APEC International Symposium

Biofuels from Agricultural and Agro-Industrial Wastes

Agricultural Technical Cooperation Working Group

May 2010

Symposium documents compiled for the
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1. **Australia**: Emeritus Professor Dr. **Peter L. Rogers**, School of Biotechnology and Biomolecular Science, University of New South Wales.
2. **Indonesia**: Dr. **Dadan Kusdiana**, Directorate General of Electricity and Energy Utilization, New Renewable Energy and Energy Conservation, Ministry of Energy and Mineral Resources.
3. **Indonesia**: Dr. **Oberlin Sidjabat**, Process Technology Division, R&D Centre for Oil and Gas Technology "LEMIGAS", Ministry of Energy and Mineral Resources.
4. **Malaysia**: Associate Professor Dr. **Lee Keat Teong**, University Sains Malaysia.
5. **Mexico**: Mr. **Roberto de la Maza**, Secretaría de Energía.

6. **Mexico**: Ms. **Irasema Infante**, Director of Economic Affairs Project for the Integration and Development of Mesoamerica, Ministry of Foreign Affairs.
7. **Philippines**: Associate Professor Dr. **Teresita R. Perez**, Department of Environmentalv Science of Ateneo de Manila University.
8. **Korea**: Professor Dr. **Choul-Gyun Lee**, Department of Biological Engineering, Inha University.
9. **Thailand**: Assistant Professor Dr. **Mallika Boonmee**, Department of Biotechnology, Faculty of Technology, Khonkaen University.
10. **Thailand:** Associate Prof. Dr. **Boonlom Cheva-isarakul**, Faculty of Agriculture, Chiang Mai University
11. **Thailand**: Dr. **Gumpanart Bumroonggit**, EGCO Co., Ltd.
12. **Thailand**: Professor Dr. **Tanongkiat Kiatsiriroat,** Faculty of Engineering, Chiang Mai University.
13. **USA**: Dr. **Kulinda Davis**, Director - Product Manager, Verenium Corporation
14. **Viet Nam**: Associate Professor Dr. **Doan Thai Hoa**, Department of Chemical Technology, Ha Noi University of Technology.
15. **Viet Nam**: Mr. **Nguyen Van Thong** (on behalf of Dr. **Pham Khanh Toan**), International Relation Department, Institute of Energy, Ministry of Industry, Electricity of Viet Nam

Introduction

The fluctuating and soaring oil prices in recent years has inevitably affected and pressured APEC economies to seek other alternative approaches in order to satisfy the ever rising demand for energy. One common strategy employed by several APEC economies is to enact the pro-biofuels policy which encourages the production biofuels from biomass materials such as bioethanol from maize and sugar or biodiesel from vegetable oils which in turn transform these starting raw materials into popular "cash crops". A number of multilateral organizations, including APEC, have voiced their supports for the production of biofuels from non-food feedstocks such as farm and forest residues, low value timber and energy crops specifically grown for conversion to fuel on marginal agricultural or saline affected land to dissipate the closely tied food and fuel prices at the present time. The symposium on "Biofuels from Agricultural and Agro-Industrial Wastes" will promote the awareness and understanding of the first and second biofuels impact on socio-economic development in urban and rural areas as well as the corresponding environmental aspect among APEC economies with the strong emphasis on bioconversion of agricultural and agro-industrial wastes as well as the forest residues. The commercialization of second generation biofuels will also be examined to realize the potential of its biotrade and respective technology risks and possible opportunities. This symposium will include the following topics:

- Biofuels history: A multiple generations of biofuels in APEC member economies. Emergence of the second and third generation biofuels. Technical information on production of biofuels and their potential benefits. Current trend and status of biofuels.
- Commercialization of biofuels: Biotrade of multiple generation biofuels. Technology risks and opportunities involved in the commercialization of second generation biofuels.
- Economic and Environmental aspects of future generation biofuels: Comparison of economic and environmental impacts to the APEC member economies of the multiple generation biofuels.

The goal of the symposium is to promote the awareness and understanding of non-food based biofuels potential of biotrade among the developed and developing APEC economies which accelerate the synergistic cooperation and networking towards the sustainable development and commercialization while mitigating the impact on food security by building on the completed work or underway by the Biofuels Task Force.

This symposium will provide a discussion platform to all APEC economies and link to EWG 01/2006A APEC project (The Future of Liquid Biofuels for APEC Economies Energy Working Group). The working group will invite representatives from APEC economies interested in the research and development of biofuels including lecturers, researchers, staff, trader, as well as policy makers from both public and private sectors as well as students and farmers that are involved in the fields to:

- Share knowledge and cost reduction information regarding second generation biofuels from experienced APEC member economies with all seminar participants.
- Exchange technical, economics, and environmental information and experiences regarding the bioconversion of agricultural and agro-industrial wastes to biofuels among APEC member economies.
- Establish a network of biofuels researchers/scientists and industry leaders working the importance of shifting the research direction from the first generation towards the second generation of biofuels with the collection of benchmark on gender-aggregated data.

Symposium Relevancy to APEC Priorities

The symposium project entitled "Biofuels from Agricultural and Agro-Industrial Wastes" responds directly to support APEC activities in the area of food and agriculture which aim to counter high food prices and ensure food security in the Asia-Pacific region (Draft: APEC Senior Officials Work Plan on Food Security, 2009) by exploring the alternative approaches to minimize the impacts between biofuels production and food. The importance of food security was also outlined in the strategic plan during 2008 – 2011 of World Food Program (WFP)[1] mentioning that millions of people on the global scale are exposed to desperation and hunger due to sky rocketing food and fuel prices which significantly undermine the purchasing power of households. The implementation of any initiative relating to biofuel should be assessed whether such activity make an impact to local staple food security (Final Report on Small - Scale Bioenergy Initiatives, Food and Agriculture Organisation of the United Nations, 2009).

As evident from the joint statement in **The Twentieth APEC Ministerial meeting 2008 in Peru**, the APEC ministers had agreed upon the topic of **Improving Food Security in the Asia-Pacific** as following; *"…to increase cooperation to foster conditions for the expeditious development and commercialization of next generation biofuels made from non-food materials, including examination of key economic, environmental and other issues impacting the emergence of this technology."* and the report prepared for APEC-EWG under EWG01/2006A entitled "The Future of Liquid Biofuels for APEC Economies" clearly expressed concerns over the conventional (first-generation) production of biofuels which relied upon starches, sugars, and vegetable oils as starting materials that resulted in the controversial arguments of food for biofuels and environmental impacts. The potential of sustainable harvested second generation biofuels from farm and forest residues was presented in "Survey of Biofuel Resource Assessments and Assessment Capabilities in APEC Economies" in which two-fifth of gasoline use and one-fifth of crude oil imports to APEC economies could be reduced. The awareness and improved understanding through exchange of ideas and research findings among participants of economies from APEC Economies are thus necessary to support and promote the development of next generation biofuels from agricultural and agro-industrial wastes while thoroughly examining the related impact of such development on global society such as economic and environment. This project will encourage and disseminate the concepts of food security and stress the importance of sufficient food supply of the APEC Economies by applying the proper technologies to limit the expansion of cultivation area used to produce edible biofuels crops.

Biofuels also provide a significant advantage over the fossil fuels in term of environmental aspect as stated in the Draft Terms of Reference by **APEC Biofuels Task Force**, EWG31, Singapore, May 2006 and more recently at NREL Golden, CO, October 2008 where cellulosic

[1] The symposium project is applicable to strategic plan V of WFP which aims at supporting the sustainable development of food and nutrition security systems.

biomass has been considered as a future resource for energy supply with the potential to replace up to 50% of gasoline. In term of air quality, the application of total ethanol fuel – a type of biofuels results in a drastic decrease of greenhouse gases emission such as CO_2, CH_4 and N_2O by 106% with the additional benefit of safeguarding the soil, water and biodiversity.

The Faculty of Agro-Industry Chiang Mai University with experiences in organizing the multinational training courses is in the triad partnership with domestic government agencies such as Energy Research and Development Institute (ERDI) and Thermal System Research Unit (TSRU) Chiang Mai University whose activities involved a number of research and development projects on biofuels production in the Northern part of Thailand. The linkage to the privatized food and agriculture sectors involving with biofuels in Thailand also exists through the cooperation with Industrial Council of Thailand. This conference will raise and strengthen the awareness as well as knowledge contribution among the representatives from both developed and developing economies towards research and development on non-food based biofuels through presentations and discussion panel with strong focus on agricultural and agro-industrial wastes such as how much of these wastes could be harvested sustainably (without degrading the land), practically (with access to roads and other infrastructure), and cost-effectively (in comparison with global oil prices and incentive of carbon value).

Key Issues & Important Findings

There will be a huge paradigm shift (including economy) from fossil fuel/petroleum based era to bio-based era. The food and energy securities of the public can be enhanced while the environment will be protected (cleaner air and water) as biofuels technology generates a much less wastes. The development of practical biofuels technology on the commercial scale will create jobs.

The current status, future trends, and sustainability of 1st, 2nd, and 3rd generations of biofuels have been discussed with the focus on bioethanol, biodiesel, as well as benefits for rural area people. The keynote speakers and active participants have learned numerous facts on the biofuels other than their expertise. The discussed topics included;

- Concerns regarding to the use of food crops for production of biofuels
- Examples of microorganisms to be used for biofuels production
- Will microalgae be a future fuel?
- Energy crisis and global warming lead to a quest for new sustainable energy
- Which biofuels to be used?
- Greenhouse gases elevated from the use of croplands for biofuels
- Biofuels carbon debt is created from first generation biofuels.
- Marine biomass to bioenergy
- How to decrease the cost of bioenergy to overcome fossil fuels selection by people?
- Sustainable biofuel implementation requires governmental supports in terms of mandatory or regulation
- Commercialization of second generation biofuels

The new international network of biofuels experts from governmental and private sectors have been established across APEC economies leading to a future cooperation and collaboration which allows for the possibility of mutual benefits based on the network as well as common problems & challenges. The group will disperse the knowledge learned to their respective communities and would like to schedule a regular meeting for this network. The best strategy for biofuels policy might be considered on a case by case basis for each economy to ensure food and energy securities in a win-win scenario. The specific policy might concentrate on the other types of raw materials such as feedstock other than the well recognized palm oil. The panelist of this network will play important roles in providing suggestion and recommendation for the upcoming APEC funded biofuels network symposium and training workshop (ATC 08/2010A) to reach the overall goal of cost-effective development of second generation biofuels.

The respondents were asked to rate their biofuels knowledge before and after participating in the symposium. It was found that 43.4% rated their biofuels knowledge level at high or highest level before participating in the event, this was compared to 92.4% after participation, an improve of 49.0%. Although the majority of symposium participating respondents (57.7%) were awared that second/third generation biofuels development in their respective economies were not at sufficient level, they realized the importance of biofuels in the future at high or highest level (94.3%). In addition, the majority of respondents (61.5%) were willing to select biofuels as an alternative to the normal biofuels at high or highest levels even though the prices of the former fuels were more expensive.

More than 40% of female (43.4%) had participated in the symposium as general and active participants. The majority of respondents (more than 80%) had education level higher than Master Degree with age range of 31 – 40 years old (32.1%). The respondents opined that the level of opportunities/roles of women in biofuels related agency/organization in their respective economies were relatively at high or highest levels (52.0%) while only 4.0% of respondents rated the level of women participation in biofuels at low level.

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International Symposium Program on

Biofuels from Agricultural and Agro-Industrial Wastes

May 24th – 27th, 2010, Chiang Mai, Thailand

May 24th, 2010

08.30 – 09.00	Registration
09.00 – 09.15	Introductory Remarks by the Dean of Faculty of Agro-Industry, Chiang Mai University
09.15 – 09.30	Welcoming Remarks by the Vice President of Chiang Mai University
09.30 – 10.00	Opening Remarks by Secretary General of the Office of Agricultural Economics (Mr. Apichart Jongskul)
10.00 – 10.15	Group Picture Coffee Break

########################### Beginning of Session I ###########################

10.15 – 11.00	**Keynote Speaker 1**: Emeritus Professor Dr. Peter L. Rogers, School of Biotechnology and Biomolecular Science, The University of New South Wales, **Australia** **(Topic: Production of Ethanol and Higher Value Fermentation Products from Lignocellulosic Raw Materials)**
11.00 – 11.30	**Panel Discussion (Topic: Bioconversion Technology of Agricultural and Agro-Industrial Wastes)** **Chair:** Emeritus Professor Dr. Peter Rogers, School of Biotechnology and Biomolecular Science, The University of New South Wales, Australia **Co-chair:** Dr. Prodpran Takeow, Faculty of Agro-Industry, Chiang Mai University, Thailand

############################ Ending of Session I ############################

11.30 – 13.20	Lunch

########################### Beginning of Session II ###########################

13.20 – 14.00 **Keynote Speaker 2**: Professor Dr. Choul-Gyun Lee,
Department of Biological Engineering, Inha University, Korea
(Topic: Will Microalgae be a Future Fuel?)

14.05 – 14.40 **Active Participants (APEC Economy 2): Indonesia,**
Dr. Dadan Kusdiana, Head for Rural Energy Division,
Directorate General of Electricity and Energy Utilization,
New Renewable Energy and Energy Conservation,
Ministry of Energy and Mineral Resources
Dr. Oberlin Sidjabat, Process Technology Division,
R&D Centre for Oil and Gas Technology "LEMIGAS",
Ministry of Energy and Mineral Resources

14.45 – 15.00 Coffee Break

15.05 – 15.45 **Active Participant (APEC Economy 3): Malaysia**,
Associate Professor Dr. Lee Keat Teong, University Sains Malaysia

15.50 – 16.30 **Panel Discussion (Topic: Policies and Programs in APEC Member Economies to Encourage the Development of the First and Second Generation Biofuels)**
Chair: Professor Dr. Choul-Gyun Lee,
Department of Biological Engineering, Inha University, Korea
Co-chair: Dr. Panida Rattanapitigorn,
Faculty of Agro-Industry, Chiang Mai University, Thailand

############################ Ending of Session II ############################

18:30 – 21:00 Welcome dinner for keynote speakers and active participants

May 25th, 2010

########################## Beginning of Session III ##########################

09.00 – 09.40	**Keynote Speaker 3: Thailand,** Associate Prof. Dr. Boonlom Cheva-isarakul, Faculty of Agriculture, Chiang Mai University **(Topic: Biogas Production as Substituted Energy and Pollution Reduction in Animal Farms)**
09.40 – 10.20	**Active Participants (APEC Economy 4): Mexico,** Mr. Roberto de la Maza, Secretaría de Energía Ms. Irasema Infante, Director of Economic Affairs Project for the Integration and Development of Mesoamerica, Ministry of Foreign Affairs
10.20 – 10.35	Coffee Break
10.35 – 11.15	**Active Participants (APEC Economy 5): Viet Nam**, Associate Professor Dr. Doan Thai Hoa, Department of Chemical Technology, Ha Noi University of Technology Mr. Nguyen Van Thong (on behalf of Dr. Pham Khanh Toan), International Relation Department, Institute of Energy, Ministry of Industry, Electricity of Viet Nam
11.15 – 12.00	**Panel Discussion (Topic: Issues Regarding Future Generation Biofuels on Economic & Environmental Aspects)** **Chair:** Dr. Phisit Seesuriyachan, Faculty of Agro-Industry, Chiang Mai University **Co-chair:** Assistant Professor Dr. Pattavara Pathomrungsiyoungkul, Faculty of Agro-Industry, Chiang Mai University, Thailand

########################### Ending of Session III ###########################

12.00 – 13.20	Lunch

########################## Beginning of Session IV##########################

13.20 – 14.00	**Keynote Speaker 5: Thailand,** Professor Dr. Tanongkiat Kiatsiriroat, Faculty of Engineering, Chiang Mai University **(Topic: Study on Algae as Energy Source at Department of Mechanical Engineering, Chiang Mai University)**
14.00 – 14.40	**Active Participants (APEC Economy 6): Philippines**, Associate Professor Dr. Teresita R. Perez, Department of Environmental Science, Ateneo de Manila University
14.40 – 15.00	Coffee Break
15.00 – 15.40	**Active Participants (APEC Economy 7): Thailand**, Dr. Gumpanart Bumroonggit, EGCO Co., Ltd. Assistant Professor Dr. Mallika Boonmee, Department of Biotechnology, Faculty of Technology, Khonkaen University
15.40 – 16.30	**Panel Discussion (Topic: Third Generation Biofuels Development in the Near Future)** **Chair:** Professor Dr. Tanongkiat Kiatsiriroat, Faculty of Engineering, Chiang Mai University **Co-chair:** Dr. Tri Indrarini Wirjantoro, Faculty of Agro-Industry, Chiang Mai University, Thailand

########################### Ending of Session IV###########################

May 26th, 2010

########################### Beginning of Session V###########################

09.00 – 09.40	**Keynote Speaker 4**: **The United States of America**, Dr. Kulinda Davis, Director - Product Manager, Verenium Corporation **(Topic: Biofuel Commercialization in the U.S.A.: A Race to the Start Line)**
09.40 – 10.30	**Panel Discussion (Topic: Commercialization of Second Generation Biofuels)** **Chair:** Dr. Kulinda Davis, Director - Product Manager, Verenium Corporation **Co-chair:** Dr.Chartchai Khanongnuch, Faculty of Agro-Industry, Chiang Mai University, Thailand (Coffee Break will be served during the discussion)

############################ Ending of Session V############################

10.35 – 11.00	Closing Ceremony
11.00 – 12.00	Lunch
12.00	Leave Kantary hotel to biofuels facility at Hod District (keynote speakers & active participants only)
14.00	Field trip activity
15.00	Leave Hod to Kantary hotel
17.30	Arrive at Kantary hotel

May 27th, 2010

9.00 – 10.00	Field Trip to Energy Research and Development Institute (ERDI), Chiang Mai University (keynote speakers & active participants only)
10.00	Leave ERDI to biofuels facility at Mae Wang District
10.30 – 12.00	Field trip activity
12.00 – 13.00	Lunch
Afternoon	Departure from Chiang Mai

Introductory Remark by Assistant Professor Dr. Charin Techapun
Dean, Faculty of Agro-Industry, Chiang Mai University
at the International APEC Symposium on
"Biofuels from Agricultural and Agro-Industrial Wastes"
May 24th, 2010, Chiang Mai, Thailand

Secretary General of the Office of Agricultural Economics (Mr. Apichart Jongskul)
Vice President of Chiang Mai University (Associate Professor Dr. Pairote Wiriyajaree)
Honorable guests, Ladies and Gentlemen

On behalf of Faculty of Agro-Industry, Chiang Mai University, I would like to thank Mr. Apichart Jongskul, Secretary General of the Office of Agricultural Economics and Associate Professor Dr. Pairote Wiriyajaree, Vice President of Chiang Mai University to be here with us this morning.

This International APEC Symposium on "Biofuels from Agricultural and Agro-Industrial Wastes" is held during 24th until 27th May 2010 with the warm supports from APEC and Office of Agricultural Economics, Ministry of Agriculture and Cooperatives.

The goal of the project is to promote the awareness and understanding of non-food based biofuels potential of biotrade among the developed and developing APEC economies which accelerate the synergistic cooperation and networking towards the sustainable development and commercialization while mitigating the impact on food security.

We have invited keynote speakers and active participants who are representatives from APEC economies namely Australia, China, Indonesia, Malaysia, Mexico, Philippines, Korea, Thailand, Viet Nam and The United States of America. These included lecturers, researchers, traders, as well as policy makers from both public and private sectors who are in the field of biofuels research and development.

In this symposium, we will have an opportunity to firstly share knowledge and cost reduction information regarding second generation biofuels. Secondly, to exchange technical, economics, and environmental information and experiences regarding the bioconversion of agricultural and agro-industrial wastes to biofuels. In addition, we hope to establish a network of biofuels researchers/scientists and industry leaders working the importance of shifting the research direction from the first generation towards the second generation of biofuels. The lecturing and economy reports will be presented and discussed during the first two and a half days. There will also be field trips to biofuels production facilities in Chiang Mai in the afternoon of 26th May and 27th of May.

I wish to thank Office of Agricultural Economics, Ministry of Agriculture and Cooperatives and APEC for their supports in the preparation of the meeting. Thanks to members of the Organizing Committee, the staff of Faculty of Agro-Industry, Chiang Mai University, who have contributed their untiring efforts in making this symposium possible.

Assistant Professor Dr. Charin Techapun
Dean of Agro-Industry, Chiang Mai University
24th May 2010

Welcoming Remark by Associate Professor Dr. Pairote Wiriyajaree
Vice President of Chiang Mai University
At the International APEC Symposium on
"Biofuels from Agricultural and Agro-Industrial Wastes"
May 24th, 2010, Chiang Mai, Thailand

Secretary General of the Office of Agricultural Economics (Mr. Apichart Jongskul)
Dean of Faculty of Agro-Industry, Chiang Mai University
Distinguished guests, Ladies and Gentlemen

It is my great honour, on behalf of Chiang Mai University, to welcome you all to the International APEC Symposium on "Biofuels from Agricultural and Agro-Industrial Wastes". I thank you all for honoring us with your participation today.

I would especially like to thank Mr. Apichart Jongskul, Secretary General of the Office of Agricultural Economics and all keynote speakers and active participants who will be with us for the next three days.

The fluctuating and soaring oil prices in recent years has inevitably affected and pressured APEC economies to seek other alternative approaches in order to satisfy the ever rising demand for energy. One common strategy employed by several APEC economies is to enact the pro-biofuels policy which encourages the production biofuels from biomass materials such as bioethanol from maize and sugar or biodiesel from vegetable oils which in turn transform these starting raw materials into popular "cash crops". A number of multilateral organizations, including APEC, have voiced their supports for the production of biofuels from non-food feedstocks to dissipate the closely tied food and fuel prices at the present time.

The symposium on "Biofuels from Agricultural and Agro-Industrial Wastes" will promote the awareness and understanding of the biofuels impact on socio-economic development in urban and rural areas as well as the corresponding environmental aspect among APEC economies with the strong emphasis on bioconversion of agricultural and agro-industrial wastes as well as the forest residues. The commercialization of second generation biofuels will also be examined to realize the potential of its biotrade and respective technology risks and possible opportunities.

I believe APEC has a very strong role to play in facilitating such frameworks at international level and we applaud the current initiative to review biofuels policy within the APEC context.

We are delighted to have this opportunity to arrange the International APEC Symposium on "Biofuels from Agricultural and Agro-Industrial Wastes" and sincerely hope that the program we have prepared will offer some fresh perspectives on biofuels potential of biotrade among APEC economies.

I wish to thank APEC and Office of Agricultural Economics, Ministry of Agriculture and Cooperatives for their support in the preparation of this meeting. Also thanks to members of Faculty of Agro-Industry, Chiang Mai University in organizing this symposium.

Associate Professor Dr. Pairote Wiriyajaree
Vice President of Chiang Mai University
24th May 2010

Opening Remark by Secretary General of the Office of Agricultural Economics (Mr. Apichart Jongskul) At the International APEC Symposium on "Biofuels from Agricultural and Agro-Industrial Wastes" May 24th, 2010, Chiang Mai, Thailand

Vice President of Chiang Mai University (Associate Professor Dr. Pairote Wiriyajaree)
Dean of Faculty of Agro-Industry, Chiang Mai University
Distinguished guests, Ladies and Gentlemen

On behalf of the Ministry of Agriculture and Cooperatives, I am honoured and privileged to join you all in the opening ceremony of the International Asia Pacific Economic Cooperation (APEC) Symposium on "Biofuels from Agricultural and Agro-Industrial Wastes" today.

First of all I would like to congratulate and extend my sincere appreciation to APEC and Chiang Mai University on the success of holding this Symposium. According to the remarkable spike in food prices from 2007 to 2008 and the subsequent global economic crisis, these highlighted the fragility of food security in global, national and individual levels. About two-thirds of undernourished population in the world resides in the Asia and Pacific region and more than one third of them in the APEC economies. Therefore, APEC member economies have continuously developed activities to alleviate the food security situation in the region. The Symposium is the first initiative to establish a network among researchers, government officials and private sectors to promote the awareness and understanding of non-food based biofuels potential for biotrade among the APEC economies which will accelerate the synergistic cooperation and networking towards the sustainable development and commercialization.

