,776	3,819	392,823
Barely	22,551	22,551	873	52,735
Perilla	18,346	17,245	10,561	167,427
Sesame	20,863	14,813	25,184	117,563
Soybean	138,570	138,570	4,391	294,371
Potato	128,520	38,556	43,531	45,521
Sweet potato	107,020	26,755	31,355	66,576
Garlic	357,824	118,082	146,666	169,415
Water melon	823,672	58,481	32	69,045
Corn	77,616	65,197	12,029	208,823
Peanut	8,257	7,431	592	20,248
Total	7,202,750	5,663,077	2,213,715	14,368,548

Yields of crude oil, OD, residue and total yield were estimated from Eq. 1, 2, 3 and 4, respectively.

The liquefaction yields according to different feeding stocks with 10% K_2CO_3 (wt/wt) on hydro thermal liquefaction were presented in Fig. 5. It was observed that there were not significantly different with liquefaction yields for different feeding stocks except for rapeseed straw. For the liquefaction products with different feeding stocks, the yields of crude oil with rice, barely, wheat and rapeseed straws were 24.3, 25.4, 24.3 and 15.5% to amount of biomasses fed, respectively. These values except for its rapeseed straw were approximately the same as the others' reported value (Qu *et al.*, 2003). However, it was observed that its minimum value was 15.5% of crude oil yield with rapeseed straw. Rapeseed was recently cultivated in the model area for alternative fuel crop production. Furthermore, it was necessary to enhance the crude oil production of rapeseed straw with different catalysts.

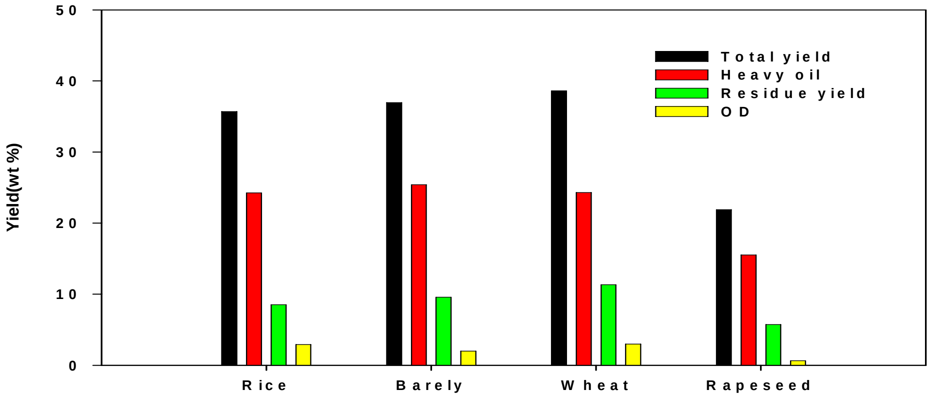

Fig 5. Effects of liquefaction yields to different crop residues with addition of 10% K_2CO_3 (wt/wt)

The liquefaction yields of rapeseed straw with different catalysts were described in Fig. 6. For their yields, it was observed that the maximum yield was 15.5% with 10% K_2CO_3, but was 12.1 and 13.8% of 10% NaOH and 10% KOH to the amount of biomass fed, respectively. For the effect of the catalysts on hydrothermal liquefaction of rapeseed straw, it was observed that addition of K_2CO_3 was the most effective to produce the heavy oil. These low conversion ratios may not be suitable to produce the crude oil for the optimum reaction temperature. It might be considered that there were furthermore need to evaluate the optimum temperature for producing the high crude oil production with rapeseed straw.

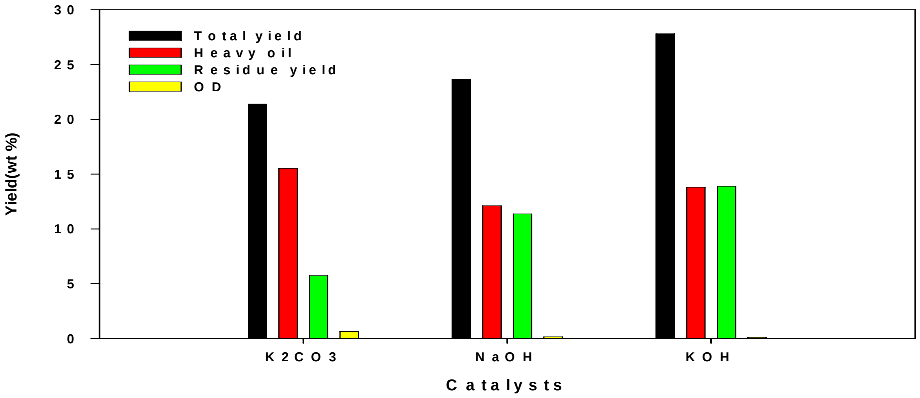

Fig. 6. Effects of liquefaction yields of rapeseed straw with different catalysts

The calorific values of feeding stocks and their crude oils were presented in Table 2. It was appeared that maximum calorific value of heavy oil from wheat straw was about 6,190kcal/kg. However, the high calorific value to be enhanced from plant residue to crude oil was estimated at 66.2% for rapeseed straw with 10% K_2CO_3.

Ucar *et al.* (2008) were reported that calorific values of rapeseed oil cake and bio-oil from pyrolysis of rapeseed oil cake at 500℃ were 1,949 and 3,317 kcal/kg, respectively. It was appeared that the calorific values of raw materials and its bio oil were approximately less 1.8 times than those of crop residues and crude oils.

Table 2. Comparisons of calorific values of feeding stocks and crude oils

Feeding stocks	Calorific values of plant residues (kcal/kg) (A)	Calorific values of crude oils (kcal/kg) (B)	(A/B)*100
Rice straw	3,589	6,120	58.6
Barely straw	3,348	5,817	57.6
Wheat straw	3,426	6,190	55.4
Rapeseed straw	3,867	5,843	66.2

As a result, more than 80% of rice hull was liquefied in co-solvents under the condition of 315-326℃/22.6-24.6MPa. In case of co-solvent with ethanol and bulk-glycerol, more than 80% of rice hull was decomposed and liquefied in its solvent at 315-326℃ for 30 min. as shown in Fig. 7 and Table 3.

Table 3. Reaction conditions and conversion rate on liquefaction with rice hull.

Co-Solvent	Temperature of reactor(℃)	Pressure(kPa)	Conversion rate (%)
Ethanol : Bulk-glycerol (6 : 4)	315 ~ 323	22.7 ~ 24.6	81.01
Ethanol : Glycerol (6 : 4)	320 ~ 326	22.2 ~ 23.7	73.36

*Conversion rate = [1-(residue weight/weight of raw material)]*100

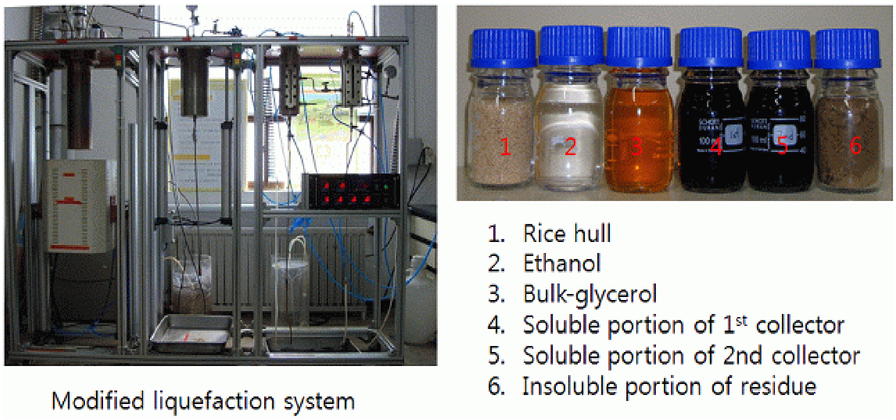

Fig. 7. A photograph of modified liquefaction system and various co-solvent soluble portions.

As compared to the molecular weight of co-solvent, high molecular weight could be obtained in the soluble portions after treatment (Fig. 8). Furthermore, these compounds need to be elucidated.

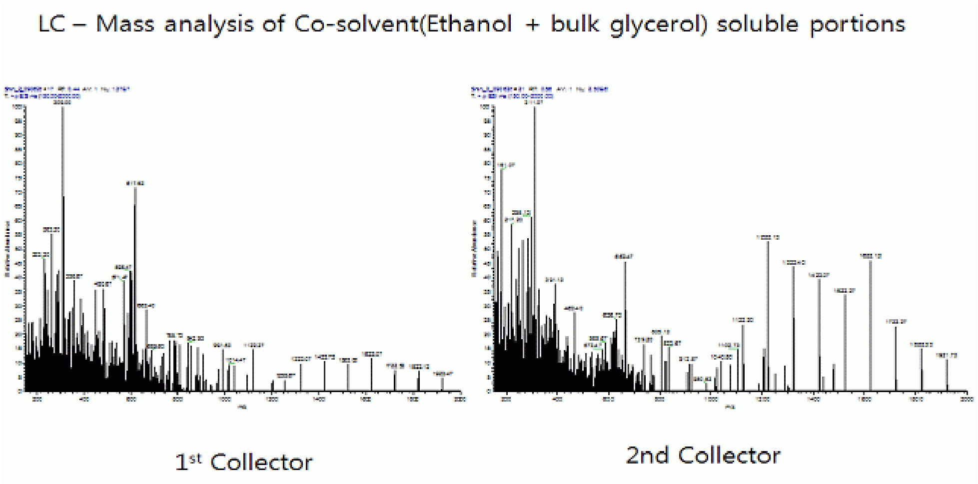

Fig. 8. LC-Mass analysis of co-solvent(ethanol + bulk-glycerol) soluble portions under liquefaction system.

Summary

Objective of this study were to estimate the caloric values of different feeding stocks and their crude oils and to evaluate the yield of liquefaction production with different crop residues and catalysts. Yield of rice straw was most abundant as 1.9 million tones, and then its garlic was 146 thousand tones per year. Total yield of main crop residues in Korea was 2.2million tones per year. For the liquefaction products with different feeding stocks, the yields of crude oil with rice, barely, wheat and rapeseed straws were 24.3, 25.4, 24.3 and 15.5% to amount of biomasses fed, respectively. For the effects of catalysts to conversion ratio of rapeseed straw, it was observed that the maximum yield was 15.5% with 10% K_2CO_3, but was 12.1 and 13.8% of 10% NaOH and 10% KOH to the amount of biomass fed, respectively. It was appeared that maximum calorific value of heavy oil from wheat straw was about 6,190kcal/kg. However, the high calorific value to be enhanced from plant residue to crude oil was estimated at 66.2% for rapeseed straw with 10% K_2CO_3.

In case of co-solvent with ethanol and bulk-glycerol, it observed that more than 80% of rice hull was decomposed and liquefied in its solvent at 315-326℃ for 30 min.

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4

Outlook of Palm Biodiesel in Malaysia

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Common Raw Materials for Biodiesel Production and Their Oil Yield

1. Palm Oil (Malaysia) 3.93* (tonne / ha / yr)
2. Rapeseed (EU) 1.33** (tonne / ha / yr)
3. Soyabean (USA) 0.46** (tonne / ha / yr)
4. Sunflower (Argentina) 0.66** (tonne / ha / yr)
5. Jatropha 1.44*** (tonne / ha / yr)
6. Coconut (Philippines) 0.66**** (tonne / ha / yr)

Source: *** Steffan Preusser (2006) **** Oil World (2006)

Availability of Palm Oil as Feedstock for Biodiesel, Malaysia (2007)

- Malaysia and Indonesia: World's largest producers of palm oil
- Malaysia: World's largest exporter of palm oil
- Production 15.8 million tonnes
- Exports 13.4 million tonnes
- Export value of oil palm products: RM45 billion

Feedstock Selection Criteria

- Availability
  - Regional production
  - Productivity
- Price
- Characteristics of oil
  - Stability
  - Cold flow properties

Highlights of Malaysia Biodiesel Technology

- Overall yield: 98%
- Products meeting full EN 14214 and ASTM D6751 specifications
- The only plant design optimized for palm oil and palm oil products as feedstocks
- Simple and proven technology. more than 20 years of experience
- Low pressure & temperature process
- Use cheaper catalyst, NaOH

Estimated Cost for the Production of Palm Biodiesel

1. Oil ~ 70%
2. Chemicals ~ 10%

3. Depreciation ~ 7%
4. Labour ~ 5%
5. Maintenance ~ 5%
6. Utilities ~ 3%

Total: 100%

Environmental Impact of Palm Biodiesel

- Environment-friendly. great reduction in CO_2, CO, total unburnt hydrocarbon, SO_2, particulates and air toxics
- Biodegradable
- Renewable
- Improved air quality and greenhouse gas mitigation. reduction in health care costs
- In-line with Clean Development Mechanism (CDM) of 1997 Kyoto Protocol.

The Malaysia Biofuel Policy

The National Biofuel Policy envisions:

- Use of environmental friendly, sustainable and viable sources of energy to reduce the dependency on depleting fossil fuels
- Enhanced prosperity and well-being of the stakeholders in the agriculture and commodity based industries through stable and remunerative prices

Thrust 1: Biofuel for Transport

Diesel for land and sea transport will be a blend of 5% processed palm oil and 95% petroleum diesel. This B5 diesel will be made available throughout the country. As this sector is the main user of diesel which is highly subsidized, it will be given priority in this policy.

Thrust 2: Biofuel for Industry

B5 diesel will also be supplied to the industrial sector including for firing boilers in manufacturing, construction machinery and generators.

Thrust 3: Biofuel Technologies

Research, development and commercialization of biofuel technologies (including technologies for extraction of minor components therein) will be effected and adequately funded by both the government and private sectors including venture capitalists to enable increased use of biofuel.

Thrust 4: Biofuel for Export

Worldwide interest reflects the important role of biofuels in energy for sustainable development. Malaysia will have an edge to supply the growing global demand for biofuel. The establishment of plants for producing biofuel for export will be encouraged and facilitated.