Distinguished guests,

As mentioned by the Vice President of Chiang Mai University, the increasing of oil prices in recent years has strongly affected and pressured all APEC economies to seek other alternative sources for energy production such as the second generation biofuels from agricultural and agro-industrial wastes. The raw materials which are of interest to some APEC economies include farm and forest residues, low value timber and energy crops specifically grown for conversion to fuel on marginal agricultural or saline affected land.

With regard to the biofuel policy of Thailand, the Ministry of Agriculture and Cooperatives and the Ministry of Energy have collaborated and disseminated the Royal Initiatives on Sufficiency Economy Philosophy and Bioenergy Project of His Majesty the King to relieve the high-priced energy by launching the community-based biodiesel units around the economy. This has alleviated the dependence on global fuel. Thailand has set the Energy Target to increase the biofuels supply from the existing 1 million liters per day to 9 million liters per day towards the year 2022.

I am very pleased to see this arrangement initiated by the Faculty of Agro-Industry, Chiang Mai University, APEC and Office of Agricultural Economics, Ministry of Agriculture and Cooperatives.

Therefore, I would strongly encourage you all to make the most out of this opportunity to exchange new knowledge and perspectives offered by the International APEC Symposium on "Biofuels from Agricultural and Agro-Industrial Wastes" during the forthcoming three days.

Finally, I wish the International APEC Symposium a brilliant success.

Thank you very much for your kind attention.

Mr. Apichart Jongskul
Secretary General of the Office of Agricultural Economics
24th May 2010

Session I

Asia-Pacific
Economic Cooperation

International APEC Symposium on
"Biofuels from Agricultural and Agro-Industrial Wastes"
May 24th – 27th, 2010, Chiang Mai, Thailand

ETHANOL AND HIGHER VALUE FERMENTATION PRODUCTS FROM LIGNOCELLULOSIC RAW MATERIALS

Peter L. Rogers *[1] and Young-Jae Jeon **[2]

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ABSTRACT

Global trends in second generation process development for bioethanol are reviewed together with associated international government and commercial support for this technology. Commercial viability is focused on achieving sustainable low cost and high yield biomass production together with reducing pre-treatment and fermentation costs by use of improved enzymes and recombinant yeast and bacteria. Current research initiatives are reviewed and include the use of recombinant bacteria (*Zymomonas mobilis*) for ethanol and a mutant strain of yeast (*Candida tropicalis*) for conversion of xylose to xylitol –an associated higher value fermentation product. The essential role of government programs to support such biofuels R&D in its early stages is emphasized.

1 INTRODUCTION

The recent increases in the price of oil, security advantages of increased domestic production, environmental benefits of reduced greenhouse gas (GHG) emissions and the potential for regional development, have all contributed recently to a greatly increased interest in bioethanol. In the longer term, second generation processes based on cellulosic materials from agricultural/forestry residues and/or specific high yield biomass energy crops offer greater potential for increased production as they avoid the food vs. fuel conflict. Second generation processes for biodiesel are also under development using lipids produced from large-scale algal cultivation rather than using oils from canola, palm nuts etc. Research over the past decades at the University of NSW has focused on the development of high productivity continuous processes for ethanol production based on the Gram-negative bacterium *Zymomonas mobilis* which has higher specific rates and ethanol yields than the traditionally used yeasts. In addition, considerable flexibility in the genetic manipulation of *Z.mobilis* has been demonstrated with strains now capable of utilizing the C5 sugars xylose and arabinose, as well as the C6 glucose present in cellulosic hydrolysates. The potential also exists for the production of higher value fermentation products from the C5 sugars in the lignocellulosic hydrolysates and these opportunities are currently being explored in the development of new biorefineries.

2 GLOBAL EXPANSION OF BIOFUELS

Brazil has played a leading role in this development after the Government mandated use of ethanol blend fuels in the mid-1980s, and it continues to be a global leader along with the US where ethanol production from corn is now similar to Brazilian levels. A major difference between Brazil and the US however, is that the industry cost structure and the use of sugarcane in Brazil as raw material (instead of corn) result in major cost advantages.

It is estimated that ethanol currently has a 16% market share of the total liquid fuel market in Brazil, with more than 40% of all fuels being ethanol blends (usually E10 or E85). Typically, about half of the sugar crop is converted to fuel ethanol (27,000 mL in 2008). By comparison, it is estimated that ethanol accounts for only 2.6% of the total US liquid fuel market, and utilises about 20% of the current corn crop. Production costs in Brazil are estimated at $US 0.15–0.20 per litre by using large-scale fermentation technology and lower cost raw materials, while in the US production costs are estimated at $US 0.25-30 per litre for similar scale processes.

There has been rapid growth in US ethanol production over the past two decades. With production in the US at 28,000 mL in 2008, this is projected to increase to close to 32,000 mL/a by 2012 with the passing of the *US Energy Policy Act* in 2005. By then biofuels will account for some 5–6% of total fuels in the US, close to the percentage projected by the European Commission, although the latter will involve a much higher proportion of biodiesel with the increasing popularity of diesel-powered vehicles. By comparison, the previous Australian Government has set a low target for biofuels of 350 mL/a by 2010 which is only 1% total liquid fuels. The Australian target includes both biodiesel and bioethanol.

3 FIRST GENERATION ETHANOL PRODUCTION

Ethanol is traditionally considered as a very low-cost, high-volume fermentation product produced from a range of sugar-based (eg. sugarcane, sugar beet) or starch-based (eg corn, grains, cassava) raw materials. Some pre-treatment of the raw materials may be necessary viz. desalting of molasses or enzymatic hydrolysis of starch, prior to fermentation by yeasts developed for high ethanol and high osmotic pressure tolerance. With such low-cost, high-volume products, the operating costs of the process are strongly influenced by raw material costs which can be up to 50-60% of these operating costs. This compares with very high value, much smaller volume biopharmaceuticals (therapeutics) – where raw material costs are relatively minor compared to the much higher product recovery and purification costs.

Production technology can vary from large batch fermentations using high yeast concentrations (as in Brazil) to more sophisticated continuous processes using cell recycling and vacuum operation to remove inhibitory ethanol, such as the molasses-based Biostil process at Sarina in Queensland (CSR Ltd). A continuous, multistage processes for conversion of starch waste to ethanol is also in operation in Australia (Shoalhaven Starches, Manildra Group). Processes are designed to achieve as great an economy of scale as possible, with those producing 50–150 mL/a (such as those in Australia) being relatively small scale by international standards. Production capacity is not the only determinant of market size, and can be limited also by the costs of raw material transportation to the plant site. To balance increased transport costs against the advantages of economies of scale, it is often considered that raw materials should only be transported (by road) from within a radius of 150 km from the plant. Capital costs for plants of capacities of 100 mL/a are likely to be of the order of $A 70–80 m with possible cost savings by using plant fabrication/construction in economies such as India.

4 SECOND GENERATION BIOFUELS

4.1 Global trends

Projections by the US Department of Energy are that by 2020, the volume of ethanol produced from the conversion of cellulosic materials (biomass) will be twice that produced from corn. However to achieve this goal, a number of technological hurdles will need to be overcome. These can be summarised as:

- the development of cost effective pre-treatment strategies for the various cellulosic materials. These include: size reduction, steam explosion and/or concentrated/dilute acid or alkali pre-treatment, as well as the enzymatic hydrolysis of cellulosic sugars to glucose,
- significant reduction in the costs of producing cellulase enzymes. The outlook is promising with 20-fold cost reductions already reported (Genencor, Novozyme) using protein engineering and gene shuffling techniques,
- the availability of robust recombinant microbes (either yeast or bacteria) for high ethanol yields from the C5 (xylose, arabinose) and C6 (glucose) sugars from the ligno-cellulosic hydrolysates. The presence of inhibitors such as acetic acid and furfural and its derivatives in the hydrolysates may require appreciable microbial strain conditioning and development
- product and market development for the non-reactive lignin by-product (approx. 15% total) with potential for its use in paints and adhesives
- higher value fermentation products (such as biopolymers and low calorie sweeteners) produced in association with ethanol will require the development of mutant and recombinant bacteria/yeast which are capable of high yields and productivities as well as being resistant to potential inhibitors in the hydrolysates.

Pilot-scale studies are being carried out in a number of economies in response to the need for technological 'breakthroughs' and for more accurate cost estimates of second generation processes. These include:

- a large-scale pilot plant which is in operation in Canada, developed by Iogen in association with Shell and PetroCanada. The plant is processing 6 t / day of wheat straw, with yields of up to 350 L /t resulting in about 700,000 L of ethanol per year. Iogen is now proposing to build a commercial scale plant (220 m L/a capacity) using 2,000 t/day wheat straw, with a projected capital cost of $US 200 m
- a Swedish company (Etek) has a pilot plant for processing 2 t/day of softwood, with a yield of 350 L/t . Production costs are estimated at $US 0.45–0.50 per litre for a plant using 600 tonnes of dry matter per day, with a plant capacity of approx. 70 m L/a based on current technology
- Dupont and Danisco have announced a three year investment of $US 140m in a process to convert corn stover and bagasse to ethanol using a recombinant strain (*Zymomonas mobilis*). Future targets include wheat straw and a variety of energy crops and other biomass sources
- a Dutch company (Nedalco) has announced the establishment of a plant to produce 200 m L/a bioethanol (2.5% European market) using a recombinant yeast and wheat bran as raw material. An investment of 150 m Euro is projected which includes support of 60 m Euro from the Dutch Government.

To stimulate development of appropriate new technologies, the US Department of Energy announced major financial support in 2007.The support included $US 385 m over 4 years to six companies for cost-shared bioethanol processes, $US 200 m for smaller scale biorefineries (10% scale) to evaluate new feedstocks, products and processing technologies for bioethanol and higher value products, and $US 125 m each over 5 years for 3 new Bioenergy Research Centres for basic biomass-related research (US Department of Energy website(2007)). In addition BP has provided $US 500m for biomass related R&D at the University of California, Berkeley.

A concept that is creating considerable interest now in the US and Brazil is that of an 'integrated biorefinery' that produces a range of fermentation products (including ethanol) from various carbohydrate fractions in the raw material. The idea draws heavily upon the extensive fractionation and range of products produced from hydrocarbons in oil refineries. In the case of the biorefinery, it offers the potential for higher value products, as well as ethanol, resulting in improved overall process economics. Archer Daniel Midlands (ADM) has pioneered this concept in the US, with large-scale fuel ethanol production from corn, and associated fermentation processes for amino acids (eg L-lysine), biopolymers, organic acids and antibiotics used in the livestock and poultry industries. Dupont has established an integrated corn biorefinery (ICBR) in which the higher value starch is converted to a biopolymer precursor 1,3 - propandiol using a GM strain of bacteria (*Escherichia coli*) with the residual lignocellulosic sugars being converted to ethanol using a genetically-engineered strain of Z. mobilis. Similar opportunities in Australia could well exist for high protein feeds (and possibly enzymes for use in local industries) in association with larger scale ethanol production.

4.2 Australian situation

The environmental and regional economic drivers behind the global expansion of biofuels are relevant also to Australia, together with the additional issue of increasing total oil imports and recent major oil price rises (Biofuels for Transport: A Roadmap for Development in Australia (2008)). Current production of bioethanol in Australia is in excess of 200 mL/a, sourced from two major producers: CSR at Sarina, Queensland from molasses, and Shoalhaven Starches P/L (Manildra Group) at Bomaderry in NSW from a starch waste stream. A new ethanol plant have been established recently at Dalby in southern Queensland, predominantly using sweet sorghum with capacity in the range 50-100 mL/a. New plants have been proposed also in NSW associated with a large-scale dairy operation and it is planned to make direct use of the valuable high protein dried distillers grain (DDG) as a feed supplement.

Support for increased bioethanol production has been provided by mandates proposed by the various Governments for blends up to E10 in 2010–12. (The NSW Government has recently mandated E2 blends increasing to E10 blends by 2011 and this has stimulated increased ethanol production and agreements with oil industry partners). However, the Federal Government's projected removal of the excise tax on imported ethanol in 2011 and reduction in the ethanol fuel tax concession (2011–15) pose an increased risk for investors, in view of the finance required for these new regional industries and the time to achieve cost reductions and establish production capacities and markets. The proposed introduction of a Carbon Emissions Reductions Scheme in Australia may counterbalance some of these investor uncertainties.

In addition, there is considerable potential for combining large-scale ethanol production with a strategy for land reclamation, particularly in low rainfall areas. For example, salt tolerant species of fast-growing cane (*Arundo donax*) and eucalypts have been developed which could be used as coppiced plantations for salinity control and as a source of biomass for fuel ethanol and/or electricity co-generation. However it is clear that much more R&D needs to be supported on these new sources of raw materials and their related second generation processes, including the use of flexible pre-treatment plant design and new strains of bacteria/yeast (for both high yield energy crops and agricultural/forestry residues).

4.3 Current Research

Biofuel research at the University of New South Wales over the past two decades has focused on the use of C5/C6 sugars for the development of high productivity continuous processes for fuel ethanol production as well as the use of a mutant yeast strain for conversion of xylose to xylitol.
Recombinant strains of *Z. mobilis* have been used to produce ethanol from C5/C6 sugars (xylose/glucose) typical of those found in lignocellulosic hydrolysates. (Davis et al., 2005; Rogers et al., 2007, 2008). High specific rates have been achieved with yields of 90-95% theoretical and ethanol concentrations in excess of 65 g/L in 48 h from equi-concentration mixtures of glucose and xylose. Stable flocculent strains of *Z.mobilis* have been isolated which are capable of achieving high density, high productivity fermentations. Various cellulosic raw materials have been evaluated for ethanol production and concentrations of specific inhibitors determined in their hydrolysates .

The production of xylitol from xylose has been studied using a mutant strain of Candida tropicalis in which the metabolic step from xylitol to D-xylulose (and subsequent metabolism) has been blocked by disruption of the xylitol dehydrogenase gene (XDH) (EC 1.1.1.9). Following a series of controlled kinetic studies, it was determined that both the parent and mutant strains had similar growth characteristics and biomass yields on glucose medium. However when xylose was provided as the carbon source, good growth occurred for the parent strain ($Y_{x/s}$ =0.5 g/g) while the mutant strain showed evidence of only minimal growth thereby confirming the negative effect on growth of XDH disruption.
When both glucose and xylose were provided in the medium, rapid growth and uptake of glucose occurred for both strains. Growth continued on xylose for the parent strain with low level xylitol production ($Y_{p/s}$ = 0.1 g/g) while close to stoichiometric conversion of xylose to xylitol occurred for the mutant strain ($Y_{p/s}$ = 0.95 g/g) with little if any further growth. A specific xylitol productivity of 0.07 g/g/h was estimated during the xylitol production phase of this mutant strain. The production of xylitol has attracted considerable recent interest as a result of its characteristics as a low calorie sweetener and potential for reducing dental caries (Granstrom et al., 2007a,b; Akinterinwa et al., 2008)

Collaborative R&D has been carried out on these and related projects with US, German, Korean and Australian commercial partners.

5 NCRIS PROGRAM

Within the Australian Government's Program of support for a National Collaborative Research Infrastructure Strategy (NCRIS), a Biofuels Sub-Program has been identified with total NCRIS funding of $A 7.7 m over five years (2007–11), and similar matching funds from state governments, industries and universities. Within the Sub-Program there are three components:

- a micro-algae photobioreactor facility for production of lipids for biodiesel, with total funds of $A 5 m from NCRIS and the South Australian Government being provided to the South Australian Research and Development Institute (SARDI)
- a pilot plant for ethanol production from bagasse with total funds of $A 6.5 m from NCRIS and the Queensland Government to the Queensland University of Technology and Mackay Sugar Pty Ltd
- an integrated R&D program on new second generation technology for conversion of biomass to ethanol, involving NSW, Sydney and Macquarie Universities, with total funds of $A 2.15 million from NCRIS, the NSW Government and the Universities.

NCRIS funding has been provided for infrastructure support and the challenge is now to build on this and develop industry-related projects and international research linkages.

6 CONCLUSIONS

Global ethanol and biofuel production over the last few years has been stimulated by the current high price of oil, fuel security and environmental concerns, as well as the potential to enhance regional development. The increased ethanol production has come largely from sugar and starch-based crops traditionally used also in the food industry. Projected further increases in biofuel production over the coming decades involve the greater use of potentially lower cost biomass (lignocellulosics) as feedstock. Achieving this will require significant technological breakthroughs (pre-treatment, enzymes, recombinant micro-organisms), while opening up the opportunity for the use of agricultural/forestry residues, new high biomass yielding energy crops and associated higher value fermentation products.

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Session I: Keynote speaker (Australia); Emeritus Professor Dr. Peter L. Rogers

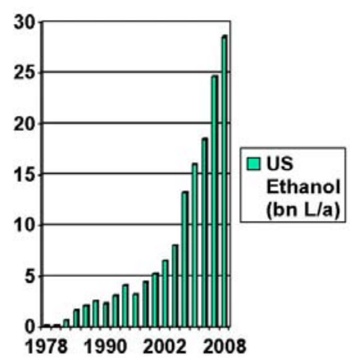
Ethanol and Higher Value Fermentation Products from Cellulosic Materials

APEC International Symposium
Chiang Mai Thailand
May 24-27, 2010

Peter L Rogers
Emeritus Professor, UNSW

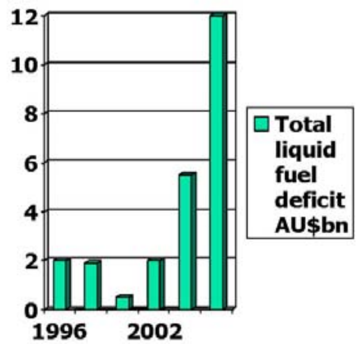
Global Growth in Biofuels

- Brazil : 27 bn L/a ethanol in 2008 from molasses, sugar cane juice, cassava
- US: 28 bn L/a in 2008 from corn (20% total crop): 2.6% total US liquid fuels
- China: current 2 bn L/a ethanol (very large scale future plants projected)
- European Commission targets 2010 12 bn L/a (6% total liquid fuel)
- Australia : 200-250 m L/a ethanol, 50 mL/a biodiesel. Target by 2010: 350 m L/a (1% total liquid fuels)



Australia's Increasing Liquid Fuel Deficit

- Total imports of gasoline, diesel and crude oil currently exceeds $12 bn
- Significant increase since 2000 due to increased demand, higher costs and declining local production
- Expenditure on oil imports has reached 3% GDP (RBA Bulletin 2008)

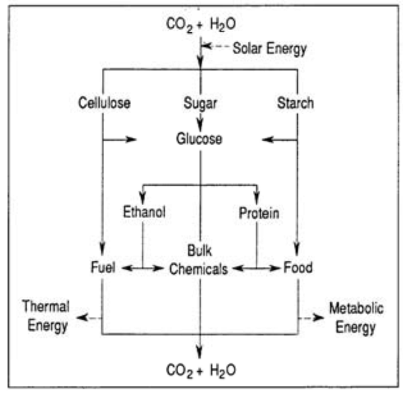


Main Drivers for Biofuels

- High oil price and increasing oil imports
- Reduced oil imports with E2,E10 (and E85) fuels and biodiesel
- Environmental issues: GHG reduction, use of renewable resources, sustainable processes
- Potential for new regional industries
- Agricultural sector capable of increased production of raw materials

Use of Renewable Resources : the Carbon Cycle

- Use of carbohydrate-based raw materials rather than those based on hydrocarbons
- Results in reduction in Greenhouse Gas (GHG) emissions
- Particular applications for commodity chemicals and biofuels (bioethanol)



Carbon cycle showing conversion of solar energy into thermal and metabolic energy

Major concerns re use of food crops for production of biofuels

- Increased food costs – direct competition for starch and sugar-based crops re ethanol production; plant oils re biodiesel
- Direct competition for arable land and associated resources (water, fertilizers)
- Major impacts in poorer, less developed countries re increased food costs
- Increased environmental impacts (eg clearing of forests for palm oil plantations in SE Asia or increased sugar cane plantations in Brazil).

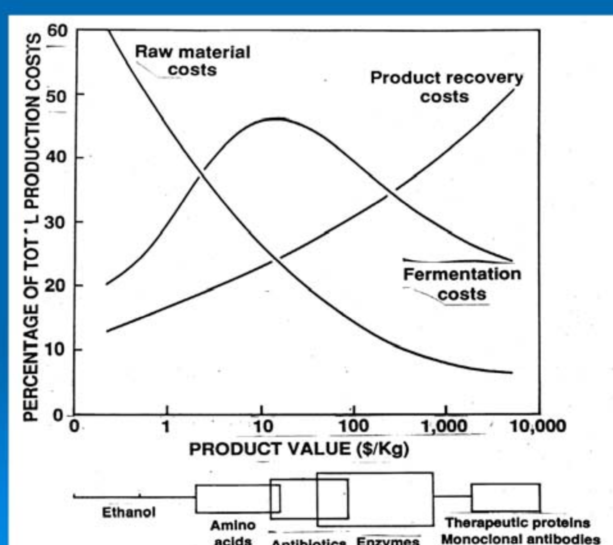
See: International Risk Governance Council Report on Biofuels (2008)

Cost comparisons for various Biotechnology Products

Commodity Biochemicals
Chemicals/Biochemicals produced by enzymatic or fermentation processes in large volume at relatively low cost ($1-5/kg) : commodity products. Examples are ethanol, organic acids, amino acids (eg L-lysine, MSG), baker's yeast, biopolymers.

High Value Products
Antibiotics, enzymes, vitamins, therapeutic proteins, monoclonal antibodies, anti-cancer and antiviral drugs etc. are produced at much smaller volume, higher cost products with values up to $10-1000/g in some cases.

Factors affecting operating costs



1st and 2nd Gen Processes for Biofuels

- 1st Gen processes :
  - starch and sugar-based processes for ethanol
  - oil-based crops (canola, palm oil) for biodiesel

- 2nd Gen Processes :
  - agricultural/forestry residues or high yield energy crops (biomass) for ethanol
  - new oil bearing crops (eg Jatropha sp) for biodiesel
  - oil/fat residues (eg tallow) for biodiesel
  - high lipid producing algae (in ponds or bioreactors) for biodiesel

- 2nd Gen Processes largely avoid competition with food-based agriculture and may have reduced water/nutrient requirements

First Gen ethanol: starch and sugar-based raw materials

Typical process : pretreatment (upstream processing), fermentation, ethanol recovery (distillation)

Ethanol from starch conversion plant

Pretreatment strategies

For sugar-based (molasses) fermentations pretreatment/ desalting may be necessary

For starch –based (corn,wheat,cassava) a 2 enzyme process is used to hydrolyse starch

-an alpha amylase to produce dextrins (T=90-100 C,pH=6.5)

-a glucoamylase to produce glucose (T=55-60 C,pH=5.0)

Microorganisms for ethanol production

Yeasts are normally used (ethanol tolerant strains of *Saccharomyces cerevisiae, S.uvarum or Schizomyces pombe)*

*Strains of the bacterium *Zymomonas mobilis* are also used for tropical fermented drinks (pulque, palm wines)

Contamination by *Lactobacillus sp* is a common problem in many fermentation processes/reduced by operating at pH=3-4

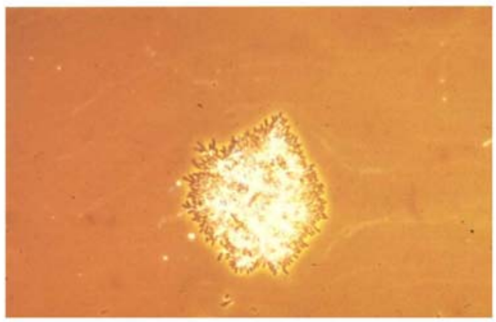
Characteristics of *Z. mobilis*

- Isolated from tropical fermented beverages
- Uses Entner-Doudoroff Pathway for glucose metabolism to ethanol producing 1 mole ATP/mole glucose
- Much faster specific rates of sugar uptake and ethanol production than yeasts
- Higher ethanol yield than yeasts (up to 96% theoretical)
- Tolerant to relatively high ethanol (16% v/v)
- However wild-type strains can only ferment C6 sugars (glucose, fructose, sucrose)

Electron microscope picture of bacterium *Zymomonas mobilis* (ZM4)

Flocculent Z.mobilis ZM401

- High productivity repeated batch fermentations achieved with flocculent cells



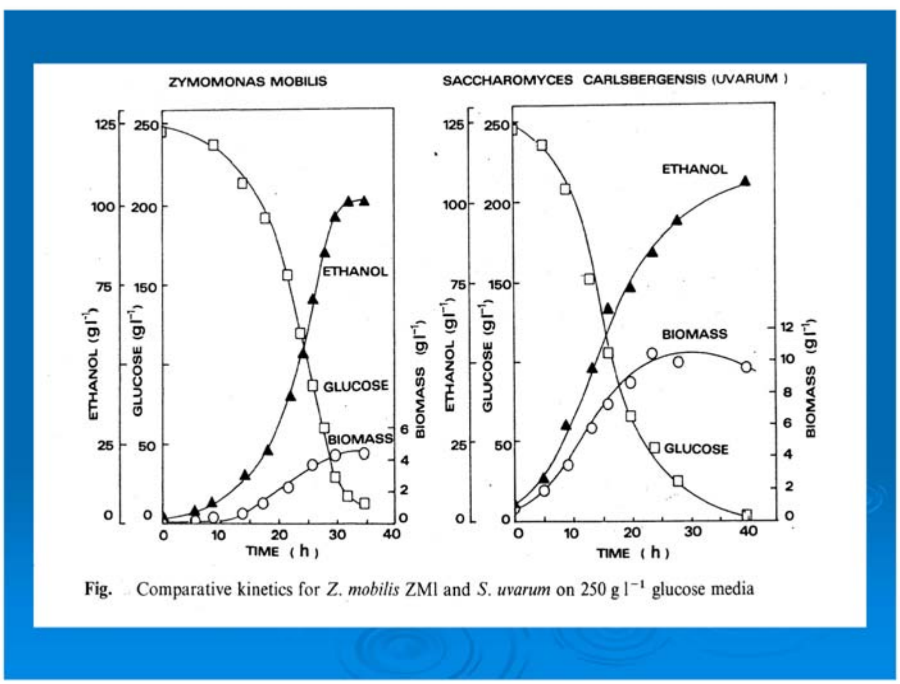


Fig. Comparative kinetics for *Z. mobilis* ZM1 and *S. uvarum* on 250 g l^{-1} glucose media

Fermentation ethanol : kinetic analysis

For fermentation by yeasts (or in some cases bacteria) stoichiometry is :

1 mole glucose gives 2 moles ethanol plus 2 moles CO2 (Theoretical yield = 0.51g/g)

Yeasts usually produce 10-12% v/v ethanol (80-100 g/l) although some saki-producing yeast can reach up to 16-18% (v/v)

Key kinetic parameters for a yeast or bacterium are :

- ethanol yield (Y p/s),
- ethanol productivity (g/l/h),
- specific growth rate (/h) and specific ethanol productivity (g/g/h)

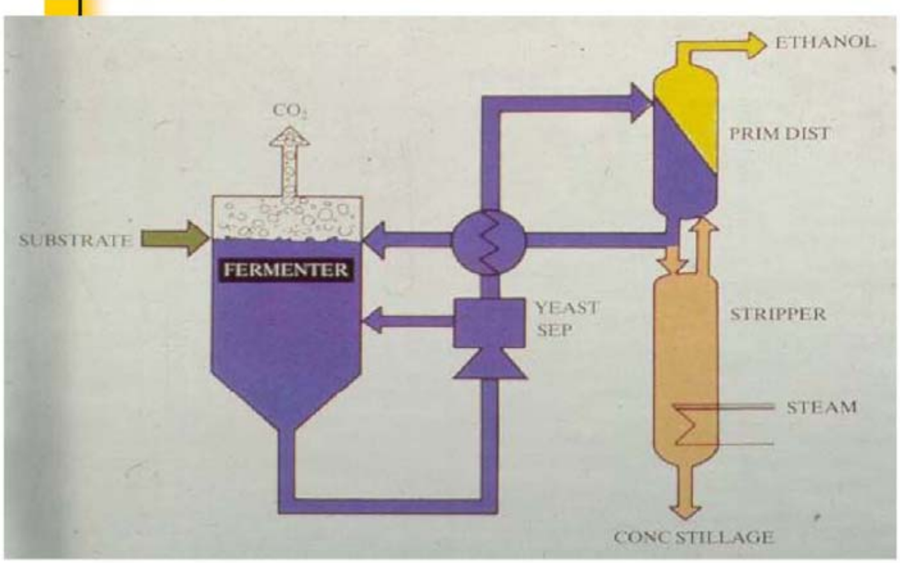
Table Comparative kinetic parameters for *Z. mobilis* (ZM1) and *S. uvarum* in batch culture ($250\ g\ l^{-1}$ glucose media, pH = 5.0, T = 30 °C)

Kinetic parameters	*Z. mobilis* (non-aerated)	*S. uvarum* (non-aerated)	*S. uvarum* (aerobic)
Specific growth rate, μ	0.133	0.055	0.12
Specific ethanol productivity, q_p	2.53	0.87	0.61
Specific glucose uptake rate, q_s	5.45	2.08	1.47
Cell yield, $Y_{x/s}$	0.019	0.033	0.045
Ethanol yield, $Y_{p/s}$	0.472	0.438	0.395
Ethanol yield, (% of theoretical)	92.5	85.9	77.5

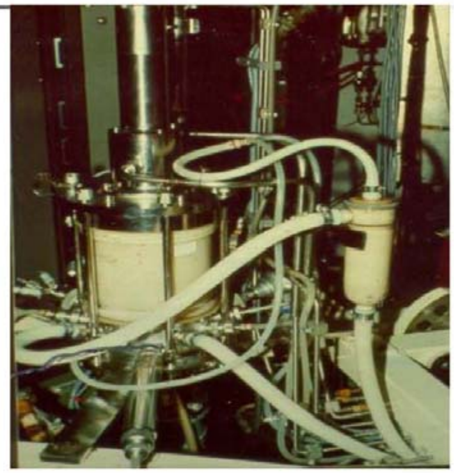
Modes of Fermentation

- Batch processes in which all raw materials are added at the beginning of fermentation
- Continuous processes with constant flow rate of raw materials and ethanol removal
- Continuous processes with cell recycle to achieve high cell concentrations and productivities

Industrial ethanol production cell recycle/vacuum fermentation



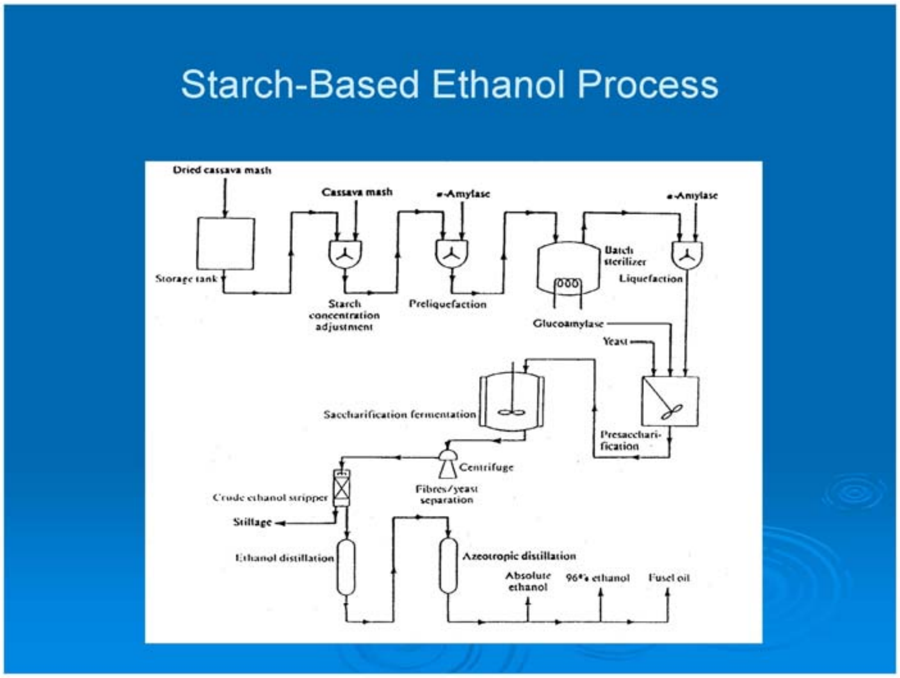
Continuous cell recycle process for high productivity fermentation

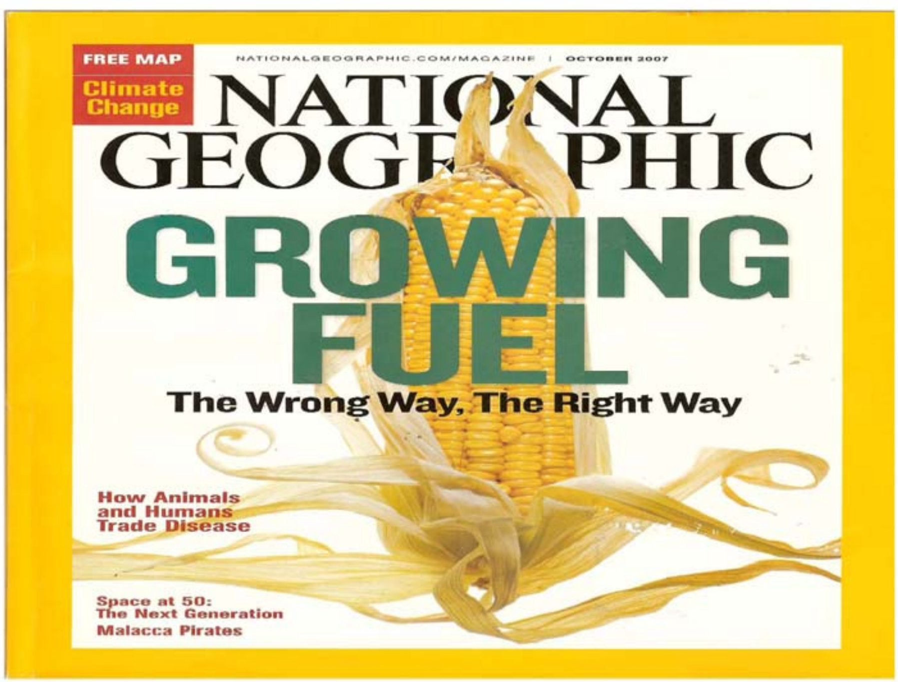


Downstream Processing/ Ethanol Recovery

•Ethanol can be produced as two basic products
- as an azeotrope (96% blend with water)
- as anhydrous ethanol following water removal using tertiary distillation, molecular sieve or pervaporation membrane techniques

The anhydrous form is required for blending with petrol or diesel (usually 10-15% blends). E5,E10 and E85 blends are currently in use (the latter in the US and Brazil)


Starch-Based Ethanol Process
Dried cassava mash
Cassava mash
α-Amylase
α-Amylase
Storage tank
Batch sterilizer
Liquefaction
Starch concentration adjustment
Preliquefaction
Glucoamylase
Yeast
Saccharification fermentation
Presacchari-fication
Centrifuge
Crude ethanol stripper
Fibres/yeast separation
Stillage
Ethanol distillation
Azeotropic distillation
Absolute ethanol
96% ethanol
Fusel oil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Climate Change
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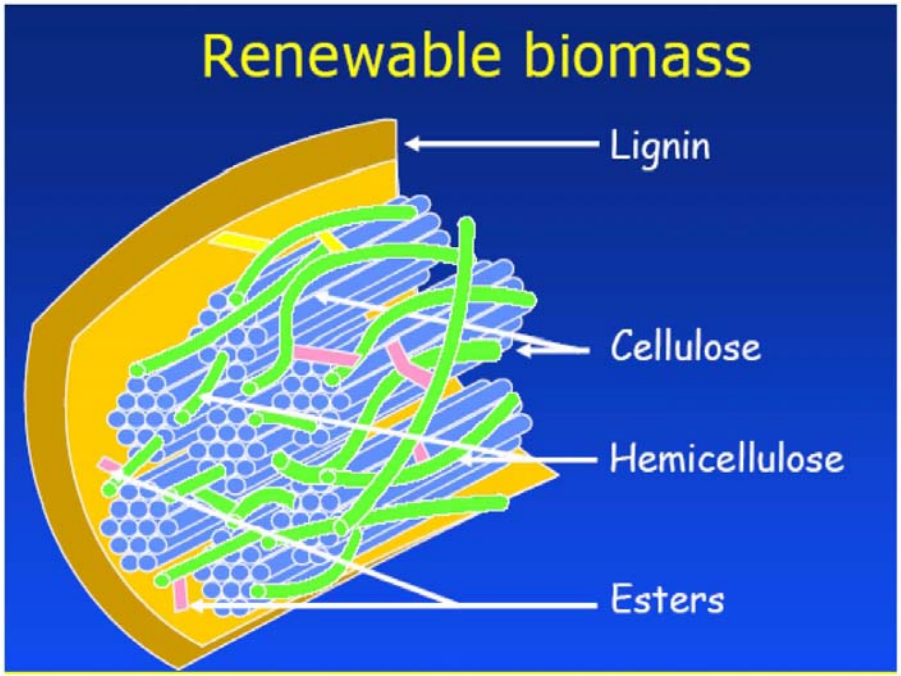
The Wrong Way, The Right Way
How Animals and Humans Trade Disease
Space at 50: The Next Generation
Malacca Pirates



Second Generation Processes : Current Status

2nd Gen processes : conversion of ligno-cellulosic biomass to fuel ethanol (cf. usual sugar or starch based processes)

Potential advantages

- lower cost raw materials
- greater availability (agricultural/forestry residues; new crops)
- no competition with food crops
- greater GHG reduction compared to starch-based crops
- potential to develop new high yield energy crops (GM?)

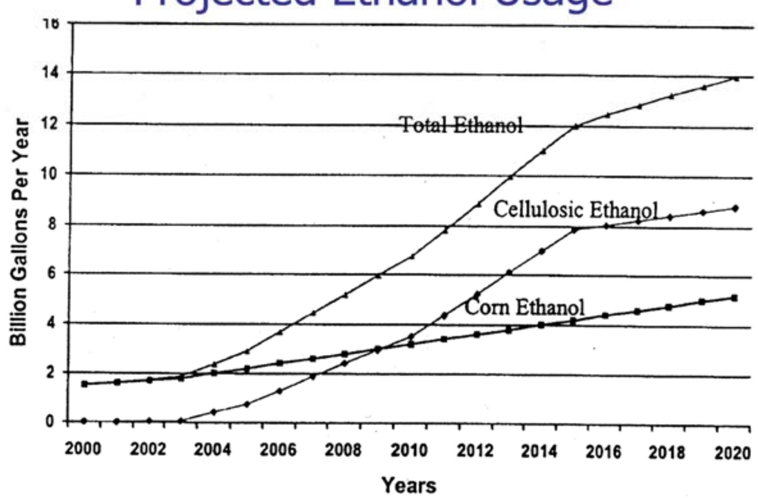
However significant R&D needed to reduce production costs involving optimized pre-treatment, new enzymes, new microbes

Projections : US Dept Energy

- By 2020, twice as much ethanol in the US will be produced from ligno-cellulosic biomass as from corn
- Reduce US gasoline consumption by 20% in 10 years
- Major DOE funding to achieve cost competitive ethanol production from biomass by 2012 announced in May 2007 :
  - $US 385m over 4 years for cost-shared integrated biorefineries
  - $US 200m for small scale (10%) facilities to evaluate new feedstocks, products and processing technologies
  - $US 375m for up to 3 new Bioenergy Research Centres

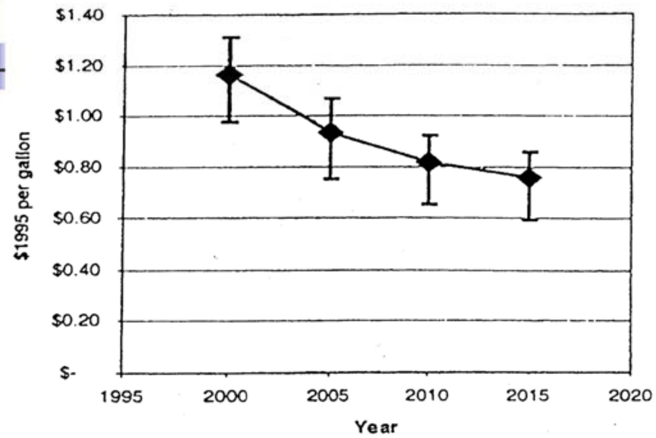
(Biorefineries will involve both ethanol and higher value fermentation products from renewable carbohydrate feedstocks)

Projected Ethanol Usage



Source: Mark Paster, Office of Biomass Program, US Department of Energy, 2002

Projected Ethanol Production Costs



Price Trajectory for Ethanol Production Costs from Lignocellulosic Raw Materials using Enzyme Based Process (Source: Woolly *et al*, 1999)

R&D Breakthroughs needed

- Improved chemical pre-treatment (methods include mild acid, strong acid or alkali pre-treatment)
- Availability of higher activity, lower cost cellulases for cellulose conversion
- Development of robust recombinant yeast/ bacteria for fermentation of C5/C6 sugars
- Lignin recovery/upgrade to higher value products
- Potential GM high yield energy crops

Dupont Integrated Corn Biorefinery (ICBR) : Biopolymers

- Joint venture with Tate and Lyle
- Production of 1,3 propandiol (PDO) as an intermediate for the biopolymer Sorona
- Use of genetically engineered *E.coli* for fermentation of hydrolysed corn starch
- Plant construction commenced early 2004.

Dupont Integrated Corn Biorefinery (ICBR) : Fuel Ethanol

- DOE supported R&D project ($A50m) in collaboration NREL/Poet/Novozyme
- Lignocellulosic residues (stover, cobs) from corn
- Use of rec *Z.mobilis* for fermentation
- Life Cycle Analysis re energy/water requirements
- Additional DOE funds (50% capital costs) - 100m L/a plant. Construction to commence 2009

Europe : Nedalco builds 2nd Gen bioethanol plant

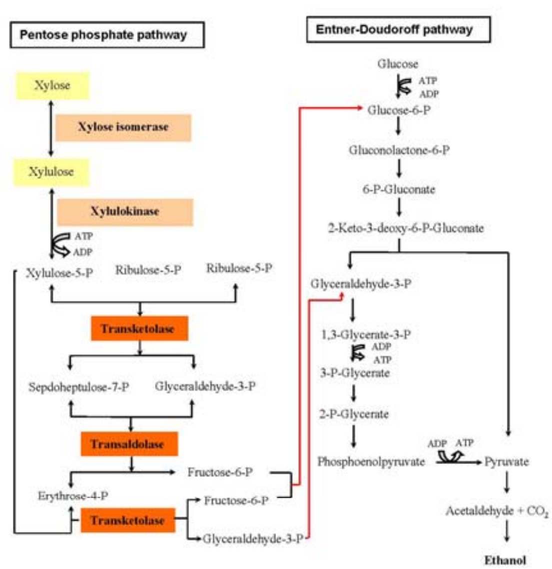
- Investment of approx 150 m Euro with some support for Dutch Govt (total 60 m Euro fund)
- Press release (March 2007) : from end of 2008 plant will be capable of producing 200 m L/a bioethanol (2.5% European fuel market)
- Use of patented yeast capable of converting major sugars in wheat bran to bioethanol. Pre-treatment 150 C, pH=3, 15 min; enzymes
- Estimated that CO2 emissions will be reduced by 60-80% compared to use of non-renewable fuels (petrol, diesel)

R&D Focus at UNSW Second Generation Biofuels

- high productivity fermentation processes for bioethanol/fine chemicals (eg with yeasts and bacteria (*Zymomonas* sp))
- R&D projects with Australian and overseas governments and industries
- collaboration with Dupont/NREL on process for ethanol from corn processing residues
- 2nd Gen processes using cellulosic biomass (agricultural/forestry residues or high yield 'energy crops')

Genetic Engineering of Zymomonas

- Smaller genome (2m base pairs) than yeasts : genome published in 2005.
- Initial cloning of single genes for other sugars such as lactose. UNSW first group to clone single genes.
- Metabolic engineering involving multiple genes to build new metabolic pathways for 2ng Gen processes (eg Zhang et al for xylose and arabinose). US Patents filed 1997.
- Dupont/Danisco plant ($US 140m) for ethanol from ligno-cellulosics (bagasse, corn stover) using rec Zymomonas



Batch kinetics of rec *Z. mobilis*

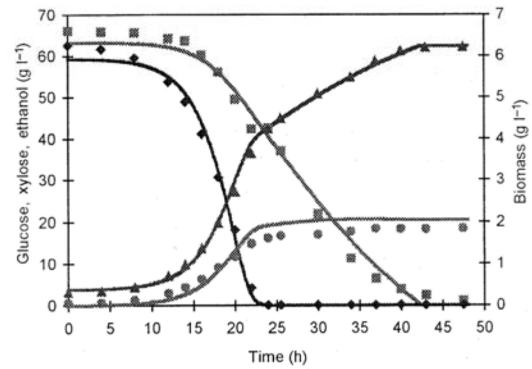
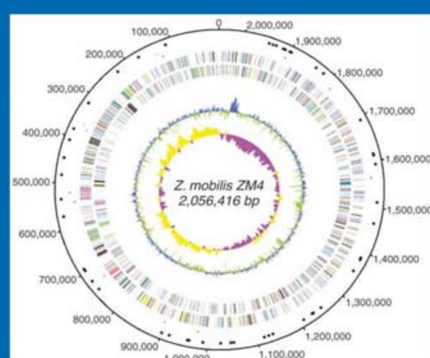
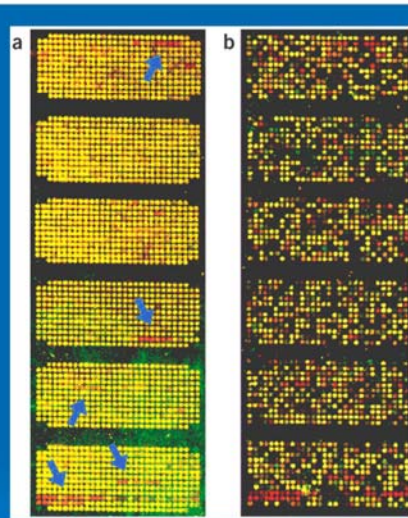


Fig. 3. Simulation of the mixed sugar system and experimental data for ZM4(pZB5) on 65 g l^{-1} glucose and 65 g l^{-1} xylose medium. ♦, Glucose; ■, xylose; ▲, ethanol; •, biomass.



Genomic Sequence of *Z. mobilis* ZM4

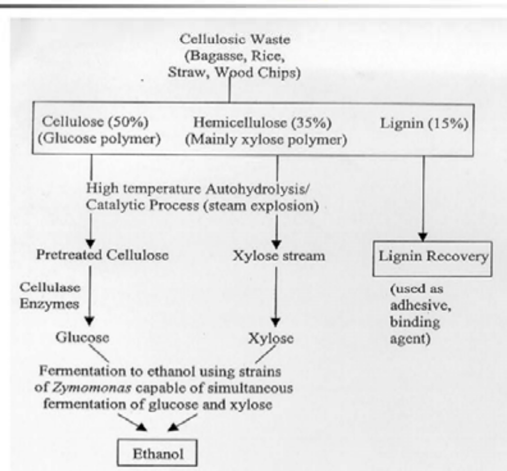
(Source: *Nature Biotech*., 23(1), 63-68, 2005)



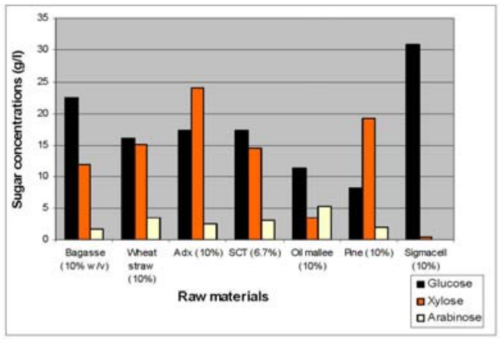
Example of Microarray Technique used for *Z. mobilis* strain comparisons

(Source: *Nature Biotech*., 23(1), 63-68, 2005)

Zymomonas-based process for conversion of lignocellulosics



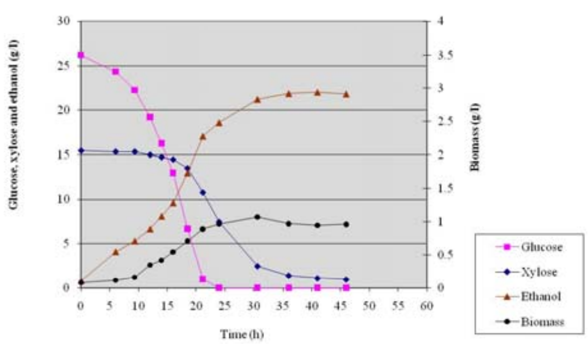
Sugar recovery from various cellulosic raw materials using acid-pretreatment



Adx= Arunda donax
SCT= Sugar Cane Tops
Sigmacell is control

Sugar extraction from biomass sources (10% w/v) using 2% (v/v) H_2SO_4, 1hr at 134°C with 2% cellulase and 4% glucosidase enzyme (Novozyme) treatment (22 h).