Thrust 5: Biofuel for Cleaner Environment

The use of biofuel will reduce the use of fossil fuels, minimize the emission of green house gases (carbon dioxide), carbon monoxide, sulphur dioxide and particulates. Increased use of biofuel will enhance the quality of the environment.

Legal Framework

- Malaysian Biofuel Industry Act 2006 passed by Parliament in 2007
- Contains provision to mandate blending of biofuel with diesel through regulations made by Minister
- Drafting of regulations under way
- No decision yet on implementation. Need to consider type of biofuel, percentage, subsidies required etc.

Updates on the R&D in the area of Biomass utilization. Eg Nanomass Technology

Conclusion

- Biofuels contribute to reduction of greenhouse gases.
- Solid, liquid and gaseous biofuels can be produced from various palm sources.
- Palm biodiesel technologies (normal and winter grades) have been well proven.
- Both normal and winter grades palm biodiesel produced using our technologies meet EN14214 and ASTM D6751 specifications.

Session

V

1. Biobutanol Production Technologies with Agricultural Biomass
2. Biobutanol : Green Energy Production
3. Overview of Legal Framework on Biofuels in Viet Nam
4. Development of Biodiesel in China

1

Biobutanol Production Technologies with Agricultural Biomass

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Abstract

Conventional acetone-butanol-ethanol (ABE) fermentation involves two phases (acidogenesis and solventogenesis), is difficult to control, and suffers from low butanol productivity and yield. A novel approach using two sequential fermentation steps to short-cut the complex ABE fermentation pathway by directing glucose fermentation to butyric acid and then to butanol. By separating the acid (butyric acid) production (using *C. tyrobutyricum*) from solvent (butanol) formation (using *C. acetobutylicum*), more glucose carbon can be used for butanol production, and a higher butanol yield of up to 40% (w/w) can be expected, which is 100% higher than that from conventional ABE fermentations. The new process also allows both bacteria to work under their respective optimal pH and temperature conditions, and thus can increase reactor productivity. In this work, a stable continuous fermentation for butanol production from glucose was developed by co-feeding the bioreactor withbutyrate, the precursor for butanol formation, so that the fermentation would shift to and stay in the solventogenesis phase, thus producing more butanol from glucose and reducing the byproducts (e.g., ethanol and acetone). The enhanced butyrate uptake rate and sustained culture stability with high butanol productivity and yield by using a novel fibrous bed bioreactor and butyrate as a co-substrate with glucose should provide an economic and energy-efficient process for butanol production from corn.

Keywords: Fermentation; butanol; butyric acid; *Clostridium acetobutylicum* fibrous bed bioreactor

Introduction

The U.S. Department of Energyhas estimated that over one billion dry tons of cellulosic biomass, including agricultural crop residues (0.446), dedicated energy crops and trees (0.377), and logging and wood processing residues (0.368), are available for bioenergy production. There are also abundant low-value agricultural commodities and food processing byproducts or wastes that require proper disposal to avoid pollution problems. For example, the U.S. corn refinery industry annually processed more than 35% of the ~12 billion bushels (~300 million metric tons) of corn to produce high-fructose-corn-syrup, dextrose, starch, and fuel alcohol, generating ~22 million metric tons of corn fibers and steep liquor that are readily available as low-cost feedstocks for fermentation to produce biofuels and chemicals such as butanol.

Currently, bioethanol is the major biofuel on the market. However, since DuPont and BP's announcement in 2006, biobutanol has attracted a lot of attention on its potential as a transportation fuel mainly because butanol has many characteristics (see Table 1) that make it a better fuel than ethanol, now produced mainly from corn and sugarcane. As a biofuel, butanol has the following advantages over ethanol: (a) butanol has 30% more energy per gallon; (b) butanol is less evaporative/explosive with a Reid vapor pressure (RVP) 7.5 times lower than ethanol; (c) butanol is safer than ethanolbecause of its higher flash point and lower vapor pressure; (d) butanol is more miscible with gasoline and diesel fuel but less miscible with water. Most importantly, unlike ethanol, butanol is noncorrosive and offers a safer fuel that can be dispersed through existing pipelines and filling stations. Currently, butanol is almost exclusively produced via petrochemical routes and used mainly in chemical and solvent markets at a price of more than ~$5 per gallon and with a worldwide market of ~1.4 billion gallons per year. At the current market price, butanol is more likely to have significant use in the industrial solvent market rather than the biofuel market in the near future. However, this may change when new bioprocessing technologies and engineered microbes are developed for commercial production of biobutanol in the near future.

Table 1. Characteristics and properties of some biofuels and gasoline and diesel.

Name	Energy Content		Water solubility	Vapor pressure (mmHg)	Octane rating	Flash Point (℃)
	(KJ/g)	(MJ/L)				
Ethanol	23.4-26.8	18.4-21.2	100%	46 (20℃)	116	14
Butanol	36	29.2	8%	4.8 (20℃)	87	35
Gasoline	48	32-34.8	nil	-	87-93	<-40

This article provides an overview on biobutanol production technologies, including those used in the past and currently being developed.

ABE Fermentation

Acetone-butanol-ethanol (ABE) fermentation with the strict anaerobic bacterium *Clostridium acetobutylicum* was once (1917-1955) one of the largest fermentation processes ever developed in industry. It produced acetone, n-butanol, and ethanol with CO_2 and H_2 as two gas byproducts (Table 2). However, since the 1950's industrial ABE fermentation has declined continuously. The last such fermentation plant in America and Europe was closed in the 1980’s. However, the ABE fermentation process declined in 1950s and virtually ceased in the United States and Britain by 1960s due to the growth of the petrochemical industry and increased feedstock costs for the fermentation process.

Table 2. End products of the industrial ABE process and the combustion energy of the products.

Product	Weight (kg/ton)[a]	Combustion energy (kJ/g)	Net calorific value (MJ/t)[a]
n-Butanol	207±10	33.1	6,852
Acetone	100±8	28.5	2,850
Ethanol	56±15	26.7	1,495
CO_2	≈600	-	-
H_2	≈19	119.8	2,276
Total	ABE: 360		Energy: 13,273

[a] per ton of starch equivalent

In a typical ABE fermentation, butyric and acetic acids are produced first by *C. acetobutylicum* the culture then undergoes a metabolic shift and solvents (butanol, acetone, and ethanol) are formed (see Figure 1). Increasing the butyric acid concentration to >2 g/L and decreasing the pH to <5 usually are required for the induction of a metabolic shift from acidogenesis to solventogenesis. However, the actual fermentation is quite complicated and difficult to control.

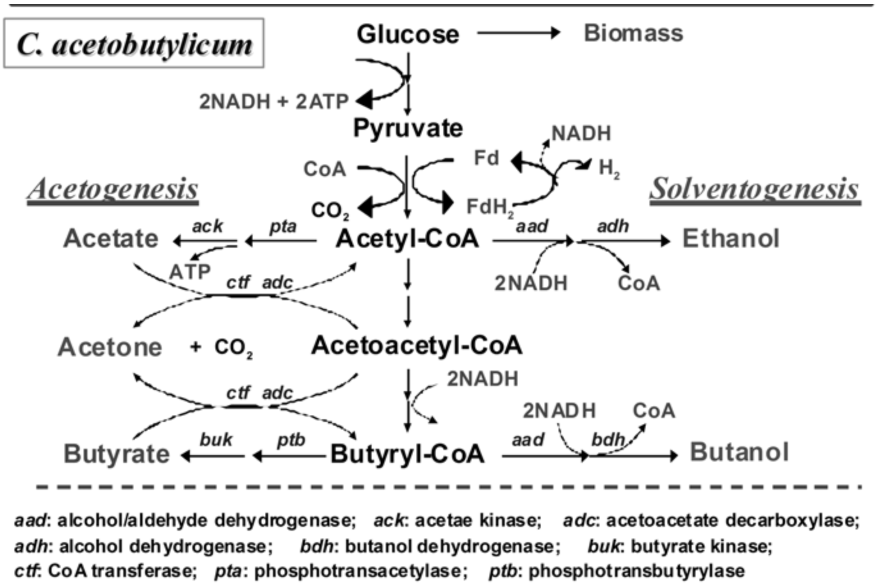

Figure 1. Acetone-butanol-ethanol (ABE) fermentation pathway in *Clostridia acetobutylicum*.

In conventional ABE fermentations, the butanol yield from glucose is low, typically at ~20% (w/w) and it rarely exceeds 25%. The production of butanol is also limited by severe product inhibition, resulting in a low reactor productivity of usually less than 0.5 g/L•h and a low final butanol concentration of less than 15 g/L. The decline in the importance of the industrial ABE fermentation after World War II resulted in a corresponding decline in research relating to the fermentation. However, after the oil crisis of 1973-1974, there was a renewal of interest in fermentation processes as a possible alternative for the production of liquid fuels and chemicals. Since then, many researches on the physiology, biochemistry, molecular biology, and taxonomy of solvent-producing *Clostridium* species have beenconducted. One important milestone among which was the accomplishment of the genome sequencing of the *C. acetobutylicum* ATCC 824 in 2001 (Nolling et al., 2001). At the same time, many application research papers and patents were published, relating to the feedstock pretreatment and utilization, strain improvement and new strain isolation, fermentation development and optimization, and downstream process development and optimization. Despite all these efforts, there has been little progress towards making ABE fermentation more economically competitive.Tables 3 and 4 summarize some of the recent ABE fermentation studies using non-lignocellulosic (mainly starch and sugar) and lignocellulosic feedstocks, respectively.

Table 3. ABE fermentation with non-cellulosic feedstocks.

Feedstock	Fermentation conditions	Best results	Reference
De-germed corn	*C. beijerinckii* BA101, with corn steep liquor, 35 °C, 84 h	n-butanol 14.4 g/L, ABE 19.3 g/L, productivity 0.23 g/L/h	Campos et al, 2002
Cassava	*C. acetobutylicum* EA2018, with ammonium acetate, 37 °C, 48 h	n-butanol 13 g/L, ABE 19.4 g/L	Gu et al, 2009
Maltodextrin	*C. beijerinckii* BA101, with corn steep water, 34 °C, 96 h	n-butanol 14.5 g/L, ABE 19.3 g/L	Parekh and Blaschek, 1999
Packing peanuts	*C. beijerinckii* BA101, 35°C, 110 h	ABE 18.9 g/L, yield 0.32 g/g, productivity 0.17 g/L/h	Ezeji et al, 2003
Soy molasses with glucose	*C. beijerinckii* BA101, 35 °C	ABE 30.1 g/L	Qureshi et al, 2001
CO in waste gas	*C. carboxidivorans* P7	n-butanol yield: 0.03 mol/mol CO	Lewis et al, 2007

Table 4. ABE fermentation with lignocellulosic biomass

Feedstock	Process conditions	ABE production	Reference
Corn fiber	pretreated with sulfuric acid, inhibitor removal with XAD-4 resin, batch fermentation with *C. beijerinckii* BA101	ABE 9.3 g/L, yield 0.39 g/g	Qureshi et al, 2008
Corn fiber, arabinoxylan and xylose	batch fermentation integrated with enzyme hydrolysis and gas stripping, with *C. acetobutylicum* P260	ABE 24.7 g/L, yield 0.44 g/g, 0.47 g/L/h	Qureshi et al, 2006
corn stover	SO_2-prehydrolysed, enzyme hydrolysis, extractive batch fermentation with *C. acetobutylicum* P262	ABE 25.8 g/L, yield 0.34 g/g, 1.08 g/L/h	Parekh et al, 1988
wheat straw	pretreated with alkaline peroxide, enzyme hydrolysis with salt removal, batch fermentation with *C. acetobutylicum* P260	ABE 22.2 g/L, 0.55 g/L/h	Qureshi et al, 2008
wheat straw	pretreated with dilute sulfuric acid simultaneous enzyme hydrolysis and fermentation integrated with gas stripping, with *C. acetobutylicum* P260	ABE 21.4 g/L, yield 0.41 g/g, 0.31 g/L/h	Qureshi et al, 2008
wheat straw plus glucose	pretreated with dilute sulfuric acid, enzyme hydrolysis, batch fermentation with *C. acetobutylicum* P260	ABE 28.2 g/L, yield 0.42 g/g, 0.63 g/L/h	Qureshi et al, 2007
distillers dried grains and solubles	pretreated with liquid hot water, enzyme hydrolysis, batch fermentation with *C. butylicum* 592	ABE 12.9 g/L, yield 0.32 g/g,	Ezeji et al, 2008
pine wood	SO_2-prehydrolysed,enzyme hydrolysis, extractive fermentation with *C. acetobutylicum* P262	ABE 17.6 g/L, yield 0.36 g/g, 0.73 g/L/h	Parekh et al, 1988

The low reactor productivity, butanol yield, and final butanol concentration, which make butanol production from biomass by ABE fermentation uneconomical for the fuel market, are mainly caused by the strong inhibition effect of butanol. Therefore, process engineering with integrated fermentation and in situ product recovery to alleviate inhibition caused by butanol and facilitate product recovery has been also extensively researched. Table 5 shows some examples of ABE fermentation with in situ product recovery. Although there have been some improvements in productivity and product titer in terms of total liquid medium used in the process, the butanol and total solvent yields are still low.

Table 5. In situ solvent recovery in ABE fermentation.

Recovery processes	Fermentation conditions	ABE production			Reference
		Titer (g/L)	Yield (g/g)	Productivity (g/L/h)	
Gas stripping	*C. beijerinckii* BA101				
	P2 glucose medium, batch	75.9	0.47	0.61	Ezeji et al, 2003
	fed-batch	233	0.47	1.16	Ezeji et al, 2004
	continuous	460	0.4	0.91	Ezeji et al, 2004
	liquefied corn starch, fed-batch	56.2	0.41	0.4	Ezeji et al, 2007
Pervaporation with silicon membrane	batch	51.5	0.42	0.69	Qureshi and Blaschek, 1999
	fed-batch	165		0.98	Qureshi and Blaschek, 2000
	continuous immobilized biofilm reactor			16.2	Lienhardt et al, 2002
	C. acetobutylicum ATCC 824				
with supported ionic liquid membrane	glucose, continuous			2.34	Izak et al, 2008
Adsorption	glucose, batch	n-butanol 22.2 g/L			Nielsen and Prather, 2009
	C. acetobutylicum ATCC 4259				
Extraction	glucose and butyric acid medium, batch	n-butanol 16.3 g/L			Evans and Wang, 1988

There have also been numerous attempts to improve butanol production in ABE fermentation via metabolic engineering of *C. acetobutylicum.* Numerous genes in the Clostridia fermentation pathway have been cloned and manipulated using modern genetic engineering techniques (see Table 6). However, the success was limited, largely due to the difficulty in cloning Clostridia and the complex metabolic pathway and gene regulation control on the physiology and sporulation. The low butanol titer in the fermentation even with engineered Clostridia strains remains a major bottleneck in the ABE fermentation. More recently, research efforts have focused on the development of novel non-clostridia hosts for butanol production, including *E. coli* (Atsumi et al, 2008 Bramucci, 2008 Gunawardena, 2008 Lee et al, 2008 Nielsen et al, 2009

Papoutsakis et al, 2008 Shen et al, 2008), *P. pudida* (Nielsen et al, 2009), *S. cerevisiae* (Raamsdonk, 2008 Steen et al, 2008), and *B. subtilis* (Nielsen et al, 2009).Although these efforts have demonstrated the concept of producing butanol in a non-native host organism, but the butanol titer produced in these novel engineered strains is much lower than that from the native Clostridia strains.

Table 6. Metabolic engineering of *C. acetobutylicum* ATCC 824.

Strain with genetic changes	Effects on ABE production	Reference
(pFNK6) with adc(↑), ctfAB(↑)	Increased n-butanol (13 g/L) and ABE (23.1 g/L) production	Mermelstein et al, 1993
PJC4BK with buk(↓)	Increased n-butanol (16.7 g/L) and ABE (23.7 g/L) production	Harris et al, 2000
solR::pO1X with solR(↓)	Deregulated, prolonged and increased n-butanol (17.8 g/L) and ABE (26.9 g/L) production	Nair et al, 1999
SolRH(pTAAD) with solR(↓), adhE(↑)	Increased n-butanol (17.6 g/L)and ABE (27.9 g/L)production	Harris et al, 2001
(pGROE1) with groESL(↑)	Increased n-butanol tolerance and production (17 g/L)	Tomas et al, 2003
EA2018 (adc) with adc(↓)	Increased n-butanol ratio by 82%) and yield by 70.8%	Jiang et al, 2009
with buk(↓), ctfAB(↓ ldh(↓), pta(↓) ack(↓), hydA(↓)	to increase n-butanol yield to 0.4 g/g glucose with no or little byproducts	Soucaille, 2008
(pAADB1) with adhE(↑) ctfB(↓)	Decreased acetone (1.4 g/L), increased ethanol (8.8 g/L), n-butanol unchanged (10 g/L)	Tummala et al, 2003
(pASspo) with SpoIIE(↓)	No spore formed in solventogenic phase	Bennett and Scotcher, 2008

Two-Step Fermentation Process for Butanol Production

Recently, a two-step fermentation process has been proposed as an alternative to the complex ABE fermentation pathway. In the two-step process (Figure 2), butyric acid production by *C. tyrobutyricum* is separated from solvent (butanol) formation by *C. acetobutylicum* i.e., acid and solvent production is conducted in two discrete fermentation steps (US Patent 5,753,474). This directs more glucose carbon to butanol production. The two-step process also allows both of the bacteria involved to work at their respective pH optima, increasing overall reactor productivity. The feasibility of this two-step fermentation process has been demonstrated with *C.*

acetobutylicum immobilized in a fibrous bed bioreactor (FBB; U.S. Patent 5,563,069) co-fed with glucose and butyrate. The bacterium produced butanol at an overall yield of 0.3 to 0.4 g/g glucose and productivity of ~5.6 g/L•h (Huang et al. 2004). Because butyrate does not serve as a good energy source for *C. acetobutylicum*, a small amount of glucose must be provided along with butyrate to provide the energy source needed by the bacteria. However, immobilizing cells in the bioreactor and maintaining cells in the stationary (solventogenesis) phase with butyrate feeding minimizes energy consumption by the cells and maximizes butanol yield. The result was a doubling of butanol yields, making butanol fermentation an economically viable process.

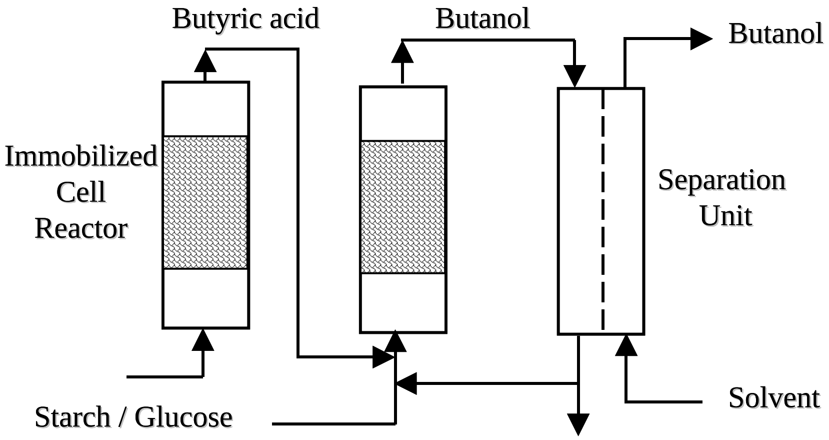

Figure 2. A two-step fermentation process to convert glucose to butyrate and then to butanol.

Figure 2 illustrates the two-step fermentation process for butanol production from glucose. A small amount of glucose is also provided along with butyrate to the second fermentation to provide the needed energy source for the bacteria; butyrate does not serve as a good energy source for the bacteria. Using immobilized cells and maintaining the cells in the stationary (solventogenesis) phase should minimize the energy consumption by the cells. Our objective was to develop a continuous fermentation process for stable butanol production from glucose and butyrate using cells immobilized in afibrous bed bioreactor (FBB), which has been successfully used to enhancereactor productivity, product yield, and final product concentration in several organic acid fermentations. In the FBB, cells are immobilized in a convoluted fibrous matrix packed in a column. The fibrous bed allows for good multiphase flows and provides renewable surfaces for cell immobilizationand a conducive environment for cell adaptation, resulting in high viable cell density and reactor productivity. The self-regeneration ability of the FBB also allows it to operate continuously for years without significant loss in its productivity. In this work, the production of butyrate from glucose by a metabolically engineered mutant of *C. tyrobutyricum* was studied. Then, the feasibility and potential advantages of the FBB for continuous production of butanol from glucose and butyrate were investigated. The effects of pH, feed concentration of butyric acid, and dilution rate on butyrate uptake, butanol production, and reactor stability were also studied and the results are briefly summarized below.

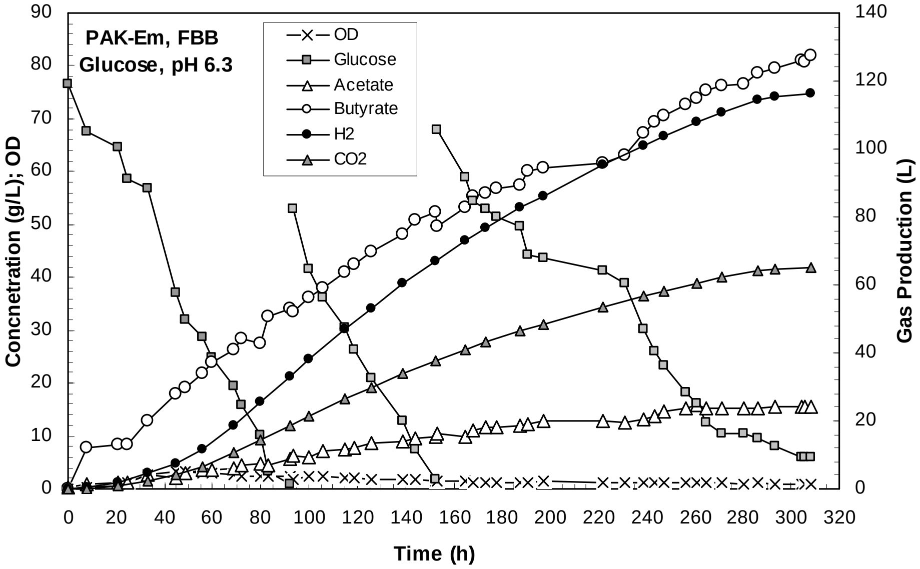

Figure 3. Kinetics of fed-batch fermentation by immobilized cells of *C. tyrobutyricum* in the FBB at 37℃ and pH 6.3 with glucose as the substrate. OD_{600} (×), glucose (▪), butyrate (○), acetate (△), hydrogen (●), and carbon dioxide (▲).

Clostridium tyrobutyricum is an acidogenic bacterium, producing butyrate and acetate as its main fermentation products. In order to decrease acetate and increase butyrate production, integrational mutagenesis was used to disrupt gene associated with the acetate formation pathway in *C. tyrobutyricum*. A non-replicative integrational plasmid containing acetate kinase gene (*ack*) fragment cloned from *C. tyrobutyricum* by using degenerate primers and an erythromycin resistance cassette was constructed and introduced into *C. tyrobutyricum* by electroporation. Integration of the plasmid into the homologous region on the chromosome inactivated the target *pta* gene and produced the *ack*-deleted mutant (PAK-Em). This mutant was used in fermentations to produce butyric acid and hydrogen from glucose, xylose, and sugars (glucose and fructose) present in the waste grape juice from wine manufacturing.

Free-cell fermentations at pH 6.0 and 37 ^{o}C produced ~40 g/L of butyric acid with high yields of butyric acid (0.42 g/g) and hydrogen (~0.024 g/g) from sugars. To further improve the fermentation, a fibrous-bed bioreactor (FBB) was used to immobilize and adapt PAK-Em cells, which increased the butyric acid production to 50 g/L at pH 6.0 and 80 g/L at pH 6.3 (see Figure 3), which is the highest concentration ever produced in the fermentation. The butyric acid yield from glucose also increased to 0.45 g/g mainly because of the reduced cell growth in the immobilized-cell fermentation. Compared to the wild type, PAK-EM produced much more butyric acid (0.42 g/g vs. 0.34 g/g) under the same fermentation conditions (pH 6.0, 37 ^{o}C, glucose).

Continuous fermentation of glucose and butyrate by *C. acetobutylicum* in a fibrous bed bioreactor was carried out at 35 ^{o}C, pH between 3.5 and 5.5, and dilution rate between 0.1 and 1.2 h^{-1} to study the effects of butyric acid concentration, pH, and dilution rate on butyrate uptake rate and butanol production. In general, increasing the butyrate concentration (up to 7.4 g/L) also increased butyrate uptake rate (to 2.4 g/L•h) and butanol production. High butanol productivity of ~5.6 g/L•h and yield of ~0.30 g/g glucose (~0.43 g/g for total solvents) were obtained at pH 4.3 and 0.6 h^{-1} (see Figure 4). The fermentation was stable and did not show any significant degeneration for the entire period of two months studied.

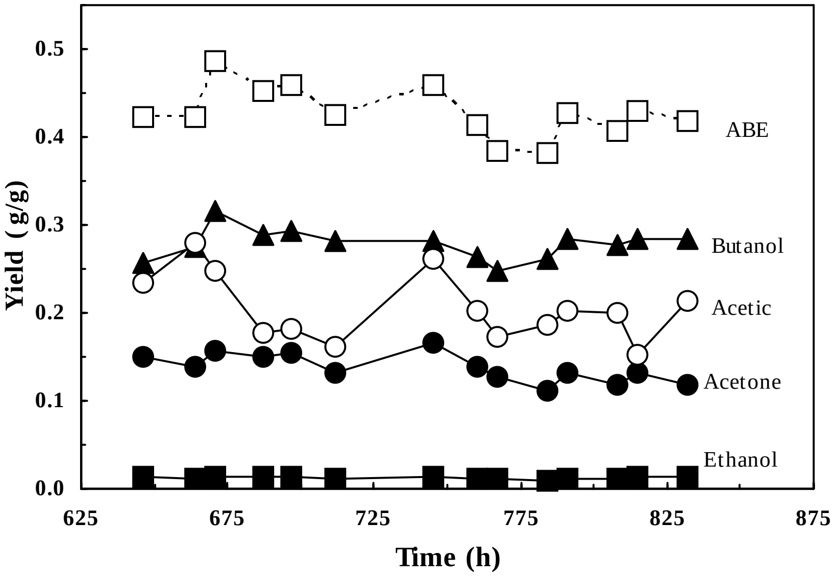

Figure 4. Long-term continuous ABE production from glucose and butyrate in a fibrous bed bioreactor with immobilized cells of C. acetobutyricum.

This work has shown that doubling the yield of butanol in the conventional ABE fermentation can be achieved by converting carbohydrates into butyrate and then butanol, which can make fermentation derived butanol economically competitive with petrochemically derived butanol. Compared to the conventional ABE fermentation with butanol yield of 0.20 g/g and productivity of 0.5 g/Lh, the FBB notably enhanced the yield of butanolby more than 50%, making butanol production from renewable resource an attractive alternative to ethanol fermentation.

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2

Biobutanol : Green Energy Production

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Abstract

It has been known that butanol has several advantages over ethanol: higher energy density, less hygroscopic, etc. Due to these properties, butanol is considered as a suitable biofuel alternative for the real application. Like other biofules, source of biomass is very challenging to produce biobutanol. Ceylon Moss, red algae is a marine biomass and contains low lignin content. Ceylon Moss Saccharified Liquid (CMSL) was used to produce butanol by solventogenic clostridia such as *Clostridium acetobutyricum, Cl. beijerlinkii, Cl. tetanomorphum* and *Cl. aurantobutyricum.* All tested clostridia were successfully cultivated on the Reinforced Clostridia Medium which was modified by substitution of CMSL (50%) instead of glucose and starch. Galactose (20 g/L) as a main carbohydrate component in CMSL was used as carbon and energy source. *n*-butanol was produced 3-9 mM with small amount of ethanol (0.7-3 mM) and acetone (0.3-5 mM) when batch culture was conducted in 72 hrs. Our results implied that CMSL can be reasonable candidate of raw biomass for butanol production.