ZM4 (pZB5) in sugarcane bagasse acid/enzyme hydrolysate



Acid/enzyme hydrolysis conditions: 2% H_2SO_4 at 134° C for 1 h; enzyme hydrolysis using 2% cellulase and 4% β-glucosidase at 60° C for 22 h

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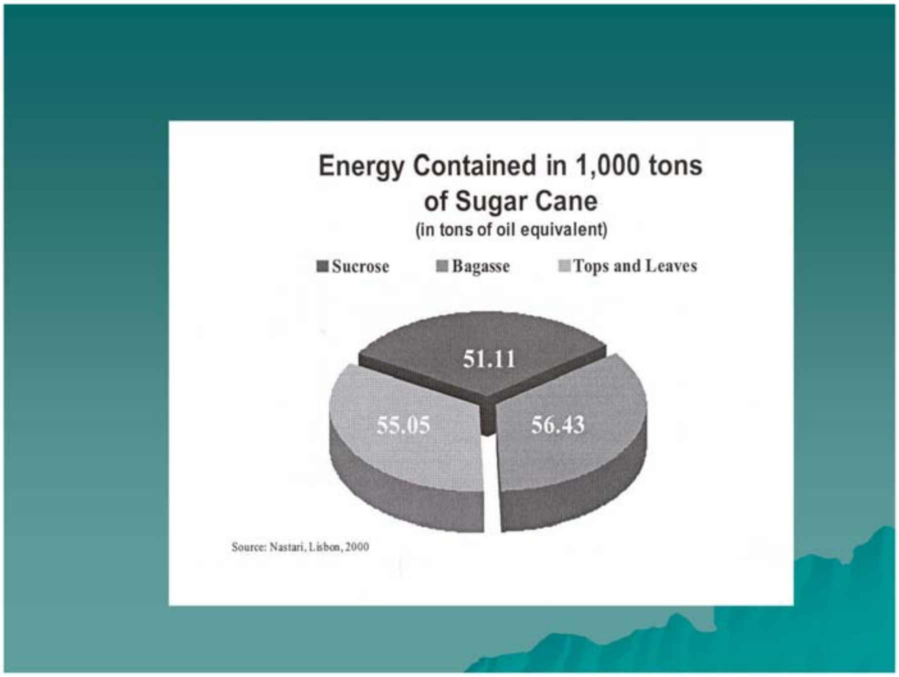


Aust Government Biofuel R&D Initiatives

- NCRIS Biofuels Sub-Program (2006-2011)
  - bagasse to ethanol pilot plant (QUT/Mackay Sugar $6.5m)
  - microalgae pilot plant (SARDI $5m)
  - integrated R&D program on pretreatment, enzyme development and fermentation (USyd, Macq, UNSW $2.15m)

- Gen 2 R&D Program (commenced mid 2009)
  $15m funds for biofuels to be provided from $500m Renewable Energy Fund for R&D and industry-linked projects

State Govt Mandates : eg. NSW mandated 2% bioethanol/biodiesel (average use) in fuels in 2006, increasing to 10% by 2011.

NCRIS BIOFUELS LABORATORY UNSW

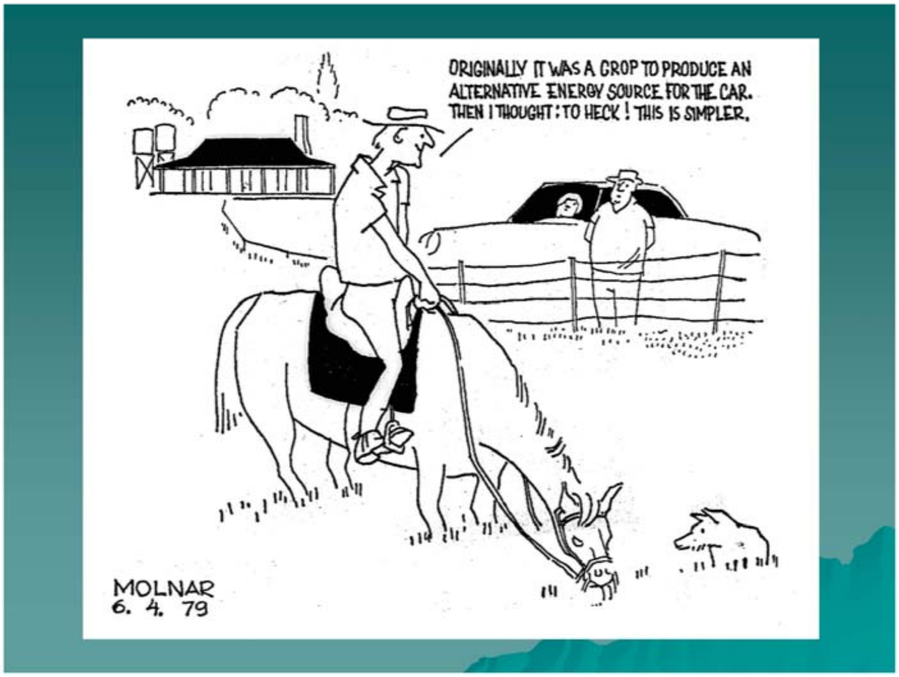
Computer Controlled 3L Fermentor for Bioethanol Production

Computer Controlled 20L Tower Fermentor for High Productivity Bioethanol Production using Flocculent Yeast or Bacteria

Opportunities in Australia: Integrated Biorefinery Concept

- Sugar industry: expanded fuel ethanol, higher value products (eg enzymes, biopolymers, high value protein feed)
- Starch industry: higher value modified proteins, ethanol from starch/waste
- Cellulosic biomass: energy crops, trees re salinity control for fuel ethanol and/or electricity co-generation
- However issues re available land, water etc as well as Govt incentives are critical to industry development

Four year old mallees grown in alleys for salinity control


ORIGINALLY IT WAS A CROP TO PRODUCE AN ALTERNATIVE ENERGY SOURCE FOR THE CAR. THEN I THOUGHT: TO HECK! THIS IS SIMPLER.
MOLNAR
6. 4. 79


NEVER EVER GIVE UP

Session II

International APEC Symposium on
“Biofuels from Agricultural and Agro-Industrial Wastes”
May 24th – 27th, 2010, Chiang Mai, Thailand

CURRENT STATUS AND READINESS OF INDONESIAN BIOFUEL IMPLEMENTATION PROGRAM

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Abstract: Since October 1st, 2008, the government of Indonesia has gradually mandated the utilization of biofuel in transportation, industry and power generation sectors. The objective of biofuel implementation program, in addition to improving energy security, is reducing fossil fuel import, poverty alleviation, job creation and reducing CO2 emission. The paper describes mainly aspects on readiness for biofuel implementation through commercial approaches. The paper also reports current status of biofuel industries in Indonesia.

Keywords: biofuel, renewable energy, Indonesia, biodiesel, bioethanol.

1 INTRODUCTION

The use of biofuel in Indonesia is indispensable due to the increase of fuel in all economic sectors, in particular transportation sector. In addition, development of biofuel will also generate multi flier economic that provide significant role in the national economic development. For example, by assuming that 3% of national diesel fuel consumption can be substituted by biodiesel, it will provide around 100,000 new jobs.

The two most common types of biofuels that are currently produced in Indonesia are bioethanol (or a blended fuel that is called "gasohol") and biodiesel. For biodiesel production, the Crude Palm Oil (CPO) from large scale palm oil plantations has been becoming the primary source. Several other programs are relying on both non-edible oil such as jatropha oil from Jarak/Physic nuts (Jatropha curcas) and edible plants such as coconuts. Municipal waste is also considered as raw material for bioenergy

The high potential for biofuel feedstock in Indonesia is proven by availability of varied biofuel feed stocks that can be developed. Palm oil and Jatropha are developed as feedstock for biodiesel, meanwhile cassava and sugar cane are utilized as feedstock for bioethanol. However, Indonesia is also opened for the development of other biofuel feedstock such as corn, sago palm, sugar palm and sweet sorghum for bioethanol and coconut for biodiesel; it depends on region's biofuel potential and .taking into consideration the issue on food versus energy. Now, Indonesia is also developing non edible feedstock such as algae, waste palm oil and lignocellulosic material for second generation biofuel.

The paper will describe mainly on the effort of Indonesia government and related stakeholder in developing and implementing biofuel as substitution for petroleum-based diesel fuel from upstream to downstream industries, policies, regulations, challenges and future plants.

2 UPDATES ON CURRENT DEVELOPMENT

The main aims of the National Energy Policy (Presidential Decree on National Energy Policy No. 5, 2006) in Indonesia are to: (i) guarantee the energy supply to meet national interests; (ii) increase the added value of energy sources; (ii) manage sustainable sources of energy in an ethical and sustainable manner; (iii) focus attention on conservation of environmental functions; (iii) provide affordable energy for low income people and for less developed areas, develop gender sensitive energy programs and develop domestic capacities. The policy has provisions for (i) supply (production exploration, energy diversification, and production optimization), (ii) demand (energy efficiency and energy conservation), and (iii) supporting actions (energy infrastructure development, subsidy policy for the poor, government and private sector partnership scheme, public involvement, research and development, biofuel standardization).

In 2007, Law on Energy was issued with special attention on new renewable energy development and energy conservation. Under this law, provision and utilization of new renewable energy should be increased by government and local government following their authorities. Furthermore, provision and utilization of new renewable energy can get incentives from government/local government for certain period until it reaches economical development stage. Currently government regulations as implementing regulation on renewable energy and energy conservation are being prepared.

Table 1. Gradual biofuel mandatory on biodiesel and bioethanol

BIOETHANOL (Minimum)						
Sector	**2008**	**2009**	**2010**	**2015**	**2020**	**2025**
Transportation, PSO	3% (Existing)	1%	3%	5%	10%	15%
Transportation, Non PSO	5% (Existing)	5%	7%	10%	12%	15%
Industry		5%	7%	10%	12%	15%
BIODIESEL (Minimum)						
Sector	**2008**	**2009**	**2010**	**2015**	**2020**	**2025**
Transportation, PSO	1% (Existing)	1%	2.5%	5%	10%	20%
Transportation, Non PSO		1%	3%	7%	10%	20%
Industry	2.5%	2.5%	5%	10%	15%	20%
Electricity	0.1%	0.25%	1%	10%	15%	20%

Since October 1st, 2008, the government of Indonesia has gradually mandated the utilization of biofuel in transportation, industry and power generation sectors. For example, even though the mandatory in transportation sector is still 1% in 2008, in some regions that are close to the biofuel production facilities, the blending percentage is 5%. The objective of the mandatory, in addition to improving energy security, is reducing fossil fuel import, poverty alleviation, job creation and reducing CO2 emission. Table 1 shows the Ministerial Decree for gradual mandatory on biofuel.

3 READINESS ON BIOFUEL IMPLEMENTATION

3.1 Aspect on quality, specification standard

In fact, biodiesel development in Indonesia is not just begun. It was dated back to the early 90th when PPPTMGB Lemigas, one of R&D Center under Department of Energy and Mineral Resources, carried out research on biodiesel process and utilization. In 2001, Indonesian Biodiesel Forum was established as a forum for communication and experience exchange between biodiesel people. The forum members comprise scientists from universities and research institutes, automotive industry associations, palm oil association, engineering industries, biodiesel producers, relevant government offices (Ministry of Transportation, Ministry of Energy and Mineral Resources, Ministry of Agriculture) and several non governmental institutions.

Utilization of biodiesel in commercial implementation should be complemented with the availability of a specification standard that will guarantee quality of biofuel product and be tested with proven test method. The standard itself was prepared to provide a quality assurance for consumer and also as guidelines for biodiesel producer. Indonesia has issued National Standard for biodiesel and bioethanol specification, and soon to be in place is specification standard for pure plant oil as the fuel for low-medium speed diesel engine. Ministry of Energy and Mineral Resources has then followed-up by new fuel specification that allows a maximum 10% blending of biofuel with petroleum based fuel.

Ministry of Energy and Mineral Resources established a task force to carry out monitoring including surveillance test for implementation of biodiesel and bioethanol specification standard. Monitoring also includes surveillance test for volumetric blending of biofuel to the petroleum fuel to ensure that biofuel mandatory regulation is in place in good quality and exact quantity.

Table 2. Biomass potential for bioethanol

Potential feedstocks	Volume
Feedstocks: wastes from agriculture, bagasse, palm oil	74.000 million ton
Potency on bioethanol	22,2 million KL
Equivalent to gasoline	10,7 million ton
Gasoline consumption	12,9 milliom ton
Potency on gasoline substitution	82,9 %

Source: APEC, 2008

3.2 Aspect on Supply (Feedstock and Product)

As located in tropical region and agricultural based economy, Indonesia has an abundant of biomass energy potential. It is estimated that Indonesia has around 50 GW of biomass energy potential from wastes excluded biofuel and other crops. As a tropical economy, Indonesia is rich and abundant with various oil producing plants such as coconut, palm oil, sunflower, kapok and jatropha. From a survey conducted by Bandung Institute of Technology, there are more than 50 plant species that can be developed for biodiesel feedstock. For bioethanol, cassava is in the top priority along with sugar cane and sorghum to be developed as bioethanol feedstock.

For biodiesel feedstock, production of Crude Palm Oil has reached 21 million ton in 2009. Of this amount, only 4 million ton was utilized for food consumption, while the rest is being exported. It is estimated that Indonesia has a potential about 5 million ton per year from sustainable crude palm oil for biodiesel production, without disturbing domestic food needs. The growth of CPO production is estimated around 12% per year. In addition to food-based feedstock, from a study carried out by APEC in 2008, as indicated by Table 2, at least 82% of gasoline consumption could be replaced by second generation bioethanol generated from cellulosic biomass.

Currently, Indonesia has an installed capacity of 270,537 kL per year of bioethanol production and 3,455,726 kL per year of biodiesel production (status on Aug, 2009) from 51 biofuel licenses that has been issued by the government. Eventhough several issues in relation to sustainability aspect are still need to be solved, it has opened the possibility to export biodiesel to other economies in particular European economies and USA.

Further, for biofuel utilization in transportation sector has been started since 2006. The share of biofuel share in gasoline and diesel oil is continuously increased until in November 2009, the share of biodiesel on diesel fuel is 5% (B-5), the

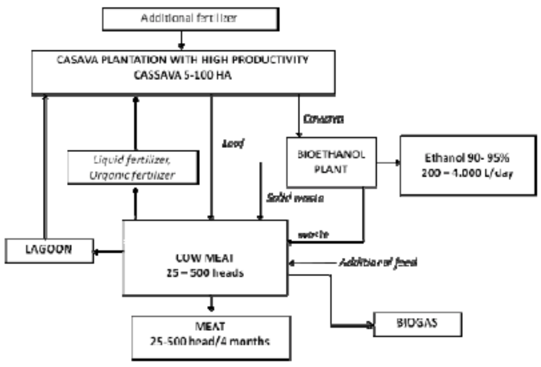

Figure 1. Scheme of cassava baseed integrated bioethanol plant

share of bioethanol on premium m gasoline fuel (PSO) is 3% (E-3) and the share of bioethanol on pertmax gasoline fuel (non PSO) is 5% (E-5).

Since 2008, the government has provided a new subsidy scheme for biofuel in retail system for transportation use. By this subsidy, retail price of blended biofuel with petroleum fuel are sold in the same price of subsidized fuel.

In addition to the subsidy, several incentives have been introduced to support sustainable biofuel implementation such as staging of mandatory biofuel utilization, tax exemption on VAT, investment tax incentives, interest rate subsidy for biofuel feedstock plantation and simplifying the license procedure on biofuel business.

As biofuel has been a new industrial sector that attracts investment, Indonesia has an association of biofuel producer, namely Association Of Biofuel Production Indonesia (APRO OBI) to support biofuel development in Indonesia. APROBI is active in promoting biofuel implementation in Indonesia and also in global market in p providing high quality biodiesel. APROBI gives a high attention also on the issue of environment and conservation of natural resources and biodiversity. In addition to large scale biofuel manufactures, initiatives to develop small scale biofuel than can be operated and utilized directly by rural people are now in the implementation a across the economy. The government through a program so called Energy Self-Sufficient Village construct a small biofuel plant with capacity around 4400 litre per day. This program has been developed since 2007 and now around 20 plants have constructed. Cassava and sweet sorghum are consider red as most interesting plantation since its multi fu unction of the product. The plant is integrated with other productive economic activities, so the rural people can advantage not only from the fuel but also other economic product and services.

3.3 Aspect on Regulation readiness

In order to force biofuel development and to maintain its sustainability, the government of Indonesia has some targets and efforts in order to achieve those targets, that are (i) Mandatory of biofuel utilization on transpoortation, industries and electricity generation sectors; (ii) Development of Energy Self-Sufficient Village; (iii) Increase the blending content of biofuel f for commercially traded fuel; (iv) Establishment o of competitive pricing policy for biofuel. Figures 1 and 2 show schemes of

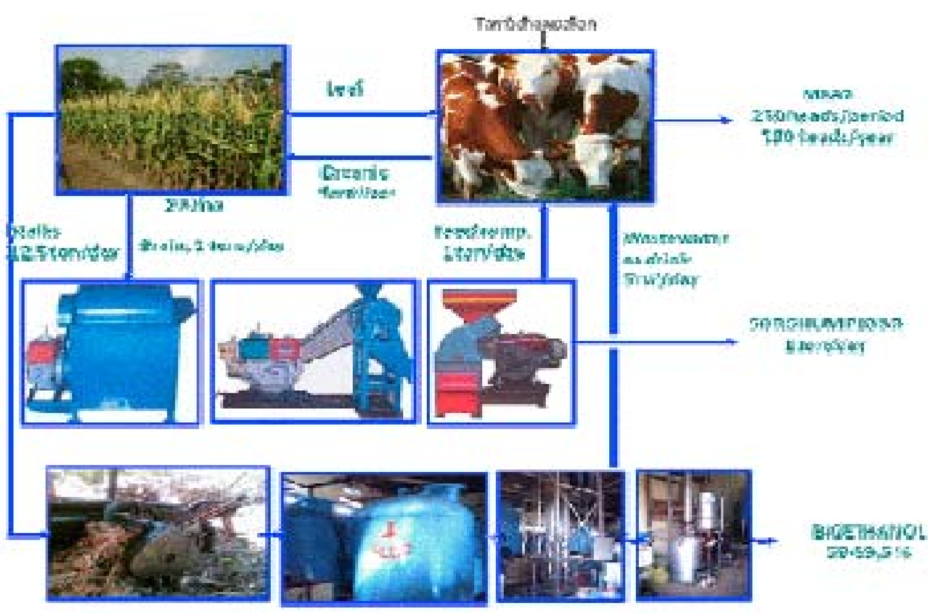

Figure 2. Schemee of sweet sorghum based integrated bioethanol plant

integrated small scale bioethanol from cassava and sweet sorghum.

Government with consultation to stakeholders has issued regulations that support a sustainable biofuel implementation, for example National Standard on biofuel specification that fits with domestic feedstocks. The current existing regulation has been proven in supporting biofuel implementation. Currently, the government is preparing a government regulation on New Renewable Energy including biofuel that will provide regulations on such as feed-in tariff, financing, R&D budget, RPS.

4 CONCLUDING REMARKS

As part of national energy policy, the utilization of biofuel will be continuously implemented and improved by combining efforts on providing incentives and diversification of feedstocks. Improving productivity of main feedstocks such as palm oil, jatropha, cassava and sugar cane are also of the concern from the government. Most research and development now are devoted to jatropha curcas to bring this highly potential feedstocks to commercial implementation.

Even though palm oil now currently can fulfil the demand for biodiesel, there is a need to start with development of non-edible feedstock and dedicated feedstock for biofuel. In addition, development of second generation of biofuel that will create sustainable and low cost biofuel industry is also in the national pipeline. It is, therefore, necessary to seek cooperation on R&D on lignocellulosic based or woody-biomass bioethanol among APEC member economy.

Biofuel program in Indonesia is also developed in small scale to allow direct use by local/rural people and at the same time provide productive activities that will improve their economic welfare.

Indonesia will still continue to work with other economies and international community to develop sustainable biofuel industry and also global environmental issues.