1. Introduction

In recent decades, a big interest is arisen in biobutanol production because of its potential as alternative fuel. Butanol is 4 carbons alcohol (C_4H_9OH) and has peculiar odor and volatility. Butanol has several advantages better than ethanol in terms of chemical property: higher energy density, low evaporation rate, and more hydrophobicity. Increased carbon numbers in organic solvents are making more hydrophobic indicating that solvent can be easy to use it as a fuel. Due to these properties, butanol can be directly mixed with gasoline and used for transportation fuel. Therefore, butanol is considered as a suitable biofuel for the real application without any modification of infrastructures that already installed (Shapovalov and Ashkinazi 2008).

Spore-forming anaerobic Gram-positive bacteria except for sulfate reducing bacteria are classified as the *Clostridium* genus (Papoutsakis 2008; Lee et al. 2008). They are divided into two groups, saccharolytic and proteolytic clostridia according to their preferred carbon and electron sources. Saccharolytic clostridia ferment carbohydrate to mainly acetate and butyrate and this clostridial fermentation is a typical branched fermentative pathway indicating a couple of metabolic products are produced by different pathways (Papoutsakis 2008). Most butyrate producing saccharolytic clostridia form a small amount of butanol, and a couple of strains such as *Clostridium acetobutyricum*, *Cl. beijerlinkii, Cl. tetanomorphum, Cl. saccharobutylicum* and *Cl. aurantobutyricum* produce butanol in high concentration with other solvents, ethanol and acetone. At the beginning of fermentation at neutral pH, these strains produce acetate and butyrate (acidogenic phase), disposing of the excess electrons to reduce proton to hydrogen. The cultures start to produce solvents (solventogenic phase) when the acidic fermentation products (i.e., acetate and butyrate) accumulate with lowering cultural pH. These two different cultural phases called biphasic culture are typical characteristics of solvetogenic clostridia. During solventogenic phase, carbohydrates are fermented directly to solvents, and the acidic products are also converted to solvents (Zheng et al. 2009; Ezeji et al. 2004). Even there are several hypotheses how and when solvents production is stimulated, it is clear that more electrons are required to produce butanol and acetone than the acidic products. In fermentation, electrons generated during catabolic metabolism should be disposed of metabolic intermediates as electron acceptors. *Cl. aceotobutyricum,* a model strain of solventogenic clostridium produced 14 g/L of butanol when it utilized 60 g/L of glucose (Ezeji et al. 2008). This butanol production ratio was shown that butanol was major fermentation product.

Like other biofuel productions, it is also very crucial the biomass source and pretreatment techniques in biobutanol production using clostridia. It is because of carbohydrate based carbon and electron source there is not any more difference of pretreatment concept that low lignin containing biomass must be utilized during fermentation. Ceylon Moss is a marine biomass which is easily obtainable near coasts of several areas including Korea, Japan, India and other oceanic countries. There is a low lignin content in Ceylon Moss; therefore, saccharification step was relatively easier than other lignin containing biomass. In this study, CMSL can be tested as a candidate of raw biomass for butanol production using solventogenic clostridia.

2. Materials and Methods

2.1 Stock culture and inoculum preparation

Four clostridia species (*Cl. acetobutylicum* ATCC824, *Cl.beijerinkii* NCIMB8052, *Cl. tetanomorphum* ATCC49273 and *Cl.aurantibutyricum* NCIMB10659) were obtained from culture collections. The cultures were incubated in the serum vial containing anaerobically prepared TPGY medium (Trypticose peptone, 50 g/L; Bacto peptone, 5 g/L; Yeast extract, 20 g/L; D-glucose, 4 g/L; Cystein·HCl, 1 g/L) at 37℃ for 28 hours. TPGY grown cells were harvested and suspended in sterilized distilled water. This suspension was dispensed into anaerobically prepared tube containing nitrogen gas and stored in refrigerator. The cell suspension was heat shocked at 80℃ for 10 min before being used for inoculums source for the culture tests.

2.2 Growth of closridia on modified RCM with Ceylon Moss Saccharified Liquid

Reinforced Clostridium Medium (RCM) was modified composition to eliminate glucose and soluble starch. Instead of glucose and starch, modified RCM was included with Ceylon Moss saccharified Liquid (CMSL) and hydrolyzate of agar. Modified RCM composition is following: Tryptose, 10 g/L; Beef extract, 10 g/L; Yeast extract, 3 g/L; Sodium acetate, 3 g/L; Cysteine·HCl, 0.5 mg/L; NaCl, 5 g/L. CMSL and hydrolyzate of agar were saccharified by acid saccharification method (S/L 10%, H_2SO_4 1%, 121℃ for 59 min) from Korea Institute of Industrial Technology (KITECH). CMSL contains galactose (18 g/L) and of glucose (2 g/L).

Hydrolyzate of agar has around 20 g/L of galactose. An aliquot (1.5 ml) of clostridia in TPGY medium was inoculated into 100 ml of modified RCM with 50% (v/v) CMSL and 50% (v/v) hydrolyzate of agar. It was cultivated at 37℃ for 3 days (72 h) and under anaerobic condition. Cultures were measured cellular protein concentration and pH every 24 hours.

2.3 Analyses

Cellular protein was estimated by BCA^{TM} Protein Assay Kit (Pierce, USA) after cell disruption with NaOH (3 N) treatment (boilng for 5 min). A fresh standard curve was prepared before each experiment, and sample data were compared to the standard curve. Concentration of galactose and glucose were quantified with a High Performance Liquid Chromatography (HPLC) using Refractive Index (RI) (Waters 410) detector. Sulfuric acid (5 mM H_2SO_4) was used as mobile phase at a flow rate of 0.6 mL/min. Volatile fatty acids and solvent were quantified with a gas chromatograph (ACME 6000, Younglin, Korea) equipped with a packed glass column of Super Q (80/100, Alltech, IL, USA) using flame ionization detector. Nitrogen was used as a carrier gas at a flow rate of 35mL/min. The temperatures of injector and detector were 220℃ and 250℃, respectively. The oven temperature was initially 170℃ for 9 min. It was increased to 195℃ at the rate of 50℃/min and further increased up to 220℃ at the rate of 30℃/min and maintained for 15 min.

3. Results and discussion

Four clostridial stains were tested their fermentation characteristics in modified RCM with CMSL and hydrolyzate of agar to see their biomass utilization. In order to determine microbial growth under given medium conditions, galactose consumption was used as bacterial growth indicator because HPLC data showed that the main carbohydrate of CMSL and hydrolyzate of agar were galactose (c.a., 20 g/L). Fig.1 shows that two clostridial strains, *Cl. acetobutylicum* and *Cl. aurantibutyricum* consumed galactose in CMSL and agar hydrolyzate, whilst *Cl. beijerinckii* consumed galactose in CMSL only. *Cl.tetanomorphum* could not use galactose in both CMSL and agar hydrolyzate.

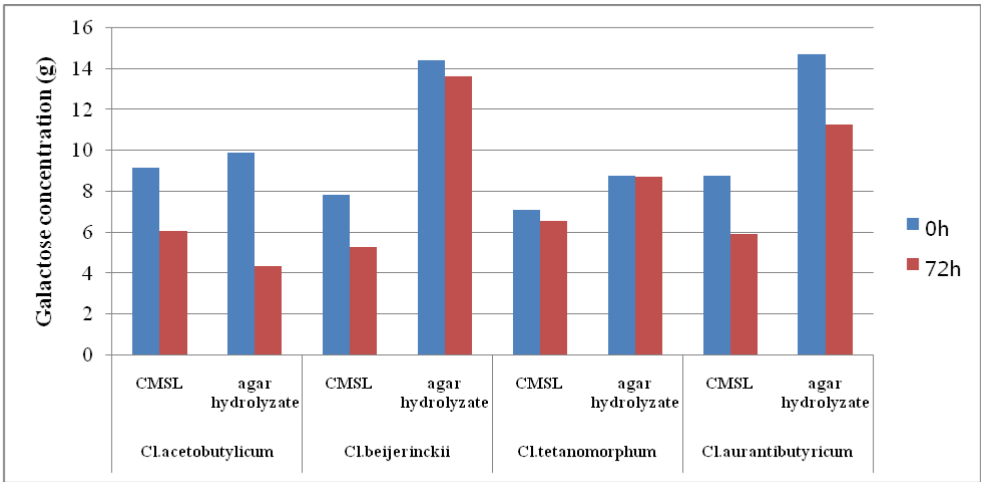

Fig.1. Galactose consumption of Clostridium fermentation in modified RCM with CMSL and agar hydrolyzate.

During fermentation, pH changes were also monitored to determine acidic products formation as well as bacterial growth. Table 1 showed that pH changes of two cultures, *Cl. acetobutylicum* and *Cl. aurantibutyricum* was observed. Initial pH (6.6) was decreased to around 5.5 when culture was finished in 72 hours. In case of *Cl. beijerinckii*, CMSL medium only decreased its cultural pH with bacterial growth. These pH change data support bacterial growth determined by galactose consumption.

Fermentation products were determined when cultures was finished in 72 hours. Acidic product (butyrate) as well as solvent products such as butanol, acetone and ethanol was observed in the culture of positive growth. Even acetate was initially added in RCM (3 g/L, equal to 50 mM), acetate concentrations were different in the cultures. Less acetate concentration was observed in the culture of positive growth. This is probably due to the conversion of acetate to acetoacetyl CoA for butyrate production. Butyrate as acidic product formation was clearly observed in the culture of *Cl. acetobutylicum* and *Cl. aurantibutyricum* in both CMSL and agar hydrolyzate in RCM. Among produced solvents, butanol was a main fermentation solvent product (Table 2). Butanol production was highly observed in the culture of *Cl. beijerinckii* in RCM with CMSL (9.8 mM). Two strains, *Cl. acetobutylicum* and *Cl. aurantibutyricum* in both CMSL and agar hydrolyzate also produced significant amount of butanol.

Table 1. pH changes and cellular protein concentrations of clostridia cultures on modified RCM with CMSL and agar hydrolyzate.

Strain	Medium	Initial pH	Final pH	Cellular protein (g/L)
Clostridium acetobutylicum	CMSL	6.56	5.40	0.44
	Hydrolyzate of agar	6.66	5.47	0.15
	w/o hydrolyzate	6.84	6.69	0.05
Cl.beijerinckii	CMSL	6.64	5.50	0.39
	agar hydrolyzate	6.27	6.19	-
	w/o hydrolyzate	6.88	6.81	-
Cl.tetanomorphum	CMSL	6.71	6.61	0.27
	agar hydrolyzate	6.51	6.59	0.21
	w/o hydrolyzate	7.12	6.94	0.12
Cl. aurantibutyricum	CMSL	6.65	5.41	0.34
	agar hydrolyzate	6.56	5.77	0.06
	w/o hydrolyzate	6.84	6.61	-

Table 2. Fermentation products formation of clostridia cultures on modified RCM with CMSL and agar hydrolyzate.

Strain	Substrate	Products (mM) at 72 h				
		Acetic acid*	Butyric acid	Butanol	Acetone	Ethanol
Clostridium acetobutylicum	CMSL	25.9 ± 0.98	22.0 ± 0.31	7.7 ± 0.01	1.1 ± 0.09	2.5 ± 0.05
	agar hydrolyzate	42.3 ± 0.75	31.2 ± 2.88	7.9 ± 0.07	1.9 ± 0.09	1.5 ± 0.08
	w/o	35.4 ± 2.46	8.9 ± 0.91	1.8 ± 0.13	0.2 ± 0.00	0.3 ± 0.08
Cl.beijerinckii	CMSL	44.2 ± 0.05	8.8 ± 0.61	9.8 ± 0.13	5.2 ± 0.03	1.2 ± 0.01
	agar hydrolyzate	38.5 ± 2.07	2.2 ± 0.2	2.7 ± 0.5	0.5 ± 0.03	0.9 ± 0.37
	w/o	34.7 ± 0.11	0.6 ± 0.00	1.1 ± 0.00	0.3 ± 0.01	0.1 ± 0.01
Cl.tetanomorphum	CMSL	33.9 ± 0.92	26.3 ± 0.15**	2.0 ± 0.22	0.5 ± 0.01	1.1 ± 0.02
	agar hydrolyzate	45.2 ± 0.78	14.9 ± 0.26**	2.6 ± 0.08	0.6 ± 0.03	0.8 ± 0.01
	w/o	36.6 ± 0.25	13.6 ± 0.01	1.0 ± 0.12	0.2 ± 0.01	0.7 ± 0.02
Cl.aurantibutyricum	CMSL	33.4 ± 3.16	25.4 ± 3.39	8.0 ± 1.03	1.1 ± 0.19	1.2 ± 0.17
	agar hydrolyzate	36.8 ± 5.23	15.4 ± 2.24	5.2 ± 0.70	1.1 ± 0.11	0.7 ± 0.05
	w/o	33.4 ± 1.72	8.4 ± 0.43	1.4 ± 0.12	0.2 ± 0.00	0.3 ± 0.07

*Acetate was initially contained in the medium with 3 g/L.
**Butyrate like products was detected on GC data.

4. Conclusion

Solventogenic clostridia could be grown on modified RCM with CMSL and agar hydorolyzate as carbon and energy sources. They could ferment galactose in CMSL and agar hydorolyzate and converted it to acidic and solvent products. Two tested strains, *Cl. acetobutylicum* and *Cl. aurantibutyricum* showed more feasibility of biomass utilization than *Cl.tetanomorphum*. The culture, *Cl. beijerinckii* could utilize component in CMSL but not in agar hydrolyzate. It could be due to bacterial growth inhibitor existed in saccharified biomass, especially in agar hydrolyzate. Further study was carried out to seek for optimum condition to operate fermenter in CMSL and agar hydrolyzate using solventogenic clostridia.

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3

Overview of Legal Framework on Biofuels in Viet Nam

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Abstract

With rapid economic growth, increasing of living standard and industrialization in Viet Nam have raised the energy consumption, which from its side leads to pollution and climate change. Like other countries, general policy of Viet Nam is to develop renewable energy to lessen dependence on fossil fuels and reduce green house gases emission. Development of biofuels in Viet Nam, however, is at the beginning stage and the government has just issued some policies and programs. A review of legal framework on biofuels development in Viet Nam has been conducted with some recommendations made for future.

Keywords: biofuels, biodiesel, jastropha, bioethanol

1. Introduction

a) Energy demand in Vietnam

Viet Nam is well endowed with diverse energy resources that consist of coal (in the North), natural oil and gas (in the South), hydropower, and renewable energies (biomass, small hydropower, geo- thermal, biofuel, wind, solar energy, etc). Energy production has been increasing over the years by annual growth of around 10%. National primary energy demand is forecasted to increase by eightfold within 25 years (2000-2025). Vietnam energy consumption per capita is 165 kg TOE/year, among the lowest figure in the world, and is projected to 700 kgTOE-800 kgTOE in 2025 [1].

Total installed capacity of Vietnam power sector is 9,255 MW in which hydropower accounts for 30%, coal thermal power accounts for 11%, gas thermal power is 27%, and others are 32%. In 2008, energy production is 65.89 billion kWh [2].

Although energy resources in Viet Nam are relatively abundant and diverse, Viet Nam is likely to fall into shortage of energy and the country will have to import electricity from China (table 1). The government has planned to develop an atomic energy factory in Ninh Thuan province by 2018 to improve the power capacity.

b) Bio-fuel in Viet Nam

Development of biofuels in Viet Nam is just at the starting point with increasing interest from local and international investors. Viet Nam has various types of crops and materials for production of bio-fuels. Bio-diesel in Viet Nam can be produced from oil-bearing seeds (jatropha, palm oil, cotton seeds) and by-products of fishery processing (cat fish) while materials for production of bio-ethanol are cassava, sugar molasses, corn, and by-products of agriculture processing. An estimated potential for ethanol is presented in table 2.

Until now there has not been any comprehensive research or survey to study the potentials of bio-fuels in Viet Nam. There are, however, quite lots of activities in bio-fuels development mainly on research and piloting while production at big scale is yet to be developed.

Researches on technologies of development of bio-fuels have been conducted by various universities, institutes such as Institute of Material science Ho Chi Minh city under National Academy of Science and Technology, Institute of Industrial Chemistry, Can Tho University, Ho Chi Minh city University of Technology, National Universities in Ha Noi and Hochiminh city, ect.

Table 1: Balance of Primary Energy Demand and Exploitable Capacity [1]

Item	2005	2010	2015	2020	2025
	KTOE	KTOE	KTOE	KTOE	KTOE
Primary energy demand	43,832	63,149	95,058	135,490	172,773
Primary energy sources	61,145	75,276	87,073	101,679	105,167
Coal	18,271	23,957	27,489	34,189	36,120
Crude oil	18,120	20,726	19,688	19,831	18,955
Natural gas	6,205	7,885	11,767	14,712	16,974
Hydropower	3,762	7,169	11,390	13,672	13,481
Small hydropower		404	568	898	1041
Biomass	14,788	15,134	16,170	18,378	18,596
Balance	17,313	12,128	-7,985	-33,810	-67,606
Import	11,605	14,641	22,634	37,328	68,031
Export	-28,917	-26,769	-14,649	-3,517	-426

Table 2: Production of cassava, sugarcane and corn in Vietnam in 2007 [3]

Region	Cassava (tons)	Sugarcane (tons)	Corn (tons)
North East	674,036	510,301	612,600
North West	400,141	526,753	495,300
Red river delta	82,717	128,331	325,000
North central coast	830,708	2,856,049	513,800
Central coast	969,014	2,059,179	165,500
Central highland	2,020,832	1,196,837	989,800
South East	2,671,345	2,825,757	561,300
Mekong river delta	65,303	4,628,380	191,800
Total	7,714,096	14,731,587	3,855,100

Pilot production has been implemented through a number of projects such as Additives and Petroleum Products Joint Stock Company (APP), Vam Co Biochemical Joint Stock Company and Thien An Company succeeded in production of B10. Saigon Petro produced E10 and E5. An Giang seafood import and export Joint Stock Company (Agifish) has studied production technology of biodiesel from catfish fats transferred it to some companies in the Mekong delta area like Agifish Company, Minh Tu Company and some other small manufacturers [4].

At bigger scale, some projects being developed can be listed as follows: (i) Bien Hoa Sugar Company contracted with a Singaporean company to build an ethanol factory with an annual capacity of 50,000 tones; (ii) Petrosetco Vietnam and Itochu (Japan) have invested around $100 million to build a factory with capacity of 100 million liters ethanol per year from cassava in Phuoc Hiep Industrial Zone in HCM City; (iii) A US$85 million plant to produce 99.7% ethanol from cassava with a capacity of 100 million liters of ethanol per year is also being built in northern Phu Tho Province and; (iv) Petro Viet Nam is building a $85 million project to produce 100 million liters of 99.7% ethanol each year in Dung Quat industrial zone in central Quang Ngai Province. These projects are scheduled to start their operation in 2009 and 2010.

On the market, E5 petrol has been distributed in Ha Noi and Hochiminh city since October 2008.

2. Legal framework of biofuels in Viet Nam

Viet Nam still does not have a special policy framework for development of renewable energy. In environmental and energy legislations, the main course of the country's policy is to encourage development of renewable energy and biofuels in line with socio-economic development guidelines such as food security, landuse policies.

a) Law on Environmental Protection 2005 (LEP 2005)

The Law on Environmental protection enhances development and use of clean, renewable energy for green house gases (GHG) reduction. The law identified clean and renewable energy can be derived from wind, solar, geothermal sources, small hydropower, biomass and other renewable sources. According to the Law, organizations and individuals investing in the development and use of clean energy, renewable energy, shall be granted by the state with preferences in tax, funding support and land.

The Government shall formulate and implement clean and renewable energy development strategies in order to achieve: (i) Strengthening national research and application capacity of clean and renewable energy; (ii) Extending international cooperation and mobilization of resources involving in the exploitation and use of clean and renewable energies; (iii) Gradual increase in the ratio of clean and renewable energy to the total national energy production; and implementation of objectives of the national energy security, saving of natural resources and reduction in the GHG's emissions; (iv) Integration of the programme on clean and renewable energy development with the programme on poverty reduction and rural, mountainous, coastal and island development.

b) National Strategy for environmental protection until 2010 and vision toward 2020

(NSEP) (approved by the Prime Minister on December 2nd 2003 according to Decision 256/2003/QĐ-TTg)

Promoting clean technology and cleaner production lines and the use of environmentally friendly and less pollution raw materials and fuels is one of the key points of view of the Strategy. The Strategy has set an objective to increase the rate of clean energy use to 5% of the total annual energy consumption by 2010, which seems not to be achieved. The Strategy has also identified “encourage the consumption of energy in an economical manner and the use of clean energy and less pollution fuel substitutes” as a fundamental task.

c) Law on Electricity, 2004

According to this Law the state policy on electricity development is to promoting exploitation and use of new energy, renewable energy sources to generate electricity. Projects of electricity generation using new energy, renewable energy will get preferences of investment, electricity price and tax according to guideline of Ministry of Finance. Organizations and individuals are encouraged to invest in developing the electricity projects using renewable energy in rural, mountainous and island areas.

d) National Strategy for energy development until 2020 and vision toward 2050

(approved by the Prime Minister on December 27th 2007 according to Decision 1855/QĐ-TTg)

One of the viewpoints of the strategy is to maintain a synchronous and rational development of energy system, which includes electricity, oil and gas, coal, new and renewable energy. A specific objective is “To strive for increase of new and renewable energy sources to 3% of total of primary commercial energy by 2010; 5% by 2020 and 11% by 2050”.

The Strategy’s guidelines for development of renewable energy include: To study and conduct planning, zoning the energy types to have a rational investment and exploitation plans; Use of new and renewable energy to be integrated into energy saving programs and other national goal programs such as rural electrification, forest planting, poverty reduction, safe water, ect.; It is encouraged development of factories which produce, assemble, repair new energy devices such as boiling water device, small hydropower, wind engine, biogas trench; Provide support for investigation, research, pilot production, developing pilot areas which use new and renewable energy; Permit international and national business organizations to cooperate in investment and exploitation of new and renewable energy sources on the basis of mutual benefits.

e) Decision 177/2007/QĐ-TTg approved by the Prime Minister on November 20th 2007 on "Program on biofuels development until 2015 and vision toward 2025"

This is the most important legal document in Viet Nam for development of biofuels.

Overall goal of the Program is "To develop biofuels, a type of new, renewable energy, for replacement of a part of traditional fossil fuels, contributing to energy security and environmental protection".

Specific objectives include:

- To 2010: produce 100,000 tones of E5 and 50,000 tones of B5 each year, account for 0.4% of the country's demand on petrol.
- To 2015: produce 250,000 tones of ethanol and vegetable oils, from which 5 million tones of E5 and B5 will be derived, account for 1% percent of the country's demand on petrol.
- Vision toward to 2025, produce 1.8 million tones ethanol and vegetable oil, from which to derive biofuel to account for 5% of the country's demand on petrol.

Total state budget for implementation of the Program tasks in 9 years (2007-2015) is expected to be about 259.2 billion VND1) (average of 28.8 billion VND each year). The budget will be spent on the main following tasks: (i) R-D research and pilot scale production of biofuels; (ii) Develop the biofuel industry; (iii) Building capacity on development of biofuels including human resources, technical equipment; (iv) International cooperation.

Measures to be taken include: (i) Strengthen application of research results into production, enhance technology transfer, attract investment in biofuels production; (ii) Strengthen and diversify investments resources; (iii) Conduct capacity building; (iv) Complete the legal framework on development of biofuels; (v) Awareness raising.

With regard to tax policies, in period 2007-2015, biofuels projects are granted with special preferences including tax exemption, maximal preferences in land rental in 20 years and lowest importation tax of material, machinery and equipments.

According to the Decision, the Ministry of Industry and Trade (MOIT) is the focal point for implementation of the Program and has to elaborate the preference mechanism, Ministry of

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1) ~ 14.8 million USD (1 USD ~ 17,500 VND. Rate in July 2009)

Agriculture and Rural Development (MARD) to develop planning, zoning for biofuels raw materials, Ministry of Science and Technology (MOST) to promote research and development of technologies, standards.

f) Decision 2696/QĐ-BCT of the MOIT dated 29/5/2009 on approval of list of selected projects which will be implemented in 2010 under "Program on biofuels development until 2015 and vision toward 2025"

This Decision was made by the MOIT Minister and approved the list of 4 projects of research and development (R-D) of biofuels production technologies and 4 projects of pilot production of biofuels.

R-D projects include: (i) Research production technology of ethanol from sugar molasses by cell fixed method in continuous fermentation system; (ii) Research to design factories which produce denatured fuel ethanol E100 from feedstock source of sliced cassava in Vietnam; (iii) Research development of production process and technology of diesohol biofuels by method of mixing technical ethanol 96% with diesel; (iv) Research development of technological process which produce Bio-Hydro fined Diesel (BHD) from vegetable and animal oils and fats by hydrogenation method.

Piloting production Projects are: (i) Complete technological process and pilot production of denatured fuel ethanol E100 by absorption method; (ii) Complete technological process and pilot production of additives for bioethanol E5; (iii) Complete technological process and pilot production of anti-oxidized additive for biodiesel B5 and; (iv) Complete technological process and develop a equipment system model of pilot production of biodiesel B100 from seeds of Jatropha plant.

g) Interministerial Circular 147/2009/TTLT-BTC-BCT issued by Ministry of Finance (MOF) and MOIT on July 21st 2009 on regulation of the state budget management and use for implementation of "Program on biofuels development until 2015 and vision toward 2025"

The Circular regulates the state budget management and the use for implementation of "Program on biofuels development until 2015 and vision toward 2025". The Circular also regulates who will be granted, supported by the State budget as well as financial resources to implement the Program on biofuels development. Requirements for getting financial support to implement technology transfer in industrial scale production of products, goods related to biofuels development is: (i) Technologies should be suitable with objectives of the Program; (ii) Feasibility of projects and; (iii) Projects should not have been yet supported from any other sources of the state budget.

h) Decision 1842/QĐ-BNN-LN of the Minister on Agriculture and Rural Development on approval of project "Research, development and use of product of Jatropha curcas L. plant in Vietnam in period 2008-2015 and vision toward 2025"

This Decision of the MARD Minister has ratified the project "Research, development and use of product of *Jatropha curcas* L. plant in Vietnam in period 2008-2015 and vision toward 2025". It set up objectives, measures to promote jatropha plantation in the country for raw material of biodiesel production.

Until 2010, pilot planting of jatropha in different ecological regions to reach about 30,000 ha. Encourage of business to invest in developing processing lines with small capacity of 3,000-5,000 tones of jatropha oil per year.

In the period 2011-2015 and vision toward to 2025, expanding processing scale of biodiesel and by-products of *Jatropha curcas* L. plant along with feedstock region development, by 2015 total processing capacity to reach 1 million tones of jatropha oil per year, ensuring replacements of about 10-15% importation diesel. The Decision provides some solutions of land, policy, science, technology and agriculture encouragement and market to achieve the objectives.

i) Bio-fuels standards

With regard to the quality management standard, the MOST has promulgated TCVN 7717:2007- Pure biofuels (B100) and TCVN 7716:2007- Denatured fuel Ethanol. At present national technical standards on biofuels are being drafted, consulted with stakeholders and will be ratified in 2009. In general, countries over the world use international quality standards including EN 14214 and ASTM D 6751 for biofuels. In the Program for development of bio-fuels to 2015, vision to 2020, companies are encouraged to accept standards of G7 countries.

3. Discussions and Recommendations

Biofuels are at the beginning stage of development in Viet Nam. There are interests of private and state sectors in the field, however, the market is underdeveloped and the legal and institutional framework seems not to be completed. There are several issues that the country needs to focus on in the time to come.