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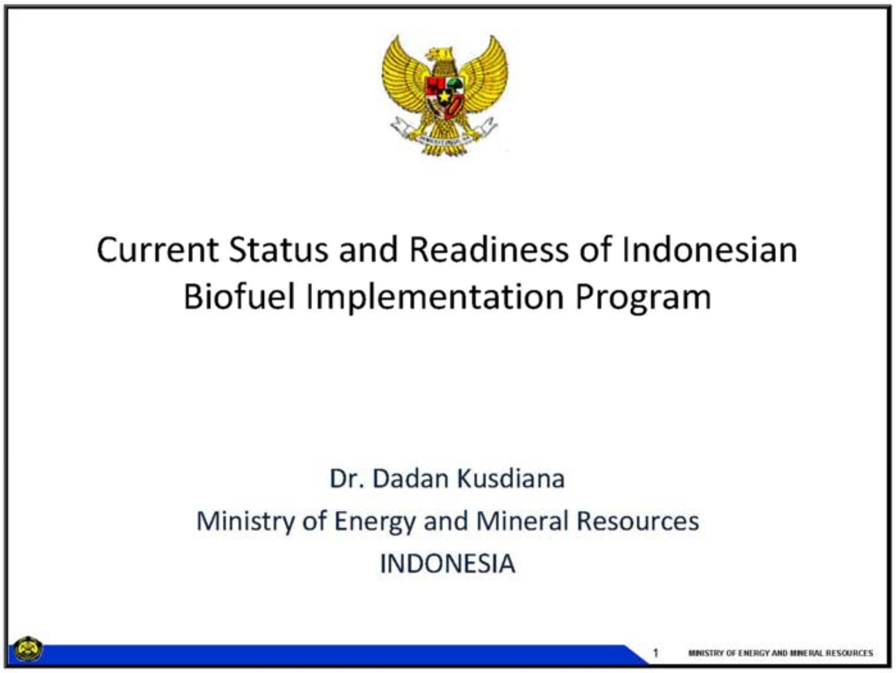
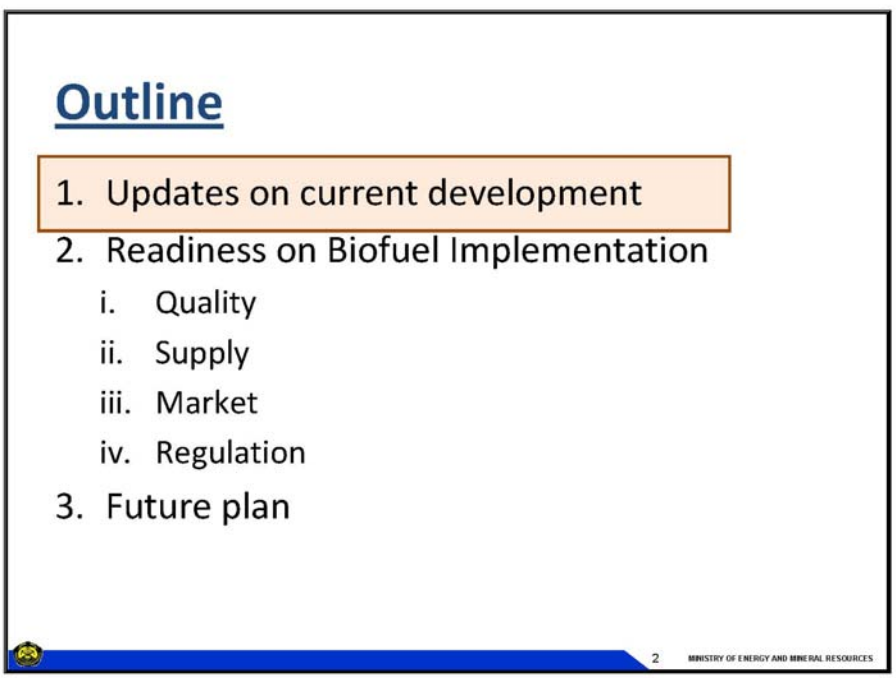
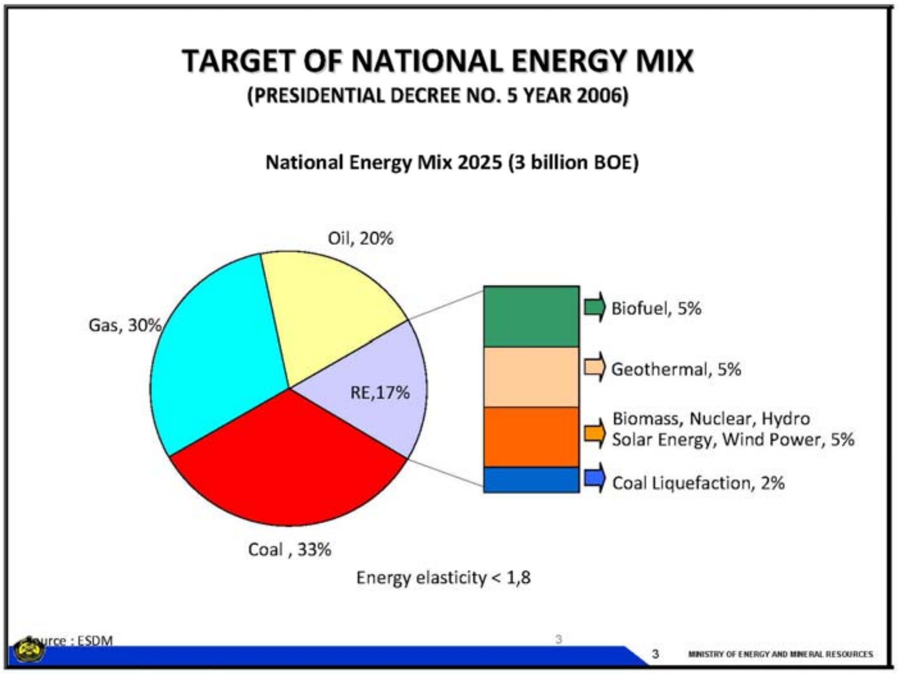
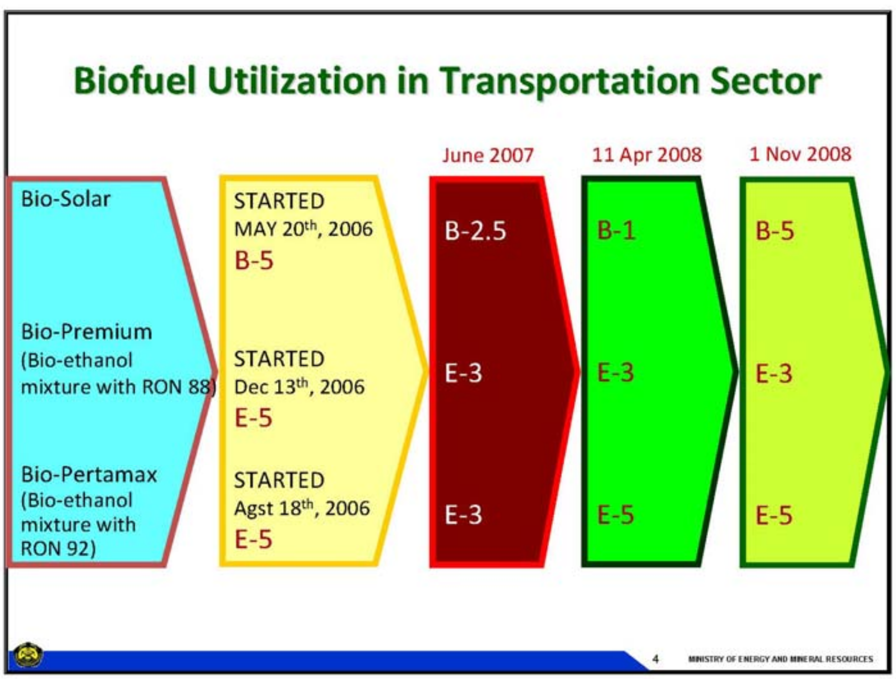
Wirawan, Soni. 2006. The experience of BPPT in developing biodiesel. Proceeding of Seminar on Development in Biofuel Production and Biomass Technology. Jakarta, 21-22 February 2006.

Session II: Active participants (Indonesia); Dr. Dadan Kusdiana






TARGET OF NATIONAL ENERGY MIX
(PRESIDENTIAL DECREE NO. 5 YEAR 2006)
National Energy Mix 2025 (3 billion BOE)
Oil, 20%
Gas, 30%
RE,17%
Coal , 33%
Biofuel, 5%
Geothermal, 5%
Biomass, Nuclear, Hydro
Solar Energy, Wind Power, 5%
Coal Liquefaction, 2%
Energy elasticity < 1,8
Source : ESDM
3
MINISTRY OF ENERGY AND MINERAL RESOURCES


Biofuel Utilization in Transportation Sector
June 2007
11 Apr 2008
1 Nov 2008
Bio-Solar
STARTED
MAY 20th, 2006
B-5
B-2.5
B-1
B-5
Bio-Premium
(Bio-ethanol
mixture with RON 88)
STARTED
Dec 13th, 2006
E-5
E-3
E-3
E-3
Bio-Pertamax
(Bio-ethanol
mixture with
RON 92)
STARTED
Agst 18th, 2006
E-5
E-3
E-5
E-5
4
MINISTRY OF ENERGY AND MINERAL RESOURCES

BIOFUEL MANDATORY

AS ENERGY AND MINERAL RESOURCES MINISTER REGULATION NO 32, 2008

BIOETHANOL (Minimum)						
Sector	2008	2009	2010	2015	2020	2025
Transportation, PSO	3% (Existing)	1%	3%	5%	10%	15%
Transportation, Non PSO	5% (Existing)	5%	7%	10%	12%	15%
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Industry	2.5%	2.5%	5%	10%	15%	20%
Electricity	0.1%	0.25%	1%	10%	15%	20%

5 MINISTRY OF ENERGY AND MINERAL RESOURCES

1. Aspect on quality, specification standard

- Road test and field socialization has been conducted from period of 90est till 2006;
- National Standard for biodiesel and bioethanol in which its formulation was involved many related stakeholders;
- Monitoring including surveillance test for implementation of biodiesel and bioethanol specification standard;
- Monitoring including surveillance test for volumetric blending of biofuel to the petroleum fuel.

6 MINISTRY OF ENERGY AND MINERAL RESOURCES

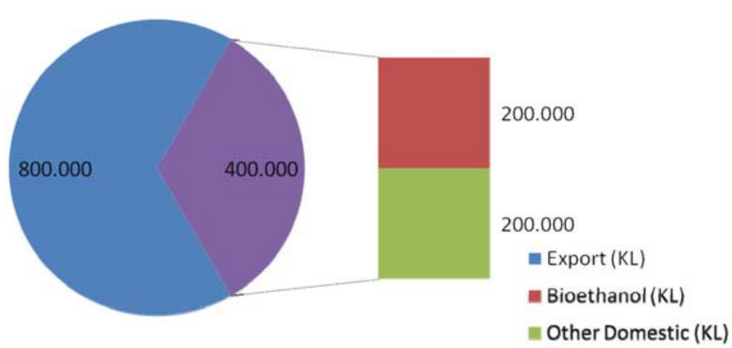
2. Aspect on Supply (Feedstock and Product)

- Provision of main feedstock: Palm oil for biodiesel and sugarcane for bioethanol;
- Diversification of feedstocks and not to compete with food, such as sweet sorghum, cassava, nyamplung, nipah, etc
- Construction of large and small scale of biofuel production facilities. For example consortium between Pertamina with PTPN (Agroindustry) for biofuel production
- Development of infrastructure for distribution, blending, storage;
- Currently, there are 51 privates holding the biofuel business license from the government

7 MINISTRY OF ENERGY AND MINERAL RESOURCES

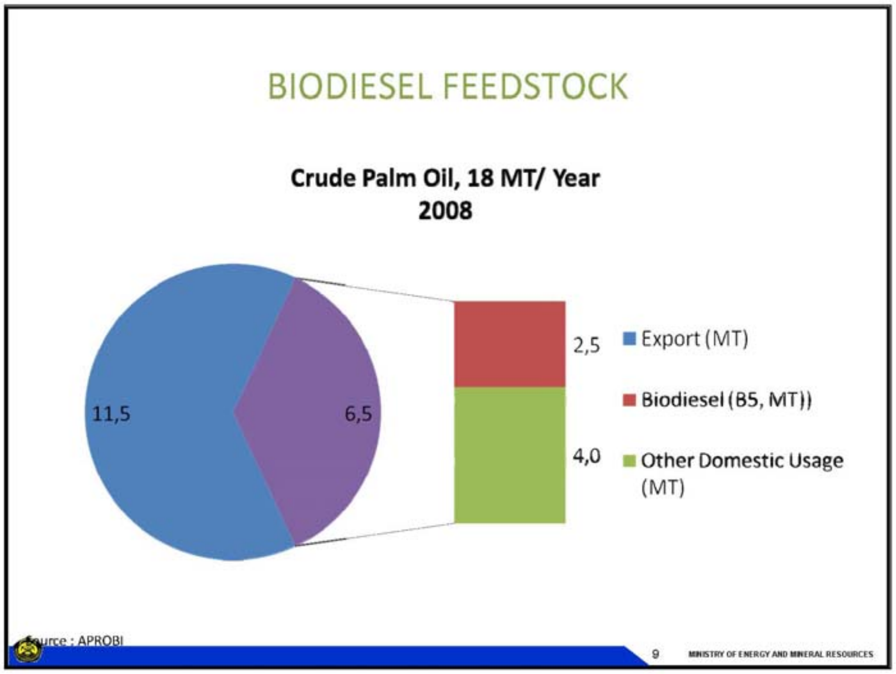
BIOETHANOL FEEDSTOCK

Molasses, Bioethanol Feedstock, Total 1.2 M KL/Year (2007)



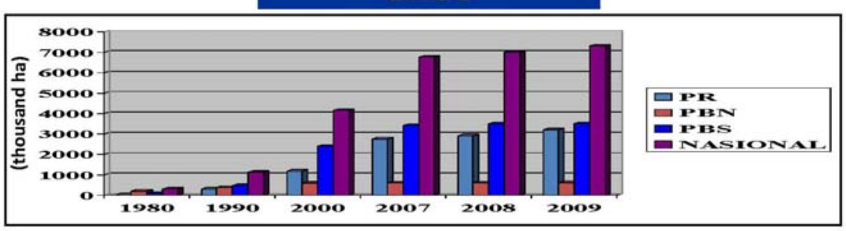
Source : APROBI

8 MINISTRY OF ENERGY AND MINERAL RESOURCES



PALM OIL PLANTATION IN INDONESIA

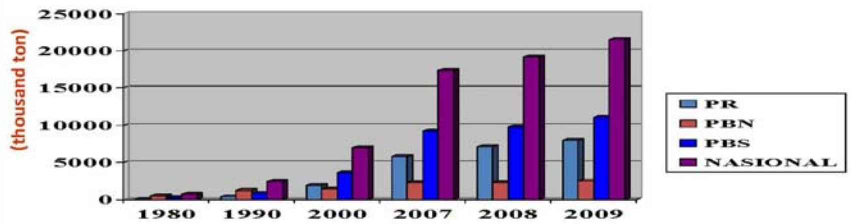
1. AREAL



Year	Area (000 ha)			
	PR	PBN	PBS	Nasional
1980	6	200	84	290
1990	292	372	463	1.127
2000	1.167	588	2.403	4.158
2007	2.752	606	3.409	6.767
2008	2.903	608	3.409	7.008
2009*	3.204	617	3.501	7.322
Growth, %/y	24,2	4,0	13,7	11,8

10 MINISTRY OF ENERGY AND MINERAL RESOURCES

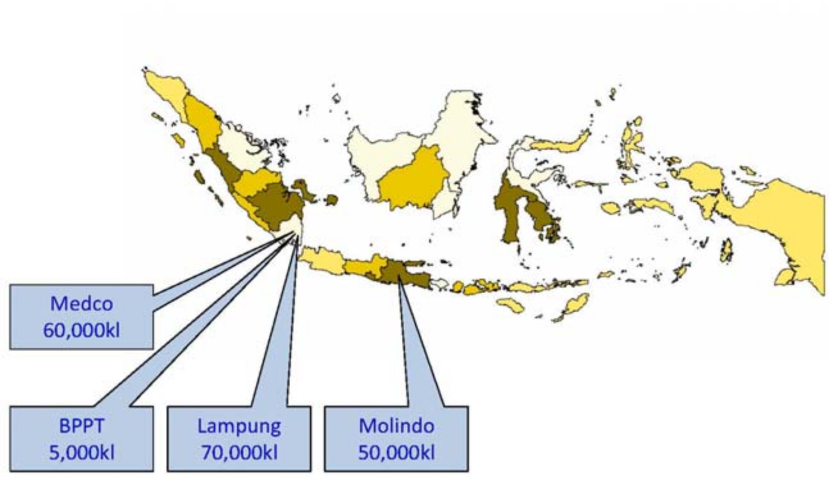
2. CPO PRODUCTION



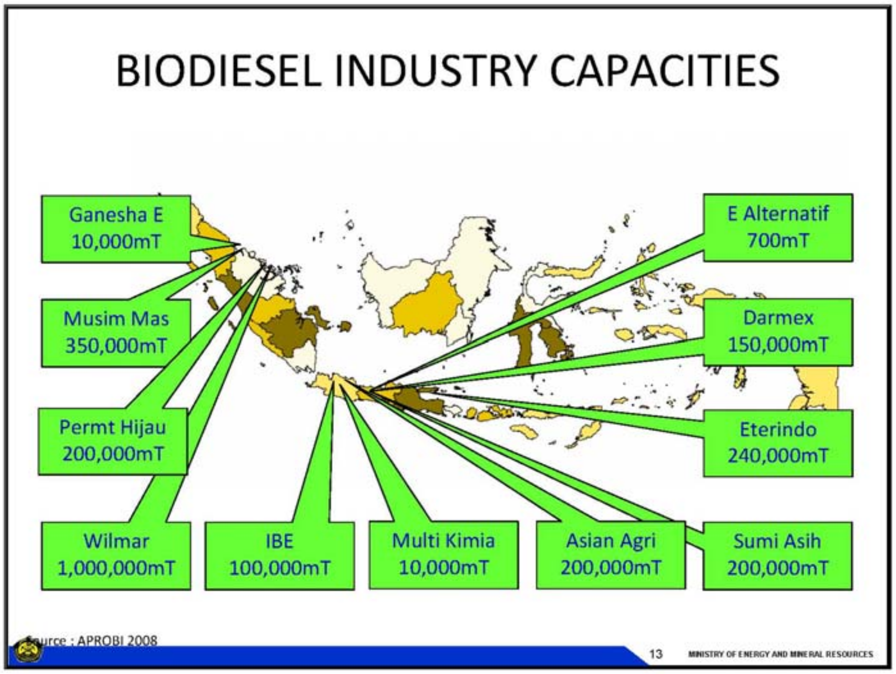
Year	Production (000 Ton CPO)			
	PR	PBN	PBS	Nasional
1980	1	499	221	721
1990	377	1.247	789	2.413
2000	1.906	1.461	3.634	7.001
2007	6.358	2.117	9.190	17.665
2008	7.105	2.295	9.800	19.200
2009*	7.976	2.495	11.040	21.511
Growth, %/y	35,8	5,3	14,0	12,0

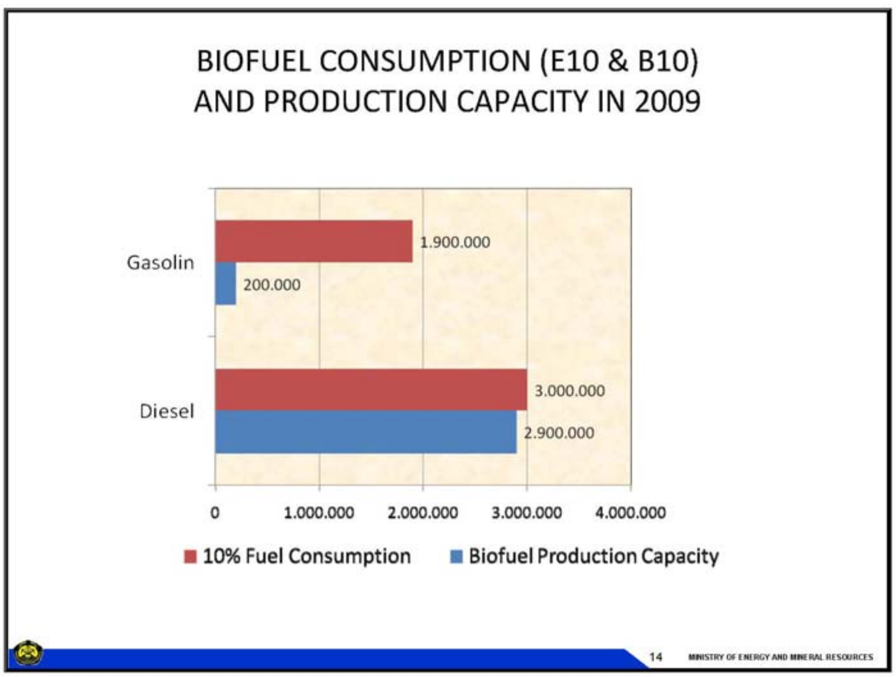
11 MINISTRY OF ENERGY AND MINERAL RESOURCES

BIOETHANOL INDUSTRY CAPACITIES



12 MINISTRY OF ENERGY AND MINERAL RESOURCES


BIODIESEL INDUSTRY CAPACITIES
Ganesha E
10,000mT
Musim Mas
350,000mT
Permt Hijau
200,000mT
Wilmar
1,000,000mT
IBE
100,000mT
Multi Kimia
10,000mT
Asian Agri
200,000mT
Sumi Asih
200,000mT
Eterindo
240,000mT
Darmex
150,000mT
E Alternatif
700mT
Source : APROBI 2008
13
MINISTRY OF ENERGY AND MINERAL RESOURCES


BIOFUEL CONSUMPTION (E10 & B10)
AND PRODUCTION CAPACITY IN 2009
Gasolin
1.900.000
200.000
Diesel
3.000.000
2.900.000
0
1.000.000
2.000.000
3.000.000
4.000.000
10% Fuel Consumption
Biofuel Production Capacity
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CURRRENT ACTIVITIES ON ALGAE DEVELOPMENT

- Culturing strains
- Cultivating microalgae using photobioreactor and small outdoor facilities
- Harvesting the biomass and extracting oil
- Analyzing biochemical content of some potential strains

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JATROPHA CURCAS

- Considered as a potential biofuel feedstock that can be utilized for fuel in transportation, electricity generation and household;
- Extensive researches and development by government, universities, private and society are being in place in Indonesia;
- To establish a Global Jatropha networking for research and development;
- Approaches for development:
  - Developed by farmers and used directly as biokerosine;
  - Privates for large capacities for biodiesel production but still involving local farmer

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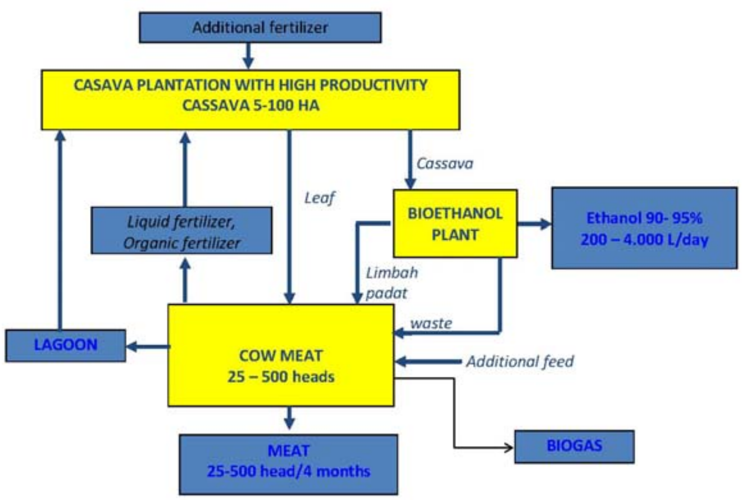
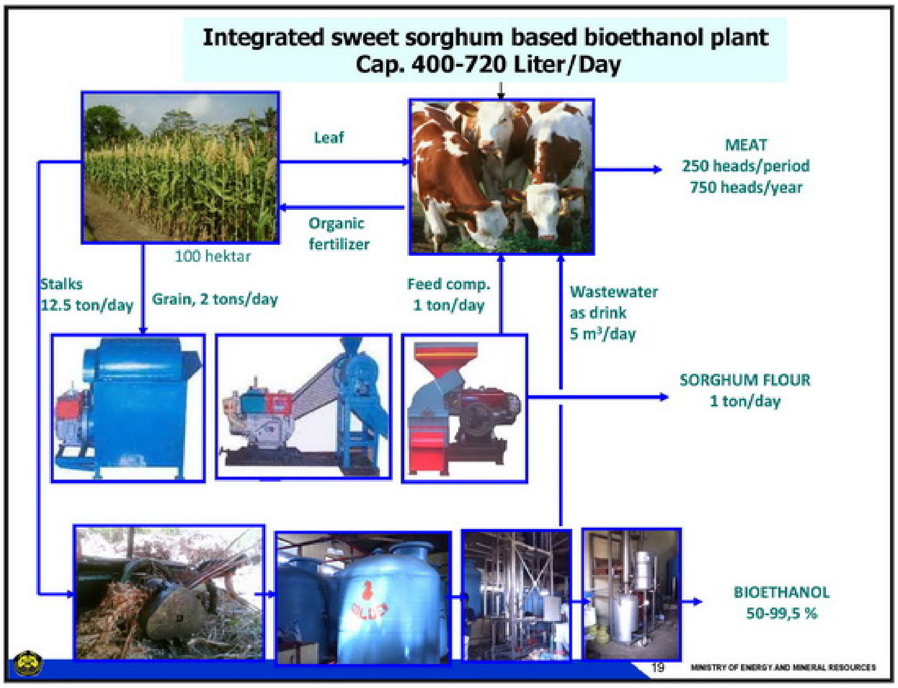
Calophyllum inophyllum L.
A Potential Plant for Biofuel

- ✓ **High survival potency**
- ✓ **Easy silviculture**
- ✓ **Does not compete with crops**
- ✓ **High multipurpose (wood, gum, leaf, flower, seed)**
- ✓ **As windbreaker and soil conservation tree**

Integrated Small Scale Bioethanol Plant




Integrated sweet sorghum based bioethanol plant
Cap. 400-720 Liter/Day
Leaf
Organic fertilizer
100 hektar
MEAT
250 heads/period
750 heads/year
Stalks
12.5 ton/day
Grain, 2 tons/day
Feed comp.
1 ton/day
Wastewater
as drink
5 m³/day
SORGHUM FLOUR
1 ton/day
BIOETHANOL
50-99,5 %
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The Jampangkulon-Sukabumi Bioethanol Plant From Cassava, Cap. 400-720 Liter/Day
Integrated with Organic Cassava and Sorghum Plantation and Tapioca 2 Tons/Day
Pretreatment
2009
2009
Sun dried tapioca
Organic cassava
Hydrolysis
Sweet sorghum
Solid waste
Fermentation
Organic fertilizer
Biogas
Bioetanol
99,5 %
Dehydration
Distillation
Bioetanol
Wastewater
20

ASOCIATION OF BIOFUEL PRODUCTION INDONESIA **(APROBI)**

- Commitment to transparency
- Compliance with applicable laws and regulations
- Commitment to long-term economic and financial viability
- Use of appropriate best practices
- Environmental responsibility and conservation of natural resources and biodiversity
- Responsible consideration of employees and communities affected by producers
- Responsible development for diversified feedstock
- Commitment to continues improvement in producing the Biofuels

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3. Aspect on the Market Readiness

- Staging on biofuel mandatory to blend with petroleum based fuel
- Implementing business mechanism that follows petroleum fuel regulation and practices; no need for special preparation
- Providing subsidy on certain product for certain uses to help biofuel compete with the petroleum fuel
- Providing the state budget for implementation and development

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4. Aspect on Regulation readiness

- Issuing regulations that support a sustainable biofuel implementation, for example National Standard on biofuel specification that fits with domestic feedstocks;
- Preparing implementable regulation and incentives;
- Currently, the government is preparing a government regulation on New Renewable Energy including biofuel that will provide regulations on feed-in tariff, financing, R&D budgte, RPS, etc.