Firstly, there are still lacks of a comprehensive legal framework for development of renewable energy and bio-fuels. Although the program for development of bio-fuels is in place, but a comprehensive national strategy on renewable energy, which to provide direction, priorities and considerations to which type of renewable energy, still needed. To develop this strategy, a comprehensive survey and investigation on biofuels and renewable energy potentials shall be conducted.

Secondly, there is still not a clear institutional organization on development of renewable energy in general and biofuels specifically. Until now, the focal point for bio-fuel development is MOIT, but under this Ministry, there are 03 departments, namely Department of Energy (DOE), Department of Science and Technology (DOST) and Agency for Technical Safety and Environment (ATSE), in some ways have mandate related to bio-fuels. The program on development of biofuels to 2010, vision to 2020 has been developed by the DOST but the DOE is responsible for renewable energy. There are overlaps of these three agencies and it is necessary to establish a division under the DOE to deal with state management on bio-fuels development and renewable energy as well.

Thirdly, it is necessary to build up bio-fuel standards to allow trading and using bio-fuel in reality. Through recent years, some company has just blended diesel with catfish fat and this bio-diesel later made troubles to the fishing boat engines. The material damage was not as big as the wrong understanding on use of bio-fuels to a certain number of people. The standards are now being developed and should be promulgated soon.

Fourthly, the country seems to give priority to jatropha, with arguments that the tree can be planted in marginal lands, which can not be used for rice and feedstock. It is needed, however, a review on landuse situation in the country with assessment of food security, assessment and cost and benefit analysis of potentials and impacts of all kinds of bio-fuels plants, including jatropha, cassava, corn and sugar cane. Then a comprehensive national master plan of bio-fuel plantation should be carried out, which will provide bases for setting up a national strategy and policy for bio-fuel development.

Fifthly, production and utilization of biofuel have existed in the country but at small scales.

It is necessary to build up of an effective distribution system to introduce biofuel as commercial products. The existing policies provide quite favorable supports in terms of tax, land, credits and it is really needed for beginning stage but in the long term it is more important to create market and demand to make the biofuel programs financially sustainable, in other words to make bio-fuel production a profitable business.

Finally, awareness raising and international cooperation, information exchange, technology transfer are also key issues that need to be promoted.

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4

Development of Biodiesel in China

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Abstract

The presentation analyses the historical development of China’s Biodiesel industry and development in the associated markets in the waste to energy value chain. Presentation breaks down the cost of producing biodiesel in China. Chinese biodiesel industry is unique due to a very different feedstock supply that leads to different direction of technical development. The presentation uses market analysis to present model of future development and work done so far. Key findings are: (1) A vertically integrated restaurant waste to energy on a scale several order larger than existing examples is needed to set precedent (2) Biodiesel application in Marine fuels has significant environmental, social and economic benefits (3) Social and infrastructural developments in a sustainable waste to energy industry is much more needed then technical development.

Keywords: China, biofuel, biodiesel, waste to energy

Introduction

China's energy sector achieved rapid development, driven by rapidly increasing demand over the last 10 years. As energy structure and policy became more market driven, energy saving, energy efficiency and emission reduction obtained remarkable results. This has strengthened technology, policy and regulation developments, as Renewable Energy Law of P.R. China were constantly improved, which provided powerful guarantee for sustainable, rapid and coordinate development of national economy. Meanwhile, some problems in the energy sector are still very serious, and requires specific consideration in the future: energy consumption and demand are increasing, meanwhile energy environment constraints are increasing; structural contradictions are outstanding and the country's sustainable development is facing challenges; the international energy market has experienced intense fluctuation leading to risky investment conditions. China's biomass science and technology level is comparatively backward, although national innovation efforts are shouldering strong responsibilities esp. within the "new socialist countryside" policy where the energy problem is prominent and the need should be solved immediately. Meanwhile urban development is still progressing at breakneck speed and severely testing the environment. Although nothing goes to waste in China, a truly sustainable and environmentally friendly waste to energy value chain has yet to be seen. The sustainable development of Chinese energy supply still needs perennial and unremitting efforts.

Overview

Biodiesel Industry in China has a relatively short but active history. Early in the decade, Chinese biodiesel flourished due to several factors, un-realistic fuel price set by the Chinese government, power shortage in the southern provinces due to government action to control power plant construction, Sino-Pec and China Petroleum 'inverse pricing policy' to control the retail market, large diesel black market distribution networks, and unregulated waste disposal industry creating easy and cheap access to waste oil of all kind.

All of these factors help to spur rapid development in Chinese Biodiesel industry, and due to abundant supply of 'gutter oil' Chinese biodiesel technology is robust, capable of handling varied quality of waste oil. However ‘easy’ money demonstrated by the early biodiesel producer spurred massive investment in Biodiesel plants around China, and cause extreme run up on feedstock prices. The fact that the waste oil industry has no regulation means that the prices are extremely irrational. Chinese waste oil prices are similar to that of the US, while there is no concept of quality, quality control, contracts or credits. As the recent crash in the waste oil market would demonstrate all the problems. The bigger energy picture also negatively affected the industry. With oil prices rising to 144.96 USD per barrel on July 11th 2008, and falling to 30.28 USD on December 22nd 2008, enthusiasm in biodiesel as a product, as a technology and as an investment have fallen. Also with the shortage of water around the world restricting agricultural output and edible oil prices catching up to realistic market prices, the low feedstock price enjoyed by many early producers vanished along with margins.

It is important to mention that agricultural prices for the last 10 years are falling when adjusted for inflation. With increasing output form better technology and efficiency, supply was greater than demand. Biofuels as an industry was created as a way to utilize surplus agricultural products and stabilizes prices. However in the excitement for energy independence, clean fuels and agricultural stimulation destabilized the fragile supply and demand balance in the industry. With actual planting acreage falling over the last 20 years, biofuel became the catalyst, not the cause, for the sharp spike in prices last year.

Many biodiesel projects across the world counted on the cheap edible oil prices, which disappeared rapidly. With food security as an issue, many agricultural products were restricted for biofuel production, further restricting supply of feedstock. Coupled with over capacity, and falling crude prices, biodiesel industry is contracting. It is important to note the industry was contracting when crude oil prices was climbing towards 144.96 USD. With high-energy price, agricultural prices climbed faster, meaning biodiesel margins was falling faster then diesel price could climb.

Chinese biodiesel industry followed the same trend. Although Chinese edible oil prices were always above that of diesel prices, waste oil prices in China follows the trend and is about 50% to 70% of edible oil prices, with palm oil as the determining price. As the presentation would calculate, Chinese biodiesel producer have a decent margin given the fuel prices, but market acceptance still lags that of other countries. Chinese consumers do not consider the environmental benefits to be of value and low prices is the only way to sell biodiesel, a very different situation from that of 2005, when biodiesel was the only way some wholesalers can maintain a profit.

Chinese government energy policy remains non-transparent. Without a clear conventional energy strategy, policies regarding biodiesel are non-existent. So far policies outlining clean energy investment are plentiful, national biodiesel standard GB -T 20828-2007 is available, but an application regulation is still in the talks. China is considering a national B5 standard, however the schedule for the application, the volume of biodiesel required and who are the parties involved, remains unknown. It seems that Sino-Pec will not be involved with the biodiesel industry and will observe only. China Oceanic Oil seems to be active with jatropha plantations and biodiesel projects in Hainan, however many of the proposed projects remain to break ground.

However, for short term and mid term project development, waste oil is the only cheap feedstock available in China. Since waste oil is a by-product of human eating activity, China with the largest and most concentrated urban population in the world, waste oil from restaurants is generated in great quantity. However, unlike that of US or Europe, Chinese waste oil exists in many different areas and comes from very different sources. This makes collection and quality control much more difficult in China. Existing collection system and process infrastructure are very simple and effective on a small scale, however many secondary pollution issues are not addressed and is impossible to scale up. For long-term development of waste oil to biodiesel industry in China and for other countries, large scale, efficient and sustainable waste oil processing facility and collection system needs to be realized. The main issues are not technology, it existing behavior that need to be modified.

This presentation proposed a complete restaurant waste to energy value chain, and demonstrated work by COBRA to prove and refine every element within the value chain.

Results and Discussion

One area of interesting development in biodiesel application that is ignored in the clean and green fuel movement is marine application. Though research marine fuels, Marine distillates and residuals fuels are more polluting then diesel accepted for automotive applications. DMB and DMC, ISO 8217 standards only require sulfur content to be less then 2% by mass, several factors above automotive fuels. With marine application using fuel on a greater volume and spilling at greater volume then automotive application, substitution of marine diesel with bio alternatives will have greater effect on the environment. It is very easy for biodisel to meet DMB and DMC standard, and production costs are lower.

Conclusion

Comprehensive work to develop a waste to energy project is needed. This will mean work in several areas;

1. Collection logistics, education and regulations. Although several companies and cities have demonstrated restaurant collection systems, but they are non scalable on a large scale because of the way waste is collected. Also by scaling up existing systems, the share numbers of people will make such system non economical and manageable. Most important part of government regulation is not to dictate the kind of equipments (hardware) needed, but rather the maintenance service (software) required and monitoring. This is critical for sanitation and food safety reasons, because excess organic waste and oils can cause sewage system break down, food waste can cause landfill to collapse, and waste oil recycling for edible oil is a public health issue. The core issue is still education. Public need to demand for clear, greener, renewable and safer environment.
2. Process technology needs to be adaptable and sustainable. Too many projects in China are too big and often ignore secondary pollution issues, However waste to energy projects need to be involved with the collection and logistic of feedstock because right action at the source can have significant impact on production costs.
3. By-product application will have significant impact on revenue of waste to energy projects.
4. Biodiesel needs more promotion in China. Without placing a value to the environmental benefit of biodiesel, biodiesel cannot compete with fossil fuel on cost. Marine application will expand biodiesel market, but if consumers do not see value in environmental benefits, biodiesel cannot compete.

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Session

VI

1. Cultivation of Energy Crops and Their Environmental Effects
2. Case Study of Energy Crops Production and Utilization In Indonesia

1

Cultivation of Energy Crops and Their Environmental Effects

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Abstract

Global climate change and the past as well as future energy crises demand new solutions. Biomass energy offers possibilities for a sustainable and renewable energy source as we enter the new millennium. Bioenergy derived from agricultural crops such a sugarcane, corn or wheat, and vegetable oils such as palm oil, soybeans or rapeseed has been portrayed as having the potential to contribute to climate change mitigation, substitution of petroleum, security of energy supply, technology development, largest still unexploited renewable energy potential and multi-purpose and continuous energy source. However, the substantial rise in the use of biomass from agriculture for producing energy might put additional pressure on farmland and forest biodiversity as well as on soil and water resources. Crop cultivation for bioenergy production has various negative effects to environment. Bioenergy crop cultivation has some potential problems with soil erosion and compaction, leaching of soil nutrient, adverse impacts on water quality, biodiversity and also the potential for release of genetically engineered plant material into the wild. As regards biodiversity, it is generally held that biodiversity is reduced for bioenergy crop plantations when compared with natural ecosystems and increased relative to arable cropping. Therefore, we are sure to consider various conditions for minimizing environmental pressures of bioenergy crop production.

Keywords: bioenergy, agriculture, biodiversity, environment, ecosystem

Introduction

Global warming is one of the most serious challenges that humankind has ever faced. Oil prices have climbed to unprecedented heights, and concerns about the environmental effects of fossil fuel use such as global climate change caused by CO_2 emission are on the rise. Bioenergy is the subject of increasing attention around the world. Global production of biofuels for transportation has grown at approximately 15% per year since 2002 and has accelerated rapidly since 2005 when output totaled about 31 million tons, consisting of 27 million tons bioethanol and 4 million tons biodiesel. The most part of bioenergy raw materials are produced in farmland. The increased intensity of farming has caused significant negative impacts on the environment. These negative impacts include pollution of water by nitrates, phosphate compounds, pesticides and pathogens, habitat degradation and species loss, the over-abstraction of water for irrigation, and substantial greenhouse gas and air pollutant emissions. The growing demand for bioenergy crops may create further competition for land and water between existing agricultural activities, energy production and the use of agricultural land for nature conservation and urbanization needs. This could result in additional negative environmental pressures from cultivating bioenergy crops. The environmental impact of bioenergy production depends to a large extent on the selection of areas that are used for bioenergy production, the crops cultivated and the farming practice. The aim of paper is focused on minimizing environmental pressures of bioenergy crop production.

What is bioenergy?

Bioenergy is made from plants, animals and its biomass which can be used instead of fossil fuels. For thousands of years, humans have used bioenergy such as weed, wood, and dung to cook, heat, and manufacture goods. In the early 20th century, liquid biofuels began to be used as transport fuel, and, in fact, ethanol and vegetable oil were originally envisioned as the fuel sources for the combustion and diesel engines. In recent decades, biofuels have become regionally important sources of electricity and liquid transport fuels in some parts of the world. The three most common biofuels are bioethanol, biodiesel and biomethanol. Bioethanol is produced from a variety of agricultural feedstock, including starch, sugar and cellulosic materials. The most typical feedstocks are corn and sugarcane. Biodiesel is derived from vegetable oils, and can either replace diesel completely or be mixed in different proportions. Biodiesel can be used in diesel engines with any modifications. Typical feedstocks for biodiesel are mainstream agricultural crops such as rapeseed and palm oil. Biomethanol is produced from woody plants. It is not as common as either biodiesel or bioethanol.

Environmental benefits of using bioenergy

Use of bioenergy for vehicle-fuel, heat or electricity generation is accompanied by significant environmental benefits such as decreased air pollution and sustainable sources of biomass do not lead to any net carbon emission. If used to substitute petroleum, there will be a net carbon benefit by reducing carbon dioxide emissions(Kgathi & Zhou, 1995). And if grown under the right conditions, bioenergy crops can contribute to better environmental management. For example, dedicated energy plantations grown on degraded lands may actually help conserve the soil, rainwater and biodiversity. As with all crops, bioenergy crops need to be grown and managed responsibly, and farm-level incentives for sustainable farming need to be in place.