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Energy Law No. 30 Year 2007

- Issued in 10 July 2007 with special attention on new renewable energy development and energy conservation;
- Provision and utilization of new renewable energy should be increased by government and local government following their authorities.
- Provision and utilization of new renewable energy can get incentives from government/local government for certain period until it reaches economical development stage.
- Currently government regulations as implementing regulation on renewable energy and energy conservation are being prepared

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Future sustainable biofuel development

- Not to cut tropical rain forest, but to optimize currently not utilized land (5.066 million ha available of non utilized arable land).
- Development of non-edible feedstock and dedicated feedstock for biofuel;
- Improving productivity of main feedstocks such as palm oil, jatropha, cassava and sugar cane;
- Development of second generation of biofuel that will create sustainable and low cost biofuel industry;
- To seek cooperation on R&D on lignocellulosic based or woody-biomass bioethanol.

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Biofuel Incentives

- Staging of mandatory biofuel utilization
- Tax exemption on VAT
- Investment tax incentives
- Direct subsidy on retail price for transportation sector
- Interest rate subsidy for biofuel feedstock plantation
- Simplifying the license procedure on biofuel business

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Potential of Feedstocks for Second Generation of Bioethanol in Indonesia

Feedstocks: wastes from agriculture, bagasse, palm oil	**74.000 million ton**
Potency on bioethanol	22,2 million KL
Equivalent to gasoline	10,7 million ton
Gasoline consumption	12,9 milliom ton
Potency on gasoline substitution	82,9 %

Source: APEC, 2008

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Concluding Remarks

- As part of national energy policy, the utilization of biofuel will be continuously implemented and improved;
- The biofuel can be produced environmentally sustainable in synergy with food and feed production;
- Integrated productions in recycle system will give more benefit for community and environment;
- Indonesia will continue to work with other countries and international community to develop sustainable biofuel industry and also global environmental issues.

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International APEC Symposium on
"Biofuels from Agricultural and Agro-Industrial Wastes"
May 24th – 27th, 2010, Chiang Mai, Thailand

PRODUCTION OF BIOETHANOL AND COMPOST FROM ORGANIC WASTE (VEGETABLE GARBAGE) OF TRADITIONAL MARKET

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ABSTRACT

Many economies, such Indonesia, are facing a crisis of energy, global climate change and increase of the municipal solid waste. In Indonesia, traditional market garbage is the second largest fraction of municipal solid waste, particularly in big cities and has a higher organic fraction.

Waste from traditional markets can be utilized not only to produce ethanol as a component of biofuel, but also to produce compost as fertilizer in order to reduce the municipal solid waste. The higher of ethanol content that can be produced from the fermentation of organic waste or vegetable garbage is 9 %. Resulted compost indicates to meet requirement for standard as fertilizer.

This research has a benefit to reduce the municipal waste and saves valuable landfill space and possible contamination of land and water due to landfill 'leachate'

Keywords: vegetable garbage, biofuel, ethanol, municipal solid waste, compost

1. INTRODUCTION

In Indonesia, also in many economies, the energy and climate crises or global warming change have to become of public awareness. Also Indonesia is facing crises of the increase waste, municipal solid waste. Despite political and scientific advances in environmentally friendly policies and technologies, there still remains much work to be done to make our lifestyles more sustainable and ecologically sensitive.

In response to the such problems, Indonesia government has provide some regulations as a part of solution in energy sector, such as Presidential Instruction No.1 year 2006 on supply and utilization of biofuels as alternative energy and Presidential Decree No.5 year 2006 on National Energy Policy, calling for 5% biofuels in the energy mix by 2025 .

There has been a remarkable increase in the need for the use of waste fuels in today's world (Zaldivar *et.al*, 2001). Since waste fuels utilize materials that otherwise would have gone to dumpsites and landfills, people believe that this would be a much more stable and environment-friendly alternative to regular diesel or gasoline, as well as some other forms of alternative energy. Ethanol is one of the most common biofuel available and is produced by heating up cellulose organic waste products with fermentation processing by microorganism (Koike *et.al*, 2009). During this process, microbes break down the starches and sugars in the plant material. This turns the waste products into ethanol.

The best-known fuel use for alcohol is as a substitute for gasoline. Up to 20 percent of ethanol can be used in gasoline without engine modification. The use of alcohol and alcohol-gasoline blends in motor transport is almost as old as the automobile itself. Alcohols, particularly ethanol, have been used in many other economies as motor fuel (BOSTID, 1983).

Waste from traditional markets in Indonesia is the second largest stream of municipal solid waste after household waste (Aye and Widjaja, 2005; Nasir, 2010). It has a higher organic fraction and may have greater potential to be managed on a business scale compared to household wastes. The attributed reason is that in general the wastes generated from traditional markets are more uniform, more concentrated and less hazardous than waste from other sources.

Usually the large quantities of waste are created in the major cities, there are inadequate facilities for dealing with it, and much of this waste is either left to rot in the streets, or is collected and dumped on open land near the city limits. For example, Jakarta produced around 6,500 tons of garbage per day (Nasir, 2010). The prime concern arising out of present waste disposal system is its impact on community health and environment.

Since solid waste to be increasing due to the increased urban populations, the management of municipal solid waste is rapidly becoming challenging particularly to utilize the solid organic waste to be a product with added value, because the common approach of landfilling or incinerating our waste often results in adverse environmental impacts (Lou and Nair, 2009).

Organic waste from traditional markets, have slightly different characteristics with waste from housing. The composition of the garbage from traditional markets are more dominated by organic waste. Moreover, if the waste came from the vegetable market or a fruit market, the organic waste will be more. More or less 60-70% component of garbage is organic material. Traditional market produces the highest quantities of organic garbage (Arifiantaril *et.al*)

Another benefit of utilization garbage from traditional market is compost production. Composting is probably the most well-known system for treatment of organic material (Isroi, 2009). Compost is the stable end product derived from the biological degradation of organic material, which can vary from dead leaves and roots to kitchen waste and vegetable remains. If well decomposed, the odourless and pathogen-free black brown mixture can be used as a soil conditioner. Compost is especially useful because of its humification characteristics and its long-lasting effects. The addition of compost to soil helps to compensate for the losses of organic material that result from intensive agriculture, and helps to maintain or restore soil fertility.

This paper presents the results of utilization of vegetable garbage as source of renewable energy and compost from traditional market waste disposal in big city.

2. METHODOLOGY

The main object of this research is to study of the organic waste (vegetable garbage) that collected locally from the Traditional Market around Jakarta. It will become the initial samples. Before degraded biologically, the collected samples get preliminary process i.e. washing to remove the impurities and the an-organic component by using of flowing water, collected samples were cut or chopping into smaller fragments, in order to reduce size of organic waste by using knife, crushing to become soft like porridge, then dried to reduce the water content. The substrate is used as feedstock for fermentation processing. The flow scheme of production of bioethanol and compost from vegetable garbage is shown in Figure 1.

There are three steps for production processing i.e. degradation, fermentation and purification. Degradation processing is conducted by using bacteria and enzyme, meanwhile for fermentation processing carried out by using yeast.

Yeast was added to product of degradation for fermentation process. After 48 hours**,** product of fermentation separated into 2 phases, liquid and solid products. Then, liquid product was purified by distillation to have an ethanol product. The obtained ethanol has to be re-distillated until the purity of ethanol close to 99.60%. The ethanol was used as mixed fuel with gasoline fuel to be biofuel as designated E10 for using 10% of ethanol. The solid product or residue of fermentation was used for composting.

Composting was conducted by anaerobic processing, whereas the fermentation residue or waste was mixed with composting activator or micro-organism (bacteria culture), then covered by dark plastic. Composting process was done by leaving for 2 – 3 weeks.

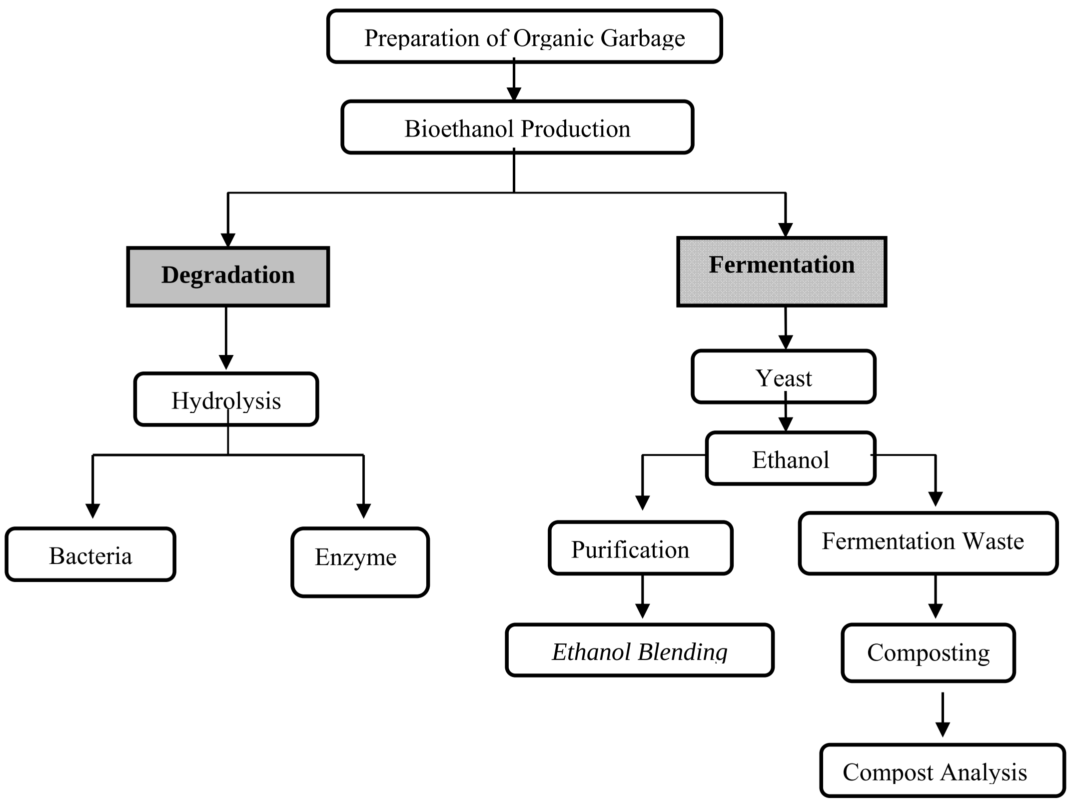

Figure 2. Flow Diagram of Ethanol and Compost Production

3. RESULTS AND DISCUSSION

3.1 Bioethanol Production

Ethanol products were analysed for qualitatively and quantitatively to measure the ethanol content, after experiments of degradation and fermentation that conducted for 24 hours and 48 hours, respectively. Qualitative analysis by Gas Chromatography showed that the product containing ethanol as shown by its chromatogram in Figure 1. The experimental results of bioethanol production from fermentation of organic waste (vegetable garbage) are shown in Table 1.

The yield of ethanol products that produced from several experimental results indicate that the experiment E7 has a highest content of ethanol (9 %). Obviously, the degradator has an influence in producing bioethanol from organic waste (vegetable garbage), whereas cellulose enzyme has a high effect in bioethanol production as compared with bacteria. Cellulase enzyme has a high activity in conversion of cellulose to β-glucose than other microorganism (bacteria). Other factor that can affect of bioethanol production is the feedstock condition as shown by using of dried garbage (E7) compared with wet garbage (E1 to E6). It seems that water content affects the bioethanol productions.

When the feedstock in semi dried condition, the water content in those organic wastes (vegetable garbage) lower compared with the wet feedstock. Therefore, cellulose content in the semi dried feedstock more concentrated than in the wet feedstock. As a result, the ethanol production of experimental has a higher in the utilization of semi dried feedstock.

All fermentations were carried out using *Saccharomyces cereviceae (yeast)*, Ethanol production by fermentation took place under anaerobic condition through glycolysis (*Embden Mayerhof Pathway*) [Glycolysis, Wikipedia]. It is the metabolic pathway which converts glucose via a series of reactions to 2 molecules of pyruvate. Under anaerobic conditions, pyruvate can be converted to ethanol in yeast. In those experiments, *Saccharomyces cereviceae* as microorganism produced the *invertase* enzyme to convert the glucose to be ethanol.

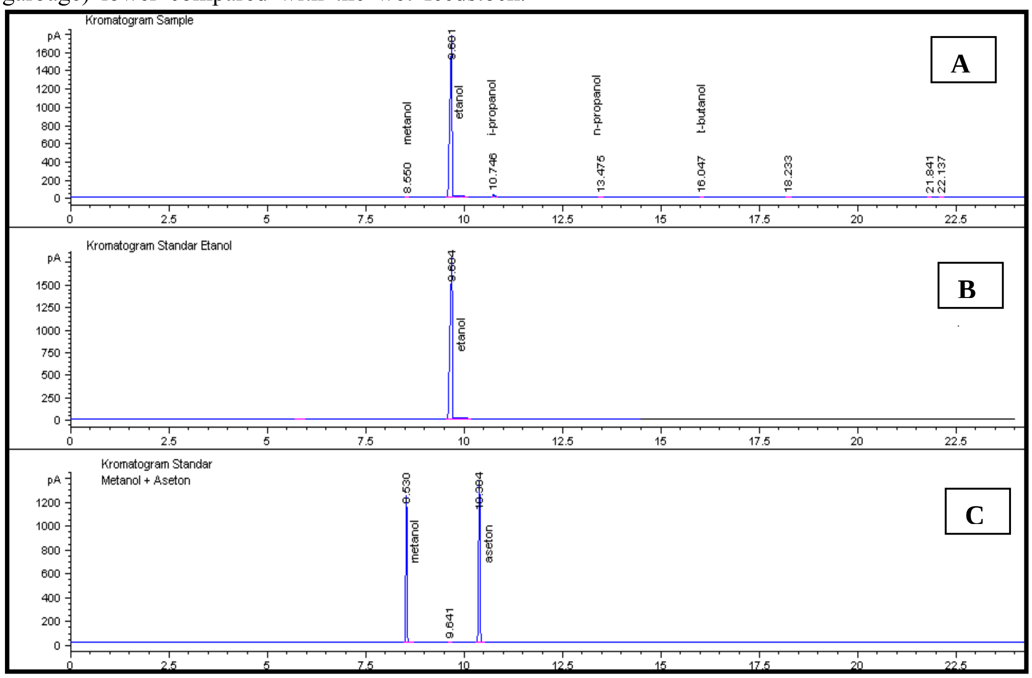

Figure 1. Chromatogram of Ethanol from GC analysis (A); ethanol standard (B), and Methanol and Acetone standard (C)

Table 1. Results of ethanol that produced from organic waste (vegetable garbage) after degradation for 24 hours and fermentation for 48 hours, with modified process treatments.

No	EXPERIMENT	ETHANOL CONSENTRATION (%)	REMARKS
1	CONTROL	**4,5**	Wet garbage + degradation microorganism BLCC + fermentation microorganism BLCC
2	E1	**3**	Wet garbage + degradation microorganism BLCC + fermentation microorganism BLCC and heated at 70^{o}C
3	E2	**3.5**	Wet garbage + degradation microorganism BLCC + fermentation microorganism BLCC and heated at 35^{o}C
4	E3	**2.5**	Similar with CONTROL, but using mixed

			culture for degradation (degradation microorganism BLCC + animal manure)
5	E4	**3.5**	Similar with CONTROL, but using mixed culture for degradation (animal manure)
6	E5	**5**	Similar with CONTROL, but using a mixed culture for degradation (degradation microorganism BLCC + animal manure)
7	E6	**3.5**	Similar with CONTROL, but using a microorganism degradation
8	E7	**9**	Semi dried garbage + Celulases enzyme

Table 2. The Characteristics of blended ethanol and gasoline (Bioethanol fuel,E10)

No	CHARACTERISTICS	UNIT	RESULTS	METHOD
1	Research Octane Number	-	92.9	ASTM D-2699
2	Reid Vapor Pressure	Psi	9.0	ASTM D-323
3	Existent Gum	mg/100 ml	1.6	ASTM D-525
4	Colour	-	Yellow	Visual
5	Odour	-	Marketable	Visual
6	Distillation:			ASTM D-86
	- 10 %-vol	^oC	48.0	
	- 50 %-vol	^oC	67.0	
	- 90 %-vol	^oC	150.5	
	- End Point	^oC	197.5	
	- Residue	5 %-vol	1.0	
7	Copper Strip Corrosion, 3 hrs/50^oC	-	1b	ASTM D-130
8	Sulphur Content	%-wt		ASTM D-1266
9	Doctor Test	-		IP-30
10	Mercaptane Sulphur	ppm		UOP-163
11	Lead Content	g/l		IP-74-010 Mod

Table 3. Analytical result of composting production

No	CHARACTERISTICS	UNIT	RESULTS	STANDARD
1	Water content	%-Volume	20	13 – 20
2	C-Organic	%	13	> 12
3	C/N Ratio	%	10	10 – 25
4	Total Content::			
	- P2O5	%	0.51	< 5
	- K2O	%	0.91	< 5
5	Heavy Metal Content:			
	- As	ppm	Trace	≤10
	- Hg	ppm	0.06	≤1
	- Pb	ppm	3.4	≤50
	- Cd	ppm	0.3	≤10
6	Micro element Content:			
	- Zn		44	5,000
	- Cu		17	5,000
	- Mn		260	5,000
	- Co		4.4	20
	- B		61	2,500
	- Mo		15.1	10
	- Fe		1,333	4,000
7	Pathogen Organisms			
	- *E. Coli*	APM/gram	< 3	
	- *Salmonella sp*		Negative	

3.2 Bioethanol Fuel

From the mixture of fermentation product, ethanol is recovered by a distillation process. Ethanol can be used as a fuel for cars in its pure form, but it is usually used as a gasoline additive to increase octane and improve vehicle emissions Bioethanol is an alcohol-based fuel which can be mixed with petrol or gasoline. Ethanol from this research blended with gasoline by 10%-volume of ethanol to determine the characteristic fuel as bioethanol fuel. According to the mandatory regulation of biofuel specification that the maximum of ethanol content is 10% as blended fuel. The result of specification testing is shown in Table 2.

3.3 Composting

Fermentation of organic waste (vegetable garbage) not only resulted of ethanol but also produced compost. Compost, as organic fertilizer, was obtained as by-product from this research. Analytical results of compost are shown in Table 3. Composting is simply the method of breaking down organic materials in a large container or heap. Composting can convert organic waste into rich, dark coloured compost, or humus, in a matter of a few weeks or months. The decomposition occurs because of the action of naturally occurring microorganisms such as bacteria and fungi.

When compared to the requirement standard for compost utilization in soil, the resulted compost from this experiment has a meet value as fertilizer. The carbon/nitrogen (C/N) ratio is very important in the nutrient balance of all organisms (Mather, 2001). Carbon is a source of energy for the micro-organisms and nitrogen is necessary for the synthesis of protoplasm. More carbon than nitrogen is required, but when there is a too great excess of either, biological activity diminishes and the completion of the process is delayed. Two-thirds of the carbon consumed by micro-organisms is given off as CO_2, and the rest is combined with nitrogen in the cell.

The main requirement for compost is that it should be suitable for use as an organic soil conditioner. Physical, chemical and biological stability, non-toxicity and a balanced mineral element content are therefore the essential elements for compost to be useful. The amount of organic material or, more specifically, the quantity of humus, can be used as indicators to determine the quality of the compost. The best quality compost will be produced from stable organic material with low levels of visible contamination, micro contaminations and heavy metals.

4. CONCLUSION

Substituting fossil fuels with organic waste or garbage-derived cellulosic ethanol is a promising strategy to simultaneously meet part of our energy needs, mitigate greenhouse gas (GHG) emissions, and manage municipal solid waste (MSW). Organic waste as vegetable garbage from traditional market can be a resource of renewable energy. Vegetable garbage (organic waste) resulted 9% of ethanol through fermentation processing. The resulted ethanol from this garbage with 10%-vol, blended with gasoline as E10, indicates to meet the specification of gasoline standard.

Another product from fermentation of vegetable garbage is compost as by product that can be utilize as fertilizer.