Negative effects of bioenergy crop cultivation

Bioenergy crop cultivation has negative effects to environment. There are potential problems with soil erosion and compaction, leaching of soil nutrient, adverse impacts on water quality and quantity, biodiversity and also the potential for release of genetically engineered plant material into the wild.

Soil erosion and compaction: Soil erosion is characterized by dry periods followed by heavy bursts of rainfall falling on steep slopes with unstable soils (Linda & Tolbert. 2000) Soil compaction results from the use of heavy machinery for activities such as ploughing, spreading organic manure and harvesting. Soil compaction has adverse effects on soil biodiversity and soil structure. It may also lead to problems such as water logging.

Leaching of nutrients: Nutrients drain in particular nitrate and phosphates from agricultural land to ground can be a significant problem in intensive farmland areas. Measures to prevent leaching of nutrients and pesticides include reducing inputs of manures and fertilizers, widening crop rotations and better farm management. Currently, agriculture is responsible for more than 50 % of the nitrate contamination found in surface waters

Water: Agricultural water use is a serious concern in the world. Effects of increased water abstraction include salinization and water contamination, loss of wetlands and the disappearance of habitats through the creation of dams and reservoirs and the drying-out of rivers. In general, there has been a significant increase in competition for water between agricultural production, urban land uses, tourism and nature conservation in drier regions.

Diversity: It is generally held that biodiversity is reduced for energy plantations when compared with natural ecosystems and increased relative to arable cropping. Continuing specialization in farming over recent decades and a simplification of cropping systems have resulted in a loss of crop diversity (Tilman et al., 2006.) This was also associated with a decrease in non-cropped habitats, such as grassland, field boundaries and tree lines. Consequently, landscape diversity has been reduced substantially leading to a loss of diversity in farmland habitats and associated farmland flora and fauna. Farmland biodiversity is affected by a combination of all the previously identified pressures. Indirect pressures include soil erosion and compaction, nutrient and pesticide leaching to ground water and surface water, and water abstraction. Direct pressures include the loss of habitats and farm and pest management practices.

How to avoid increased environmental pressures?

In bioenergy crop cultivation for the bioenergy production, there should be sufficiently considered to various conditions for minimizing environment impacts.

Minimum level of set-aside as ecological compensation area: Minimum ecological compensation area of intensively used farmland is assumed to be set-aside for nature conservation purposes. This standard helps to re-create ecological compensation areas, which increase the survival and/or re-establishment of certain farmland species. A number of studies have shown that creating non-cropped habitats field margins and 'grassland pockets' in arable regions can be effective measures towards supporting bird biodiversity (Opdam et al., 2003; Vickery et al., 2004). It is important, therefore, that such grassland pockets and other habitat elements are established in intensive farmland areas to form ecological compensation areas at a landscape scale.

Bioenergy crops with low environmental impacts are selected: The types of crops for the bioenergy production to be cultivated should minimize soil erosion and compaction, nutrients leaching and surface water, water abstraction, pesticide and pollution. Ideally, they should also have a positive impaction in farmed landscapes and biodiversity (Sanderson & Adler. 2008). Different bioenergy crops have different environmental impacts. An environmentally compatible crop mix should aim to reduce the main environmental pressures of the region, in which bioenergy is produced

Environment-friendly agriculture: Environment-friendly agriculture includes both agricultural area under organic cultivation and high nature value farmland. Both high nature value and organic cultivation have a high biodiversity value. Research has shown that organic cultivation generally provides benefits to landscape and biodiversity, for example, through a greater range of wildlife habitats (Stolze et al., 2000; Hole et al., 2005). Farming practices of high nature value farms are more extensive and also more synchronized with natural processes and the natural fluctuations which take place within these processes from year to year (Andersen, 2003).

Improving agricultural productivity: Biofuels can be a sustainable part of the world's energy future, especially if bioenergy agriculture is developed on currently abandoned or degraded agricultural lands. Using these lands for energy crops, instead of converting existing croplands or clearing new land, avoids competition with food production and preserves carbon-storing forests needed to mitigate climate change. The ways to produce more crops is achieve higher yield on the currently used land by improvement of cultural practice and breeding. Genetically engineered biomass should be supported only where the benefits outweigh the risks, and where traditional breeding or other alternative approaches are not feasible.

Development of bioenergy conversion technology: A recent review of life cycle assessment(LCA) studies on liquid biofuel systems for the transportation sector concludes that conventional grain- and seed-based biofuels can provide only modest green-house gas mitigation benefits by any measure (Larson, 2005). One of the reasons is that grains and seeds often constitutes less than half of the biomass produced and it is difficult in the LCA to compensate for the co-products. With future technological improvements including conversion of lignocellulosic raw materials the prospects for use of primary biomass may change. Increased focus on integration of several technologies in single industrial units using a biorefinary concept is also expected to improve the overall energy efficiency(Nielsen et al., 2007).

Conclusion

Global climate change and current energy crises demand new types of renewable energy such as bioenergy. The growing demand for bioenergy crops may create further competition for land and water between existing agricultural activities, energy production and the use of agricultural land for nature conservation and urbanization needs. This could result in additional negative environmental pressures from cultivating bioenergy crops. The environmental impact of bioenergy production depends to a large extent on the selection of areas that are used for bioenergy production, the crops cultivated and the farming practice. The environmental conservation and ecological sustainability of bioenergy cropping systems can be accomplish by minimum level of set-aside as ecological compensation area, selection of bioenergy crops with low environmental impacts, environment-friendly agriculture, improving agricultural efficiency and development of bioenergy conversion technology. Especially, the right choice of biomass crops and cultivation methods greatly contribute to conservation of stabilized environment and ecosystem.

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2

Case Study of Energy Crops Production and Utilization In Indonesia

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Abstract

In line with Indonesia economic growth, demand for national energy has grown very high. High international price of energy also cause some problems in Indonesia economy, especially in fullfilling national energy, people purchasing power. An alternative energy whice is renewable one such as biomass from the agriculture production have to be considered. In the face of its depleting oil reserves, fluctuating world oil prices and as well as an awareness of global warming, Indonesia has launched an intensive biofuels production program aimed at replacing its fossil oil consumption by 5 percent in 2025. More than 40% of populations engage in this sector those depend on kerosene, gasoline, diesel oil and wood to run theirs daily activities such as cooking and house lighting as well as for water pumping, agricultural land preparation and product processing. So there is a need for a sustainable source of fuel in the rural area. The Indonesian richness in varieties of energy's crops is a good challenge to develop biofuel in Indonesia. These crops are oil palm, coconut, jathropa curcas (for biodiesel) and sugarcane, cassava, and sorghum (for bioetanol) and others potensial energy's crops as well. The map of suitable land and climate for some energy's crops have been established. Beside for producing biodiesel and bioetanol, the diversification of utilization the energy's crops is being encouraged to have an added values of the crops for the farmer, such as producing biogas and briquite from seed cake as an alternative source of energy. There are now minimum mandatory on biodiesel and bioetanol utilization in Indonesia since 2009, and gradually increase till reaching 25 % for biodiesel and 15 % for bioetanol from fuel national consumption in 2025. Among the energy crops, palm oil is the most available in technology and plantation as well.

Keywords: bioenergy crops in Indonesia, feedstock, biogas, biodiesel, bioetanol

Ⅰ. Introduction

In the face of its depleting oil reserves, fluctuating world oil prices and as well as an awareness of global warming, Indonesia has launched an intensive biofuels production program aimed at replacing its fossil oil consumption by 5 percent in 2025. Based on the national energy policies, Indonesian President stressed the importance of developing biofuels for Indonesia. The development of biofuels will also create more jobs, reduce poverty, develop cooperatives and small businesses and re-green denuded land. Besides reducing dependence on fossil fuels, the cultivation of bioenergy crops such as oil palm, cassava, sugar cane and jatropha curcas and other crops was also seen as a way to help boost local economies, particularly for create the jobs. At the same time, mitigation aimed at stabilizing atmospheric concentration of greenhouse gases are a fundamental pillar of climate policy, including the development of a sustainable source of energy as weel as biomass energy.

The Indonesian richness in varieties of plants has created a greater possibility to develop biofuel since the source of its main ingredients can easily be found in Indonesia. The fact shows us that agriculture is a strategic sector in Indonesia. More than 40% of approximately 225 million populations engage in this sector those depend on kerosene, gasoline, diesel oil and wood to run theirs daily activities such as cooking and house lighting as well as for water pumping, agricultural land preparation and product processing. So there is a need for a sustainable source of fuel in the rural area. The Indonesian richness in varieties of energy's crops is a good challenge to develop biofuel in Indonesia. These crops are oil palm, coconut, jathropa curcas (for biodiesel) and sugarcane, cassava, and sorghum (for bioetanol) and others energy's crops as well. In Indonesia, beside for producing biodiesel and bioetanol, the diversification of utilization the energy's crops is being encouraged to have an added values of the crops for the farmer.

Ⅱ. Energy Crops Production

As stated in the national energy policy, fosil fuel consumption has to be come from biofuel. In order to increase biofuel production, the Indonesian government plans to develop plantations of oil palm 1,5 million ha, jathropa curcas 1.5 million ha, sugar cane 0.75 million ha and cassava 1.5 million ha. These bioenergy business will not only produce biodiesel and bioetanol, but can also create job opportunity for approximately 3.5 million people hopefully. The energy source coming from potential crops in Indonesia have quite of varieties. However to make the system of production to be sustainable, the suitable plant has to be considered, especially that will not be competition with food production. These condition are enhancing the development of biomass energy technology in the world, by producing the sustainable feedstock from several energy's crops. There are energy crops in Indonesia, such as palm oil, coconut, jatropha curcas and other potensial one like nyamplung (*Calophyllum inophyllum L.*) and kemiri sunan (*Aleurites trisperma BLANCO*) as source of biodiesel feedstock, and sugarcane, cassava, sorghum, sago and aren as feedstock of bioetanol.

2.1 Biodiesel Feedstock.

More than 17.5 mill tons CPO in Indonesia is produced from more than 6.1 mill ha of palm oil plantation. There are some ready materials to be converted into biodiesel with good technique and best quality of seed from National Palm Oil Research Center (Darmosakoro, 2006). Around 53.7 % ha of palm oil plantaion is run by private companies, 34.2% owned by the local farmers, and PTPN (state company) owned about 12.1%. The productivity of Indonesian palm oil is 2-3 tons/acre, and ar aoun 12.1 mill tons is exported, around 4.5 ton for domestic food industry/consumption and only less than one percent for biodiesel. The high yielding varieties of palm oil are now available in the research center for supporting the biofuel production.

Jatropha curcas is also developed as another option in creating biodiesel based on some considerations, which are the limited usage of the plant other than the benefit as a biofuel. Although in other countries there are some Jatropha which not contain toxic, but so far in Indonesia the kind of Jatropha curcas found contains toxic (for humans). The good adaptabilty and the limited usage of Jatropha is a factor on which make this plant as one of the consideration to be planted as a biofuel source. The main challenge in developing this plant as a biofuel source is the unavailability of the best quality seeds. Nowadays, the number of Jatropha curcas plantation area is about 130 thousand hectares that scattered in all over Indonesia. Based on the land mapping, the suitable land is about 14,7 million hectares (Mulyani and Allolerung, 2007; Mulyani et al. 2008). The Indonesian Centre for Estate Crops Research and Development has selected seed of best Jatropha curcas. The strategic steps has been started in 2006 and improved population of jatropha curcas seeds has been launched named IP-1, and another improved population is IP-2 has been launched again in 2007, with potensial seed yield 4-5 t/ha (IP-1) and 6-8 t/ha (IP-2). These seeds has been developed that suitable for wet climate (IP-1P and IP-2P), medium (IP-1M and IP-2M) and for dry climare areas (IP-1A and IP-2A) (Puslitbangbun, 2007).

Parts of coconut or the secondary product which can be used as a source of alternative energy are the coconut fruit (the endosperm) for its oil and biofuel, the coconut shell,its shells' fibre and tree can be burnt to produce heat. Other parts of coconut which can be made as bioethanol is the sap. The coconut is field in Indonesia today is around 3,8 million hectares. The price of coconut which not attractive enough has caused improper treatment of coconuts by the farmers. About 20-30% coconut plantation in Indonesia should be replated or rehabilitated, because the coconut trees are already old. Other than copra, the technology of coconut usage as the source of alternative technology actually has been mastered by the farmers. Some high yielding varieties have been released since couple years ago, i.e. Tenga variety, Palu, Genjah Salak etc.

Nyamplung (*Calophyllum inophyllum L.*) and Kemiri Sunan (*Aleurites trisperma BLANCO*) are other potensial energy's crops in Indonesia. But nyamplung plantation is only 638 ha and kemiri sunan is scattered in some area in Java. Nyamplung fruit is non toxic one, and their seed cake can be for animal feed. People in Indonesia particularly in Java have been recognizing nyamplung since longtime ago, so actually it will not be difficult to developed. Indonesia has just started in studying this crop.

2.2 Bioetanol Feedstock.

There are some new improved variety of sugarcane for rice fields or dry land. The varieties has been tested in any condition of land in Java or outside Java, that includes varieties which has potential to be processed as bioethanol, such as PSCO 90-2411 (Mirsawan *et al*., 2006). Sugarcane plantation area is around 382.354 hectares, with cane production of 31.140 tons, or sugar production about 2.3 thousands of tons and in molases more than 1.2 thousand tons. About 40 % of the production of the molases has been used as bioethanol, while 60 % of it is used as MSG etc. The constrainst will be land avaibility for dedicating the areas for sugarcane. Indonesia is now still importing the white sugar, so the excisting areas can not be used for producing bioethanol easily.

Cassava is one of the plants which can be one of the source of biofuel specially bioethanol. Nowaday the production of cassava nationally is about 18,99 million tons of fresh casssava spreaded in 26 provinces, with area about 1,23 million hectares and productivity 15,4 t/ha. The production areas are located in 14 provinces concludes 55 kabupaten. The improved varieties are available, i.e. UJ-3 (short term), Adira-4 (medium term), and Malang-6 and UJ-5 (long term) (Suyamto and Wargiyono, 2006). The constrainst will be the competition with othe secondary crops. Based on the Indonesia land and climate condition, there 14 provinces are suitable or can the productuon center of cassava.