Another advantage of this research is to reduce the municipal waste and saves valuable landfill space and possible contamination of land and water due to landfill 'leachate'

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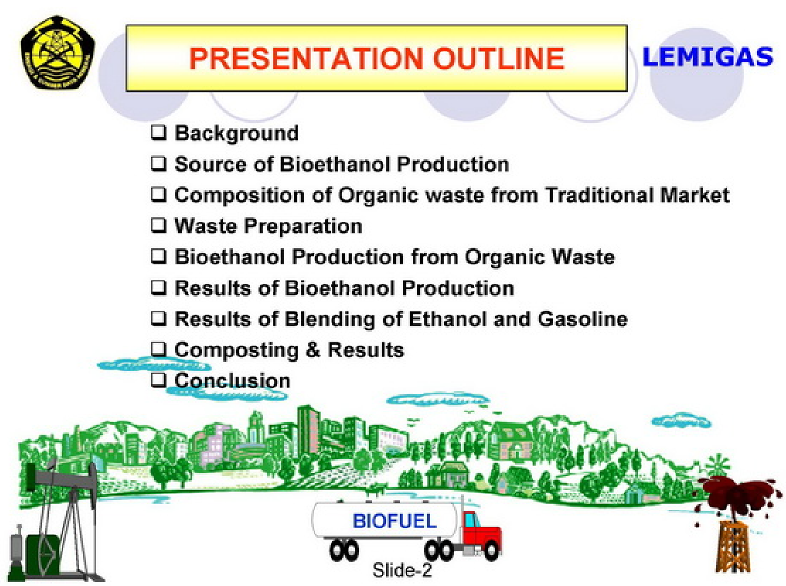

BACKGROUND

LEMIGAS

- **PROBLEMS (WORLDWIDE):**
  - **Increase of polluting emissions involved in climate change**
  - **Depletion of fossil fuel resources**
  - **Increase of municipal solid waste such as: organic waste from traditional market → Environmental Problem →**

    Example: Jakarta produces 6,500 tons/day of municipal solid waste
- **A CHALLENGE:**
  - **Find a clean, abundant, reliable and affordable energy for the future (Sustainable energy system)**

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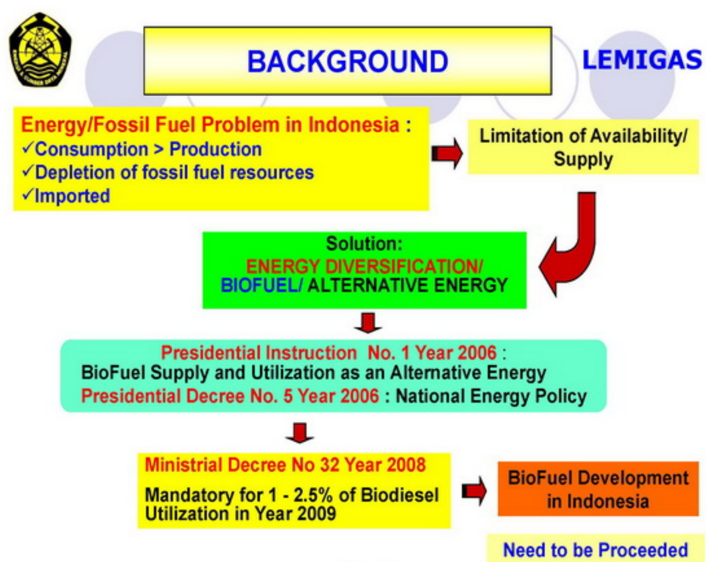
Slide-3



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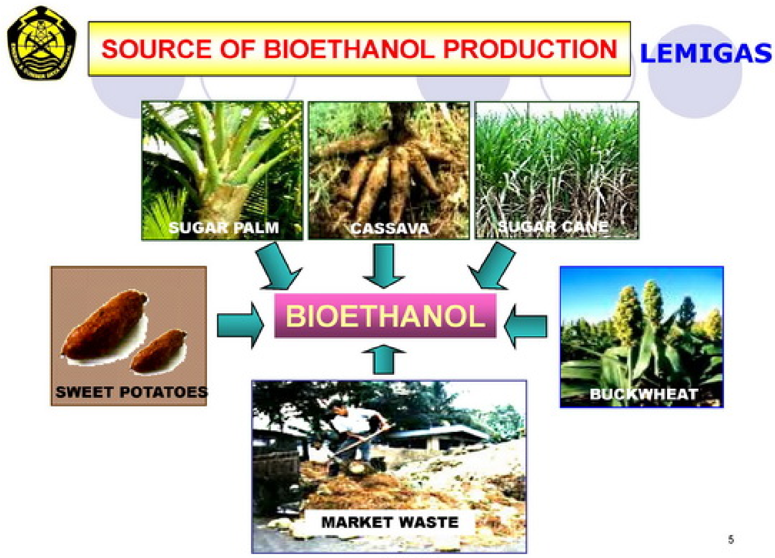

Slide-5

ORGANIC WASTE COMPOSITION FROM MARKET WASTE

LEMIGAS

***Non-compostable matter* (%)**	**25,82**
Paper	**10,18**
Wood	**0,98**
Fiber	**1,57**
Rubber/leather	**0,56**
Plastic	**7,86**
Metal	**2,04**
Glass	**1,77**
Others	**0,86**
***Compostable, Organic matter* (%)**	**73,92**

Source: Local Government of Jakarta

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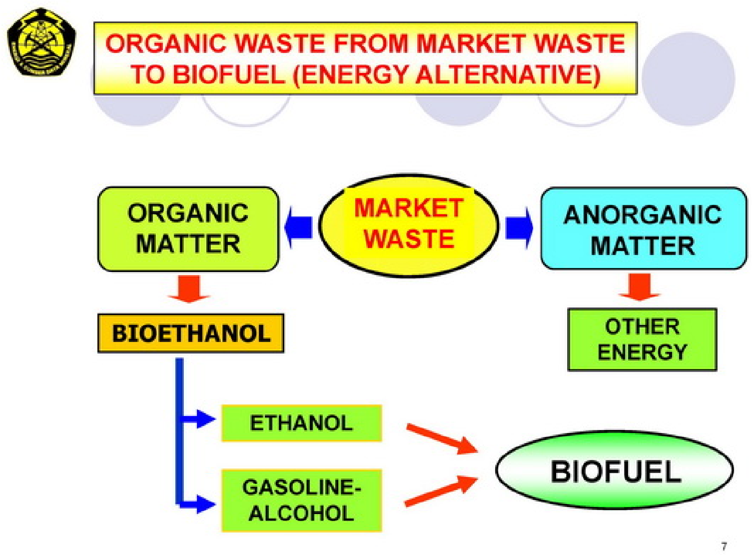
Slide-6



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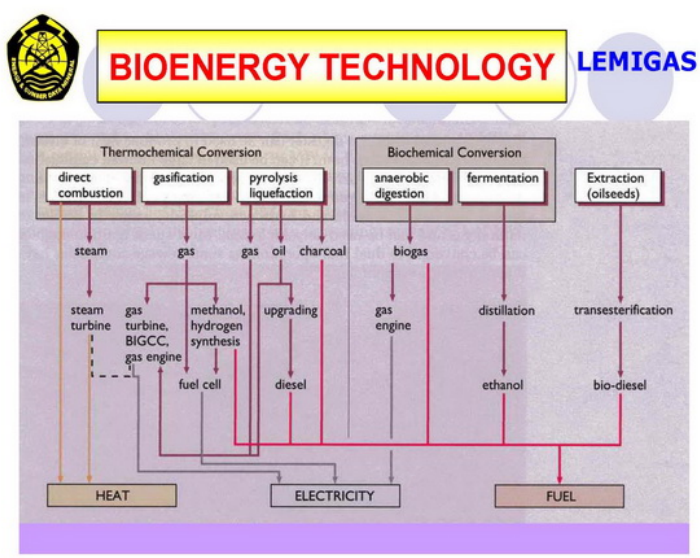

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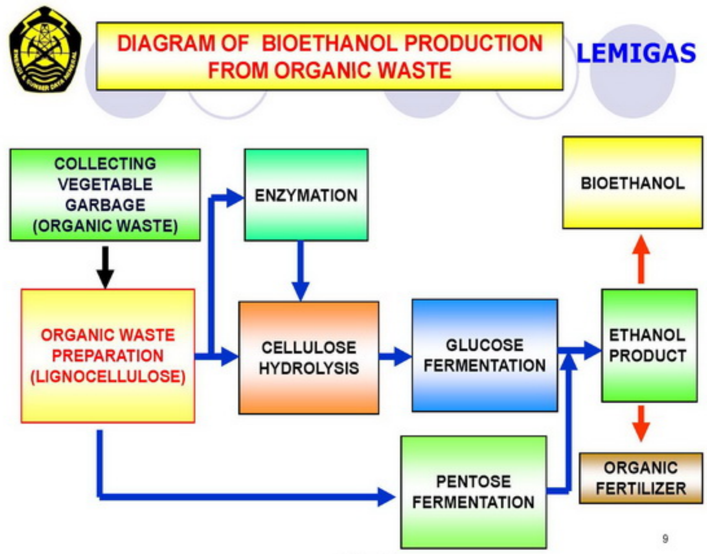

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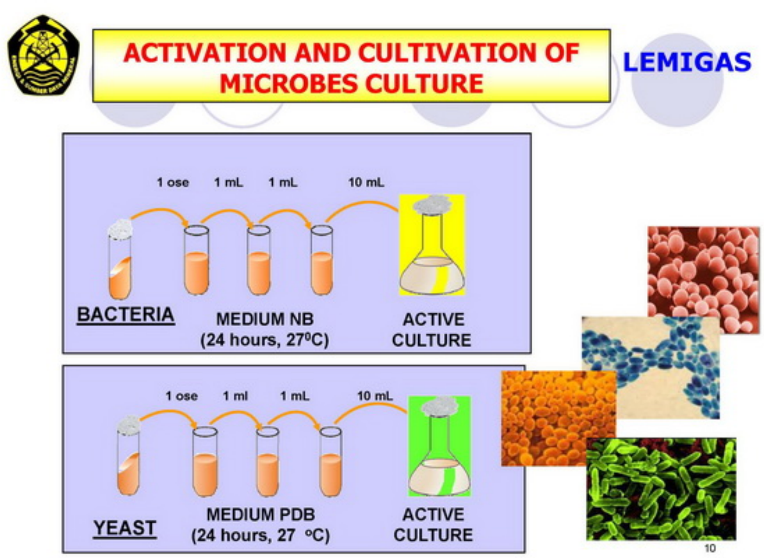

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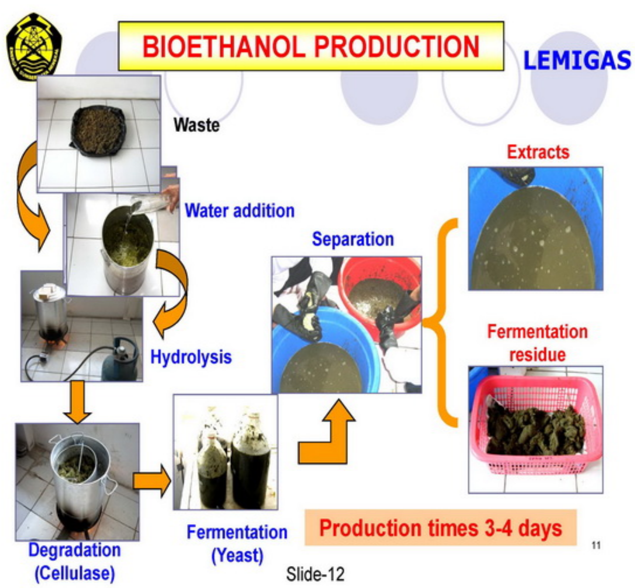

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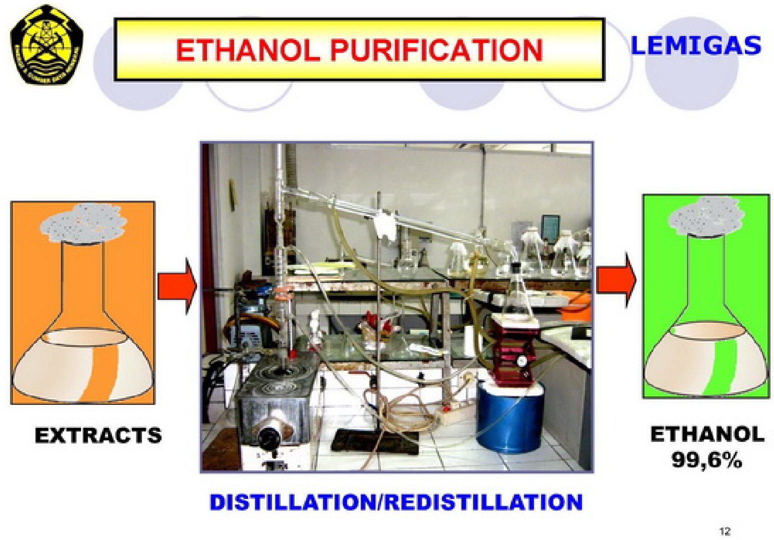

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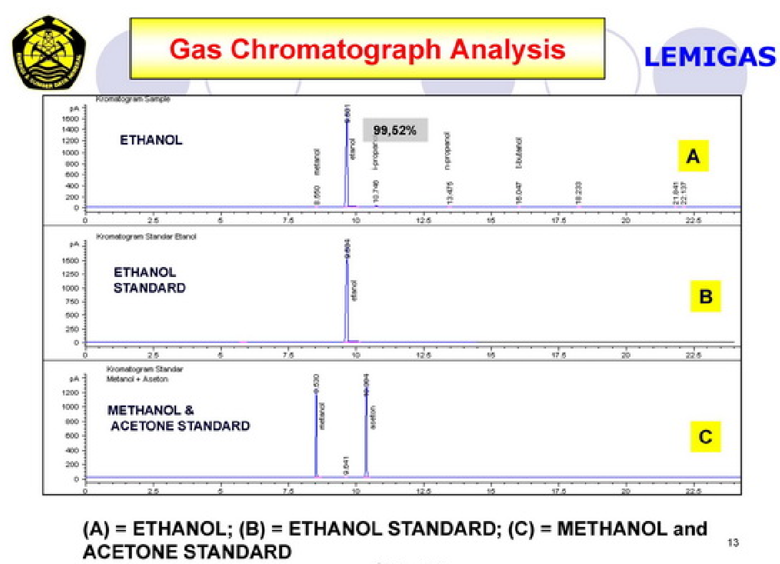

Slide-14

Table 1. Results of Ethanol that Produced from Organic Waste (Vegetable Garbage) after Degradation for 24 hours and Fermentation for 48 hours

No	EXPERIMENT	ETHANOL CONSENTRATION (%)	REMARKS
1	CONTROL	4,5	Wet garbage + degradation microorganism BLCC + fermentation microorganism BLCC
2	E1	3	Wet garbage + degradation microorganism BLCC + fermentation microorganism BLCC and heated at 70°C
3	E2	3.5	Wet garbage + degradation microorganism BLCC + fermentation microorganism BLCC and heated at 35°C

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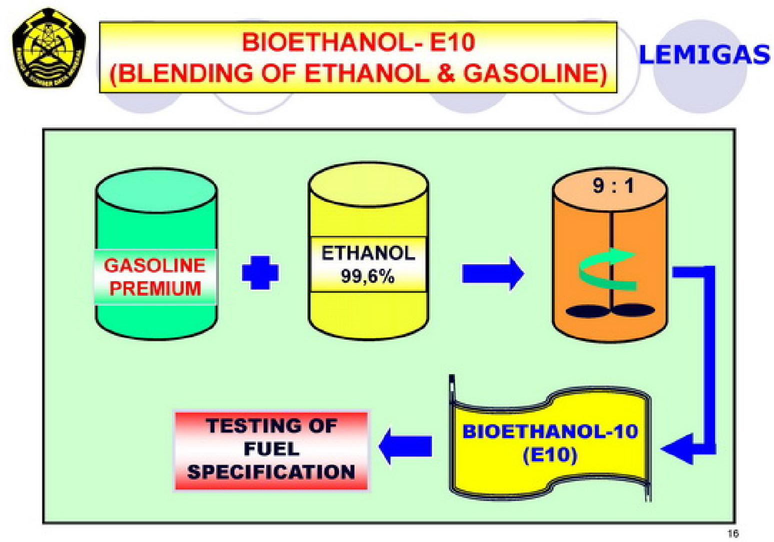
Slide-15

Table 1. Results of Ethanol that Produced from Organic Waste (Vegetable Garbage) after Degradation for 24 hours and Fermentation for 48 hours

No	EXPERIMENT	ETHANOL CONSENTRATION(%)	REMARKS
4	E3	2.5	Similar with CONTROL, but using mixed culture for degradation (degradation microorganism BLCC + animal manure)
5	E4	3.5	Similar with CONTROL, but using mixed culture for degradation (animal manure)
6	E5	5	Similar with CONTROL, but using a mixed culture for degradation (degradation microorganism BLCC + animal manure)
7	E6	3.5	Similar with CONTROL, but using a microorganism degradation
8	E7	9	Semi dried garbage + Celulases enzyme

Slide-16



Slide-17

Table 2. The Characteristics of Blended Ethanol and Gasoline (Bioethanol fuel,E10)

No	CHARACTERISTICS	UNIT	RESULTS	METHOD
1	Research Octane Number	-	92.9	ASTM D-2699
2	Reid Vapor Pressure	Psi	9.0	ASTM D-323
3	Existent Gum	mg/100 ml	1.6	ASTM D-525
4	Colour	-	Yellow	Visual
5	Odour	-	Marketable	Visual
6	Distillation:			ASTM D-86
	- 10 %-vol	ºC	48.0	
	- 50 %-vol	ºC	67.0	
	- 90 %-vol	ºC	150.5	
	- End Point	ºC	197.5	
	- Residue	5 %-vol	1.0	

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Table 2. The Characteristics of Blended Ethanol and Gasoline (Bioethanol fuel, E10)

No	CHARACTERISTICS	UNIT	RESULTS	METHOD
7	Copper Strip Corrosion, 3 hrs/50°C	-	1b	ASTM D-130
8	Sulphur Content	%-wt		ASTM D-1266
9	Doctor Test	-		IP-30
10	Mercaptane Sulphur	ppm		UOP-163
11	Lead Content	g/l		IP-74-010 Mod

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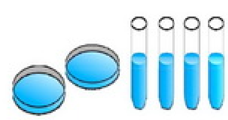
Slide-19 LEMIGAS

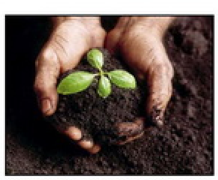
COMPOSTING

LEMIGAS

Fermentation Residue



Microbes Culture



Composting times is (2-3 weeks)

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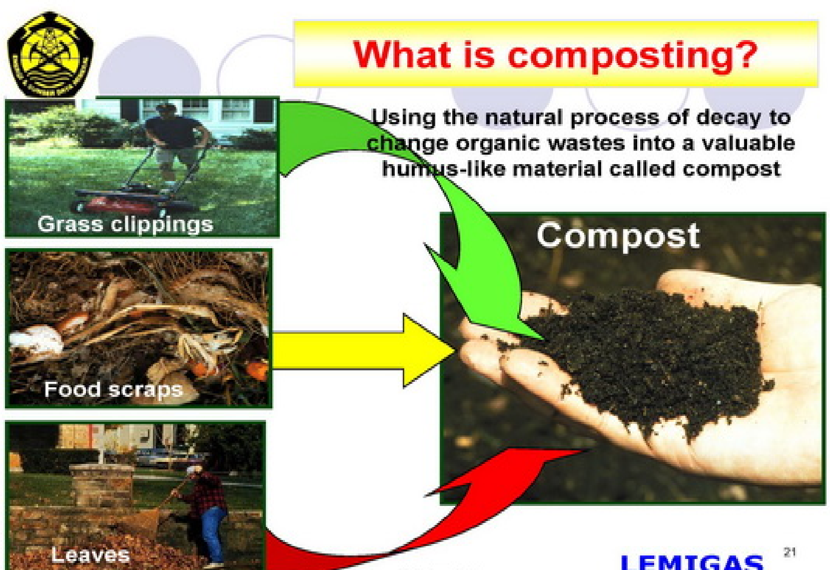

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Table 3. Analytical Result of Composting Production

LEMIGAS

No	CHARACTERISTICS	UNIT	RESULTS	STANDARD
1	Water content	%-Volume	20	13 – 20
2	C-Organic	%	13	> 12
3	C/N Ratio	%	10	10 – 25
4	Total Content::			
	- P2O5	%	0.51	< 5
	- K2O	%	0.91	< 5
5	Heavy Metal Content:			
	- As	ppm	Trace	≤10
	- Hg	ppm	0.06	≤1
	- Pb	ppm	3.4	≤50
	- Cd	ppm	0.3	≤10

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Table 3. Analytical Result of Composting Production – cont'd

LEMIGAS

No	CHARACTERISTICS	UNIT	RESULTS	STANDARD
6	Micro element Content:	ppm		
	- Zn		44	5,000
	- Cu		17	5,000
	- Mn		260	5,000
	- Co		4.4	20
	- B		61	2,500
	- Mo		15.1	10
	- Fe		1,333	4,000
7	Pathogen Organisms			
	- *E. Coli*	APM/gram	< 3	
	- *Salmonella sp*		Negative	

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CONCLUSION - 1

LEMIGAS

- Substituting fossil fuels with organic waste or garbage-derived cellulosic ethanol is a promising strategy to simultaneously meet part of our energy needs, mitigate greenhouse gas (GHG) emissions, and manage municipal solid waste (MSW).
- Organic waste as vegetable garbage from traditional market can be a resource of renewable energy.
- Vegetable garbage (organic waste) resulted 9% of ethanol yield through fermentation processing.

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CONCLUSION - 2

LEMIGAS

- The resulted ethanol from this garbage with 10%-vol, blended with gasoline as E10, indicates to meet the specification of gasoline.
- By product from fermentation of vegetable garbage is compost that can be utilize as fertilizer.
- Another advantage of this research is to reduce the municipal waste and saves valuable landfill space and possible contamination of land and water due to landfill ‘leachate’
- *Still needed the research for optimalisation the ethanol production from organic waste of traditional market*

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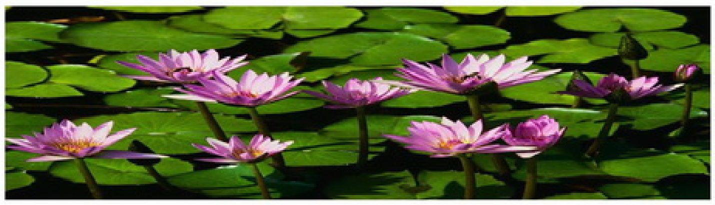
LEMIGAS

THANK YOU
FOR YOUR ATTENTION !!!



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International APEC Symposium on
"Biofuels from Agricultural and Agro-Industrial Wastes"
May 24th – 27th, 2010, Chiang Mai, Thailand

PROGRESS AND CHALLENGES OF BIODIESEL FROM PALM OIL IN MALAYSIA: AN OVERVIEW

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ABSTRACT

The environment and social concerns pertaining to the excessive usage of fossil fuels has driven world-wide demand for implementation of biofuels from agricultural and agro-industrial waste resources. Malaysia is one of the economies which actively advocate for biofuels to play a greater role in the current energy mix. With huge area of palm oil plantation to supply ample feedstock, Malaysia has been pioneering both the scientific research and industrial development for biofuels processing. Even though Malaysia has reaped a lot of benefits from its earlier intensive investments in the biofuels industry, many more challenges are still awaiting to be overcome. In this paper, Malaysia's past, present and future outlook in biofuels industry will be discussed extensively.

Keywords: Biofuels, Biodiesel, Palm oil, Challenges, Malaysia

1 INTRODUCTION

The widespread usage of fossil fuels dated back in late 18th has contributed significantly to the advancement of human civilization. The advantages of fossil fuels which include high combustion efficiency, widely available and easily distributed are unparalleled at that time and thus rapidly becoming the primary energy source all over the world. Unfortunately, as time goes by, fossil fuels have becoming increasingly problematic largely due to their excessive usage. Their supply security which is constantly under jeopardy has lead to their fluctuating market prices and thus increased unnecessary burdens to the end users. On top of that, the serious sustainability issue associated with the proliferation usage of fossil fuels such as global warming has been put under severe scrutiny recently. Realizing the fact that fossil fuels will be depleted sooner or later, the race with time is on to search for a sustainable renewable energy. Contrary to other green technology such as solar and fuel cells, biofuels derived from agriculture have been lauded as the most promising substitution energy for fossil fuels in the next few decades. Biofuels such as biodiesel and bioethanol are most compatible with the conventional energy supply system and thus can serve as the transitional energy for fossil fuels with minimal transformation cost until a better clean energy has been developed.

In 2006, about 95% of the total primary energy production in Malaysia was derived from fossil fuels such as natural gas, coal and petroleum as shown in Figure 1 (IEA, 2006). For developing economies like Malaysia, this dominant trend is expected to continue until 2030. Due to the huge dependency on fossil fuels, the total carbon dioxide emissions in Malaysia had been increasing steadily since 1998 (IEA, 2006). Realizing the detrimental effects brought by fossil fuels for energy generation, Malaysia has been actively advocated for the commercial production and usage of biofuels from its rich palm oil resources as fossil fuels replacement. In this paper, the progress and recent status of biofuels from palm oil in Malaysia will be discussed extensively. Existing and future challenges which will obstruct its further development will also be brought to the attention before concluding with several recommendations from the author's point of view to re-establish Malaysia's biofuels sustainability status in the next few decades.

2 PROGRESS OF PALM OIL BIODIESEL INDUSTRY IN MALAYSIA

2.1 Previous history and achievements

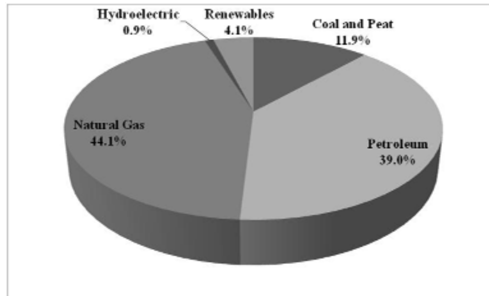

Figure 1: Malaysia total primary energy production in 2006

Malaysia is one of the leading palm oil producers in the world with 17.56 million tonnes of crude palm oil being produced in the year 2009 alone (MPOB, 2009). Since early 1980s, Government of Malaysia has adopted pro-active stance in pioneering palm biodiesel industry through the laboratory scale development projects by Malaysian Palm Oil Board (MPOB) or formerly known as Palm Oil Research Institute of Malaysia (PORIM). Successful output from the research projects coupled with the collaboration with local oil company, Petronas had enabled the construction of palm oil biodiesel pilot plant in 1984 with annual production capacity of 3,000 metric tonnes. The encouraging results from the extensive laboratory quality tests, stationary engine evaluations and field trials which proven that the diesel fuels blended with biodiesel had comparable performance with pure mineral diesel in terms of engine's life expectancy as well as total mileage covered had fuelled the momentum to further championing the development of biodiesel industry in Malaysia. The biodiesel industry made another gargantuan leap when the first winter-grade biodiesel was successfully developed which could prevent gelling issue when utilized in colder climate. However, insufficient demand and political support had restricted more breakthroughs to be achieved.