Sorghum is a plant producing seeds which cultivated mostly in hot and dry climate. It has a great adaptive ability which makes it can grow in any kinds of climate, needs relatively smaller input and useful mainly as source of cattle food, staple food and also for the industrial needs. Sorgum plantation is now around 0.11 mill hectares with productivity around 0.85 t/ha. The development of sorghum in Indonesia is very limited, however the potential of development is still widely open.

The sago palm fields (mostly located in Papua) in Indonesia nowadays is estimated about 1-1.5 million hectares (Flach, 1984; Jong, 2005 and 2007). Theoritically, about half of the plants can be processed as to produce ethanol. One sago palm tree from Papua can produce 200 kg of sago flour and can produce ethanol of 30 litres. Sago from Maluku can produce about 400-500 kg sago flour. Sago is harvested about 35 trees per ha per year. The ethanol price in the market is quite interesting, it’s a factor which hopefully will increase the use of sago palm as a source of alternative energy. There are some constrainst, such as the spread of plantation population, especially since it is located in difficult places to be reached. However, sago is stupple food in some areas, so the local goverment should consider it before developing sago for producing biofuels.

Another source of ethanol is aren with around 60-100 thousand ha plantation in more than 13 provinces. The constrainst is that thge plantation is scatterly in all over the island so that is not easy to harvest the bunch. Coconut and palm research institute is now developing the seed establisment.

Ⅲ. Energy Crops Utilization

Most of crude palm oil (CPO) in Indonesia is exported and some of them is for domestic consumption. It is only less than one percent for biodiesel production, but since 2008 the biodiesel production is getting higher come from CPO. Cononut is ussually for domestic and cooking oil, but the amount of this is very little compare to the cooking oil from the CPO. Sugarcane and cassava are mostly for domestic food consumption like for white sugar from sugarcane, feed and traditionil food from cassava. Most of bioetanol in Indonesia is produced from mollases and small amount from cassava, but the constrainst is that mollases is also for producing mono sodium glutamat (MSG).

3.1 Utilization of Jatropha Curcas.

Eventhough jatropha curcas is now still under studying, but in research level, the utilization of the seed has just developed. Jatropha curcas crude oil is tried for producing biodiesel. Beside the big biodiesel plant, mini biodiesel processing plant has also been developed, specially for the villages use. Other utilization of jatriopha curcas is from the seed cake, specially for producing biogas and briqute as source of energy. As source of biomass, agriculture in Indonesia as a whole can produce more than 430 million GJ/year (Abdullah, 2003) and then more than 441 million GJ per year (Bambang, 2007b) (Tabel 1). All of these calculation were excluding jatropha curcas, eventhough this plant as source of biomass potentially can be utilized.

Jatropha curcas biomass yield residu is produced from process of expelling jatropha seed that produce crude oil. People usually utilize this crude oil from the seed by pressing it, either then using it for pressure plant oil stove (Bambang, 2007a) or process it for producing biodiesel. Oil content of jatropha seed, based on the improved population of jatropha curcas seed IP-1 and IP-2 released by ICERD is around 34-35 % (extracted base). So, there will be at least 65 % seed cake as biomass yield residu can be used as biomass source of energy (Figure 1). Ofcourse there will be other biomass come from brances, dry leaves etc, but in this case, we can not utilize it as a sustainable source of biomass energy. Agronomically, prowning of jatropha's brances will be done each year in the first year or sometime two years either. So, jatropha curcas as a source of biomass continuesly will be mostly come from the seed yield. Ofcourse beside the cake, we will have some pod husk from the jatropha fruits. As the cacao pod husk that can be used for producing biogas (Srimulato, 2008), jatropha curcas can be used so, but generally that prefer to be used as a organic fertilizer. So the seed cake of jatropha curcas is the main simple source of biomass renewable energy especially in the rural areas.

Tabel 1. Biomass Residu Conversion Energy from Agriculture Sector in 2007

Commodity	Yield (mill GJ)	Biomass Residu (mill GJ)
Palm oil	170	69.7
Coconut	130	---
Rubber	---	144.8
Rice	---	158.6
Sugarcane	2.66	78
Sago	58	---
Cattle	0.33	---
Total	360.99	441.1

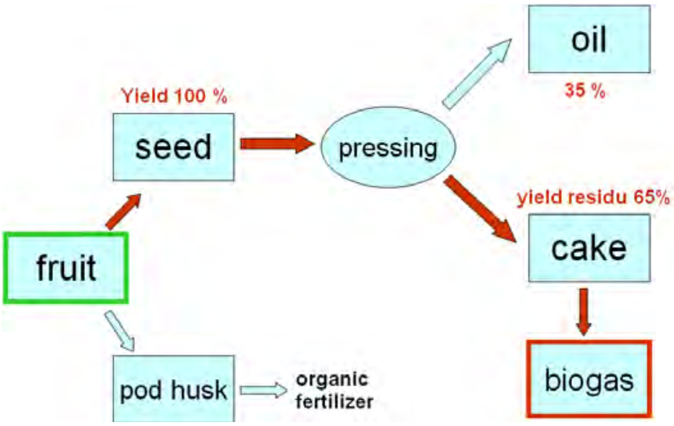


Figure 1. Potency of Jatropha Curcas Yield Residu for Biofuel

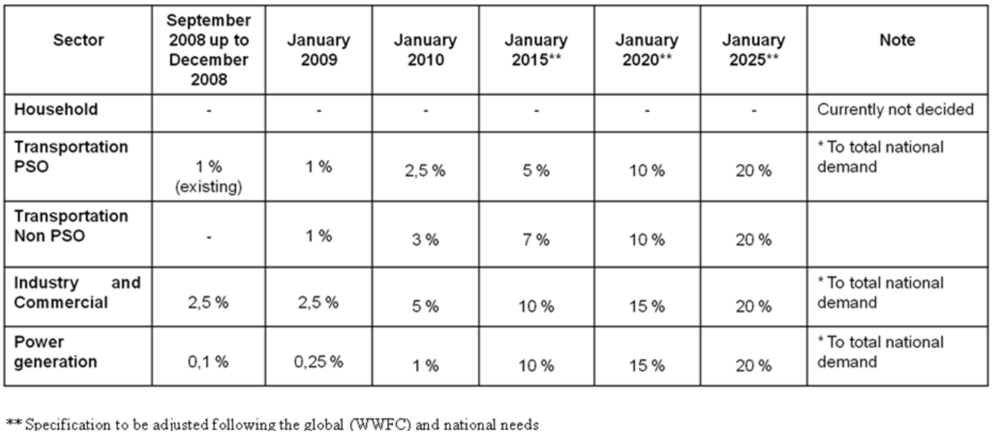
Biogas can be produced from the seed cake of jatropha curcas with small amount of catlle manure as an innoculum in the very simple reactor. As business as usually, cake have to be mixed with water in a couple days, before inputed into the reactor. After one to two months digestion time, usualy biogas can be resumed. From around 224 kg seed cake, reactor can produce around 112 ㎥ biogas during 3 months, with biogas quality that can boil 3 liter water in 14 minutes (Balittri, 2008), or around 2.0 M Joule per 3 months. As comparation, 4 liter water can be boiled by plant oil stove in around 11-12 minutes or around 9-10 minutes by karosene stove.

Indonesia has targeted to have 1,5 million hectares of jatropha curcas plantation in 2010 (Timnas BBN, 2007). As an animal manure, due to the constrainst in distribution and also the utilization or practical consideration, so the effective potency of the usage of jatropha cake will be approximately only 10 %. So with the average yield of jatropha curcas 4 t/ha (minimum potential yield of jatropha curcas IP-1), 65 % of it can be as seed cake and 10 % are used for producing biogas, so there will be around 3,51 million GJ energy per year can be generated from jatropha curcas plantation in Indonesia since 2010. This energy will be higher than potencial energy produced from molases, that produce only around 2,66 GJ per year from 40 % of 1.186 thousand ton of molases (Reksowardojo dan Soerawidjaja, 2006). The challenges is how to reach the targeted plantation of jatropha curcas as well as the yield.

3.2 Future Utilization of Feedstock.

Goverment effort to achieve biofuel utilization can be to increase its utilization on transportation sector, biofuel utilitization for other activities such as electricity generation and household sectors, develop Energy Self-Sufficient Villages, increase the blending content of biofuel for commercially traded fuel, and also establishment of competitive pricing policy for biofuel. For commercialization of biofuel, domestic fuel specifications were revised on 17 March 2006 for both gasoline and diesel, biodiesel and bioethanol are allowed to be blended with diesel and gasoline, but technical specifications for biodiesel and bioethanol have to follow the government standards. Nowaday, biofuel has been available at around 500 gasoline stations in four major cities in Indonesia (Jakarta, Surabaya, Malang and Denpasar) since May 2006. Currently, regulation on mandatory for biofuel blending on petroleum fuel has been issued and was enforced on 1 January 2009 (Table 2 and Table 3).

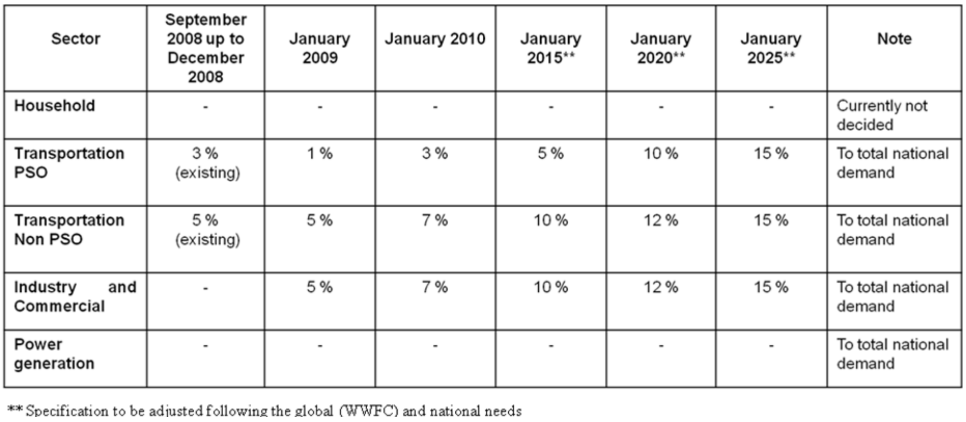
Table 2. Minimum mandatory on biodiesel utilization based on the Ministry of Energy and Mineral Resources No. 32/2008)



Sector	September 2008 up to December 2008	January 2009	January 2010	January 2015**	January 2020**	January 2025**	Note
Household	-	-	-	-	-	-	Currently not decided
Transportation PSO	1 % (existing)	1 %	2,5 %	5 %	10 %	20 %	* To total national demand
Transportation Non PSO	-	1 %	3 %	7 %	10 %	20 %	
Industry and Commercial	2,5 %	2,5 %	5 %	10 %	15 %	20 %	* To total national demand
Power generation	0,1 %	0,25 %	1 %	10 %	15 %	20 %	* To total national demand

** Specification to be adjusted following the global (WWFC) and national needs

Table 3. Minimum mandatory on bioetanol utilization based on the Ministry of Energy and Mineral Resources No. 32/2008)



Sector	September 2008 up to December 2008	January 2009	January 2010	January 2015**	January 2020**	January 2025**	Note
Household	-	-	-	-	-	-	Currently not decided
Transportation PSO	3 % (existing)	1 %	3 %	5 %	10 %	15 %	To total national demand
Transportation Non PSO	5 % (existing)	5 %	7 %	10 %	12 %	15 %	To total national demand
Industry and Commercial	-	5 %	7 %	10 %	12 %	15 %	To total national demand
Power generation	-	-	-	-	-	-	To total national demand

** Specification to be adjusted following the global (WWFC) and national needs

Data from the Indonesian Biofuel Producer Association (APROBI) show that for producing biodiesel from crude palm oil (CPO) will be much easier rather than producing bioetanol. The national production of CPO can supply all amount of mandatory biodiesel demand. The constraint will be the arrangement of the domestic market allocation of it, and also the competition with the demand of CPO derivatives industries.

Jatropha curcas has not been ready for producing biodiesel yet, at least until next 3-5 year, due to the availibility of feedstock and others constraints. Regarding the bioetanol, the problem will be the supply of bioetanol since 2010. National production of bioetanol until the end of 2008 was about 180 thousand Kilo Liter per year (Murdiyatmo, 2006), while the mandatory demand of bioetanol based on the Ministry Decree No. 32/2008 will be similar amount of these production. APROBI are planning to establish the new bioetanol factory in 2009 until reaching around 1,5 million Kilo liter, but the next problem will be the availability of land for the plantation. But this condition is also a big challenge for the new investor to have new business on it. In this case, cassava will be more attractive rather than sugarcane.

A major challenge for achieving all of the national goals of the biomass development is financing, and the government has provided a set of incentives to attract domestic and foreign investors, and government also prohibits rainforest deforestation for biofuel purposes. These impressive potency of the biomass energy in Indonesia have also challenged us to facilitate and solve the constraints in developing the biomass energy by developing the condussive business climate for either the private sector or society. As described before, some regulations have been available, so the society including private sector are challeged to increase their role in developing biomass energy and its utilization, including the research institutes in improving the technology continuesly.

Ⅳ. Concluding Remarks

Priority commodities as feedstocks mainly will be palm oil, jatropha curcas, coconut and cassava. Some high yielding varieties of the crops are available and some suitable map for these commodities have been established. Among these energy crops, palm oil is the most available in technology and plantation as well. Beside establising the dedicated areas for the energy crops, the effort for improving the productivity of the energy's crops is also continued. Beside for producing biodiesel and bioetanol, the diversification of utilization the energy's crops is being encouraged to have an added values of the crops for the farmer, such as producing biogas and briquite from seed cake as source of alternative energy. There are now minimum mandatory on biodiesel and bioetanol utilization in Indonesia since 2009, that will accelerate the development of energy crops in Indonesia.

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❖ Profiles of Keynote Speakers and Active Participants ❖

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