The stagnation continued until a series of government policies were declared in early 20th which sparked renewed interest in developing biodiesel industry. Fifth Fuel Policy was declared under the Eight Malaysian Plan (2001-2005) to announce renewable energy such as biofuels as the fifth fuel supply in Malaysia. National Biofuel Policy and Biofuel Industry Act were carved out in 2005 in order to develop a systematic legal, political and social framework for the usage of biofuels. As the support for the biodiesel industry in Malaysia being given due recognition again, its development started to grow by leaps and bounds. The first biodiesel refinery was set up in Labu, Seremban from the partnership of local companies in late 2005. The introduction of Envo Diesel, which comprised blending of 5% of straight palm oil and 95% mineral diesel, in late 2006 held great promises as it was believed could generate up to USD 380 million savings from imports annually (EIBM, 2005).

2.2 *Collaborations*

The progress of Malaysian biodiesel industry was made viable not through individual efforts alone but rather close related to the collaborations with foreign parties. In the early research and development stage, MPOB had cooperated with various foreign private companies and universities such as Brandies University from U.S., Prignitzer Eisenbahn (PE) Arriva from U.K., Cycle & Carriage and Diamler-Benz from Germany. These collaborations had not only speeded up the introduction of palm oil biodiesel to the commercial market, they had also built up trust and confidence with foreign biofuels investors. Subsequently, companies such as Mission Biofuels from Australia, Japanese Yanmar and Middle East Dubai Group were attracted to invest in several biodiesel developing projects in Malaysia (Reuters, 2008). Biodiesel exportation contracts to European economies were also successfully inked while the biodiesel production expertise and know-how technology was sought after by Korean company.

As a result, Malaysian biodiesel industry was able to stand at the forefront of the biofuels development compare to the rest of the world. Currently, total oil palm cultivation in Malaysia stood at 4.48 million hectares in 2008 which brings in export earnings of about RM65.2 billion (MPOB, 2009). Malaysia's Ministry of Plantation Industries and Commodities has approved a total of 91 biodiesel licenses to private companies with 10 active biodiesel plants currently in production. The total combined annual capacity can reach up to 1.7 million tonnes per year with additional four biodiesel plants are expected to commence commercial production at the end of 2009. This represents about 30% of the total world biodiesel demand in 2006 (NBB, 2009).

2.3 *Current status*

Biofuels industry in Malaysia are expected to continue revolving around the progress and development status of oil palm agriculture in the future decades. Malaysia is currently the second largest producer of palm oil after Indonesia and the largest palm oil exporter in the world. It exports more than 90% of the palm oil products to 150 economies which accounts to about 50% of the world total oil palm exportations (MPOB, 2009). From the 22.43 million tonnes of palm oil and related products being exported in 2008, 0.18 million tonnes was biodiesel and was exported to leading markets such as USA (71,324 tonnes), EU (70,273 tonnes), Singapore (29,485 tonnes), Korea (6,594 tonnes), Chinese Taipei (3,081 tonnes) and Australia (1,203 tonnes) as shown in Figure 2 (MPOB, 2009). This sector currently provides employment to more than 590,000 direct workers and contributed to about 3.2% of the economy's real gross domestic product (GDP) in 2008. Palm oil biofuels industry was also being highlighted as one of the main thrusts in achieving sustainability, high-income and inclusiveness for Malaysia under the New Economic Model (NEM) launched recently by Malaysia's Prime Minister on March 2010.

In view of the energy security and environmental concerns, Malaysian government has decided to implement the B5 Biofuels Programme by phases starting June 2011. Under this initiative, oil companies in Malaysia will need to perform mandatory blending of 5% palm methyl ester with 95% mineral diesel. This is expected to provide additional demand of about 0.5 million tonnes of palm oil annually to the biodiesel production, which will drive the growth of the industry. Currently, palm oil remains the sole commercial-scale raw material for biodiesel production in Malaysia. As an effort to diversify the raw material feedstocks for producing biodiesel, Jatropha has received considerable interest and development lately. Malaysian Rubber Board, which is responsible to oversee the Jatropha research in Malaysia, has announced several measures to encourage its farmers to cultivate Jatropha on marginal lands (Fitrian et al., 2009). On the other hand, National Tobacco Board is entrusted to investigate the feasibility of operating large-scale Jatropha plantation on bris soil in the northern part of the Peninsula Malaysia. Other types of promising feedstocks for biofuels such as waste oil, animal fats, biomass and microalgae are still under nascent research status and are unlikely to develop into commercial production in the near future.

3 FUTURE CHALLENGES

Even though environmental awareness on the usage of fossil fuels has increased considerably over the years, many daunting challenges still await for the full implementation of biofuels as a sustainable renewable energy. Malaysia has managed to establish a solid framework for the processing of biodiesel from palm oil over the past few decades.

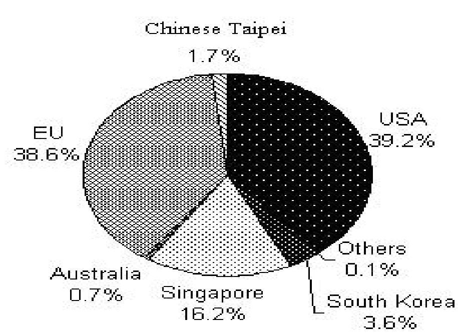

Figure 2: Exportation of Malaysia's biodiesel by economy in 2008

Therefore, it is imperative to continue riding on the experience gained to spearhead the challenges for continuous transformation of biofuels from agricultural and agro-industrial waste either in local context or international worldwide.

3.1 Pricing mechanism

The development of biofuels is still depended largely on the relative pricing between their feedstocks and fossil fuels. One of the main challenges to attract investments in biofuels industry is due to the difficulty in commercializing the biofuels as their relative pricing is higher than their counterparts in fossil fuels. In the year of 2008 when the price of crude oil reaching historical high, demand for cheaper alternative fuels such as biodiesel was at its peak which subsequently catalysted their increased production. However, all the anticipation sizzled after the price of crude oil dropped drastically to an all-time low where energy users were abled to enjoy cheaper fuels again. Suddenly, production of biodiesel from palm oil in Malaysia was no longer economically feasible as energy users were reluctant to bear the extra processing cost due to the comparatively expensive raw materials. This scenario had severely destabilized Malaysia's palm oil biodiesel industry. Most of the biodiesel plants had to either cut back or cease their production activity. As evident from Figure 3, the relative pricing between biofuels' feedstocks and fossil fuels is a key element in determining biofuels' competitiveness in the energy supply market (IndexMundi, 2009). Low feedstocks cost for biofuels processing must be accompanied with high price for fossil fuels in order for biofuels to gain attention. Moreover, biodiesel industry still lacks a proper cost subsidization scheme as compare to fossil fuels. It is thus important to deal with the fluctuations in feedstocks pricing in relation to fossil fuels as well as uncertainty in biofuels demand to continue develop the industry.

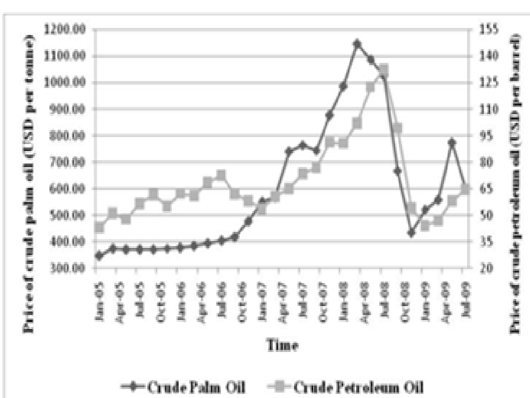

Figure 3: Relative price of crude palm oil and crude petroleum oil

3.2 Sustainability debate

Development of biofuels from agricultural as fossil fuels replacement is not supported by all parties. Several environmentalist groups especially in the western hemisphere in fact protested the development as they claimed that it was more detrimental to environmental sustainability in the long run. Palm oil is one of the major vegetable oils being traded around the world to be processed into edible food. As millions of population in the earth are suffering from malnutrition, processing potential food source for the poor into fuels seems to be unethical. Several non-governmental organisations (NGO's) have also expressed their concerned on the large-sclae switching of edible oils from food to biofuels as it may excerbate the hike in food cost to compensate for the more profitable biofuels industry. Besides the food issue, rapid expansion of oil palm plantations to cater for the increasing demand can greatly affect the equilibrium of the ecosystem in place (Fargione, 2008). Reports have been made on the increased logging and clearing activities of primary forests in Indonesia due to the expansion. As oil palm plantations encroach further into the forest, biodiversity of the ecosystem will be severely threatened such as extinction of wildlifes. These activities if left uncontrolled can cast a serious doubt on the sustainability criteria of the whole biofuels from agricultural production chain. Several importer economies such as EU had already started to impose sustainability conditions on all imported palm oil biodiesel into their economy. Therefore, more proactive monitoring and surveilancing actions are required to tackle the environmental issues to prevent affecting its exportation markets.

3.3 Government policy

On a whole, biofuels industry still lacks the financial profitability as well as sufficient infrastructure as enjoyed by conventional oil and gas energy industry. Consequently, many biofuels investments are deemed as risky and few investors are willing to commit their funds to participate in the industry. Without necessary support from the private industry, Malaysian government will find it hard to develop the biofuels industry without sacrificing lots of time and tax revenues. Therefore, government's encouragement through policies implementation is important to remove the political and geographical barriers which obstructing the development of biofuels industry (Micheal, 2007). During the early stage, Malaysian government had given strong support to its biodiesel industry and thus managed to carved out excellent output such as the introduction of winter-grade biodiesel and huge exportation demand from foreign economies. However, sluggish response and poor policy enforcement during the times when price of crude oil dropped drastically had caused diminishing interest in biofuels industry. As the demand reduced, fewer than 20% of the biodiesel production plants were active while most of the active plants were operating at less than half capacity. The long delaying in the implementation of 5% biodiesel mandatory blending in the mineral diesel had also caused disinterest among biofuels developers. This incident has proven that a coherent policy and comprehensive enforcement scheme are very much desired for continuous improvement of the biofuels industry which is still in its nascent stage.

3.4 Scientific research

Contrary to the mature processing technology in conventional oil and gas industry, biofuels production from agricultural and agro-industrial waste still requires further research and development in order to raise its conversion efficiency and thus lower the production cost. Malaysia itself is on the leading edge of biofuels industry with the inception of winter-grade biodiesel and the world's first integrated palm oil processing plant. Recently, Sime Darby, a Malaysian oil palm company had successfully decoding oil palm tree DNA for the first time in the world, which can double the current crude oil production to more than 10 tonnes per hectare annually (Loong, 2009). This technological leap is important in order to optimize the production capacity of palm oil without sacrificing the already limited arable land. Even then, more breakthrough in scientific research will be needed for Malaysia to continue protecting the sustainability status of biofuels from palm oil. Harvesting and plantation techniques, biofuels processing technology and handling of agro-industrial waste generated are some of the grey areas which still demand higher efficiency with the aid of state-of-the-art technology.

3.5 Raw materials selection

One of the major disadvantages of the current energy supply system is over-dependency on a single energy source which is fossil fuels alone. Consequently, its energy security and pricing are constantly in jeopardy (Lim et al., 2010). Biofuels in Malaysia are currently facing with the same problem as their production is largely depended on the availability of palm oil only. This is one of the reasons which explains the collapse of biofuels industry when the price of palm oil was relatively higher than the fossil fuels. Moreover, several allegations made by the environmentalists questioning the oil palm sustainability had directly reduced the demand for biofuels derived from palm oil and thus thrown the biofuels development out of track. The uncertainties surrounding the oil palm has clouded the efforts to develop biofuels to a higher level with palm oil as the primary raw materials. In order to disconnect the biofuels industry from the problems associated with its raw materials, it is imperative to diversify the choice of raw materials for the production of biofuels. Malaysia has already geared up to promote alternative biofuels feedstocks such as Jatropha and microalgae to supplement the biofuels from palm oil. The transition from single feedstock to multi-feedstock biofuels production will be a challenge for Malaysian biofuels industry in order to ensure the security and sustainability development in the future.

4 CONCLUSIONS

Even though biofuels industry in Malaysia must still address numerous problems and challenges, their implementation as fossil fuels substitutions to the current energy mix is imminent. Many economies such as USA and EU have already passed the law for mandatory blending of biofuels in their energy usage with many more economies are likely to follow suit in the next few years. Malaysia's effectiveness in tackling with the current issues and versatility in responding to the future challenges will determine its success in leading the biofuels industry. Several recommendations from the author's point of view are presented below which are crucial in taking Malaysian biofuels industry to a newer height.

- Malaysian government should take proactive role in preparation for the incoming implementation of biofuels to the conventional energy mix in the economy which include devising a comprehensive industry standard for biodiesel quality, allocating incentives to the usage of biofuels, setting up adequate infrastructure and supply system to deliver biofuels to the end users and educating the public to support the usage of biofuels.

- Centralized research centre specifically to cater for biofuels regardless of any feedstock should be set up to coordinate research efforts, enhancing development cooperation, exchanging scientific information and training necessary human capital.

- Malaysian Biodiesel Association (MBA) should play a greater role to bridge the gap between government and private industry by developing pertinent accreditation scheme for biofuels companies, fostering higher industrial cooperation and suggesting solutions at economic, legal, political, institution and technical levels.

- Future research direction in biofuels should be made to address their sustainability criteria as well as economic feasibility by developing more value-added processing such as bioethanol from lignocellulosic materials and dietary supplement (tocotrienols, tocopherols and carotenoids) through construction of an integrated refinery facility.

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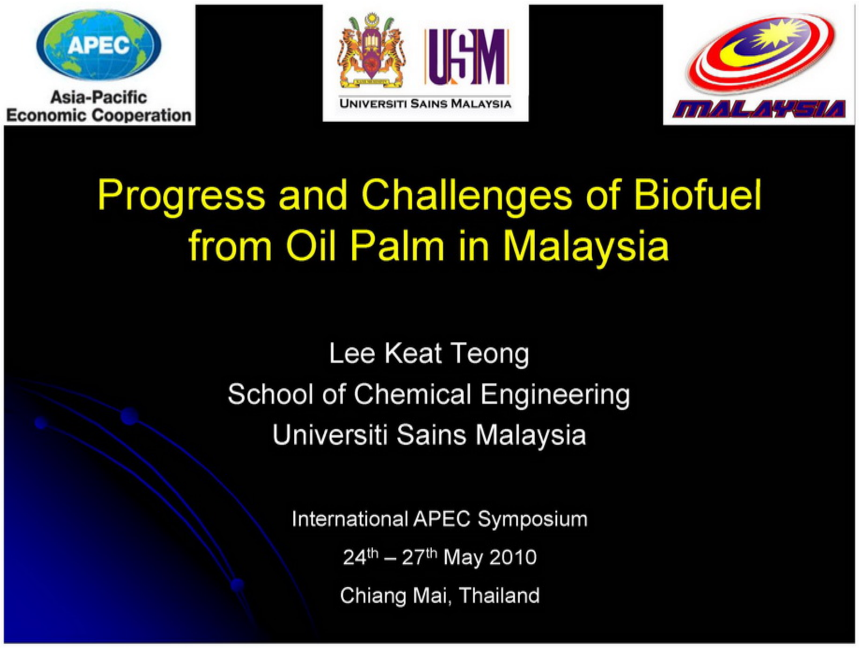
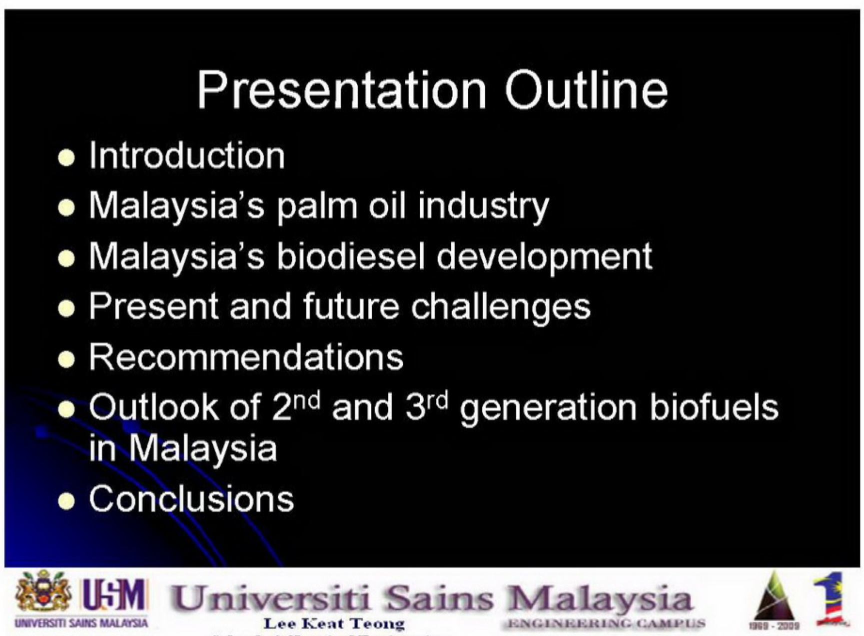
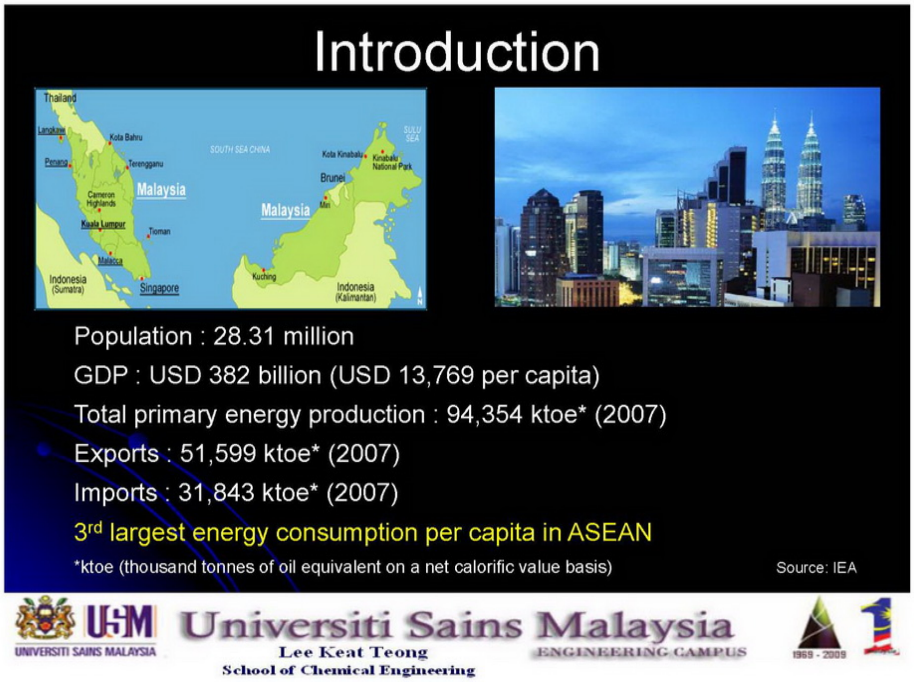
Session II: Active participant (Malaysia); Associate Professor Dr. Lee Keat Teong






Introduction
Thailand
Kota Bahru
Terengganu
Penang
Cameron Highlands
Malaysia
Kuala Lumpur
Tioman
Malacca
Indonesia (Sumatra)
Singapore
SOUTH SEA CHINA
Kota Kinabalu
Kinabalu National Park
SULU SEA
Brunei
Malaysia
Miri
Kuching
Indonesia (Kalimantan)
Population : 28.31 million
GDP : USD 382 billion (USD 13,769 per capita)
Total primary energy production : 94,354 ktoe* (2007)
Exports : 51,599 ktoe* (2007)
Imports : 31,843 ktoe* (2007)
3rd largest energy consumption per capita in ASEAN
*ktoe (thousand tonnes of oil equivalent on a net calorific value basis)
Source: IEA
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School of Chemical Engineering
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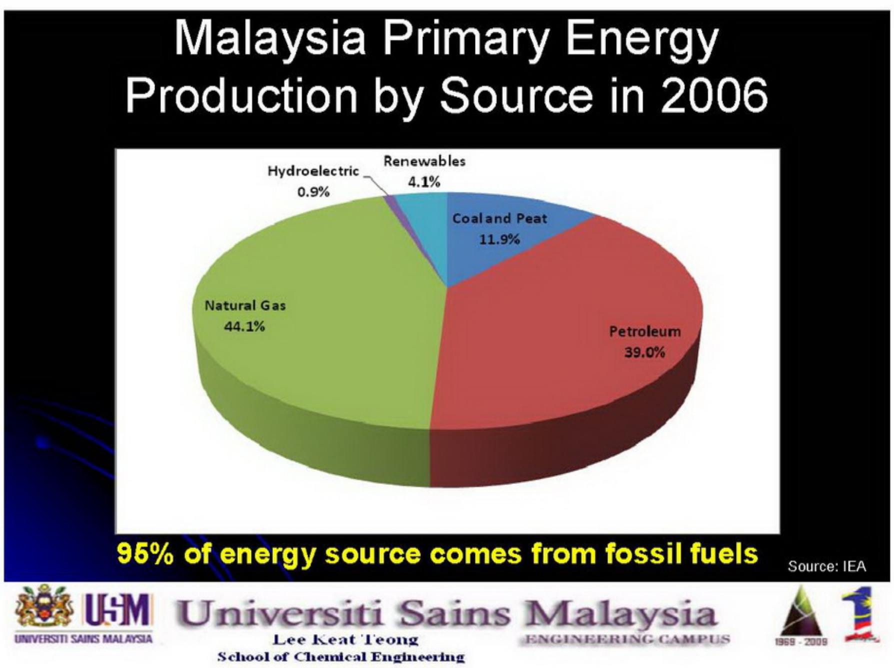
Malaysia Primary Energy Production by Source in 2006
Hydroelectric 0.9%
Renewables 4.1%
Coal and Peat 11.9%
Natural Gas 44.1%
Petroleum 39.0%
95% of energy source comes from fossil fuels
Source: IEA
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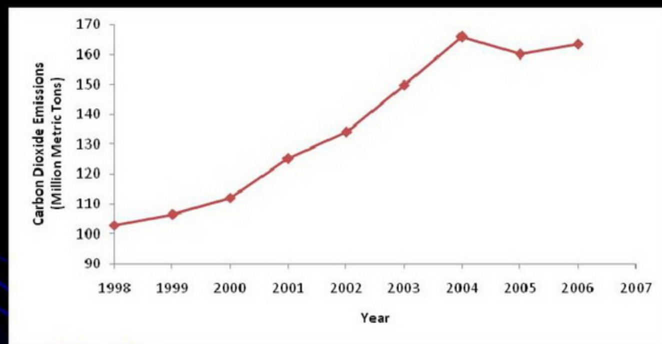
Malaysia Total Carbon Dioxide Emissions from Fossil Fuels



Source: IEA

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School of Chemical Engineering

Malaysia with Palm Oil

- One of the leading palm oil producers in the world
- 4.69 million hectares of oil palm cultivation (2009)
- 17.56 million tonnes of crude palm oil (CPO) being produced in 2009
- Largest palm oil exporter in the world (~50% of world palm oil exportation)
- Export earnings in 2008: USD 20.50 billion
- Exported to more than 150 countries worldwide

Source: MPOB

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Malaysia with Palm Oil Biodiesel

- Initial Stage
  - Early 1980s, laboratory research by Palm Oil Research Institute Malaysia (PORIM)
  - Construction of palm oil biodiesel pilot plant with Petronas in 1984
  - Field trials and stationary engine evaluations
  - First winter-grade biodiesel being developed in 1992
- Stagnation Stage
  - 8 years of stagnation phase without significant breakthrough (1992-2000)

Source: MPOB

Malaysia with Palm Oil Biodiesel

- Growing Stage
  - Fifth Fuel Policy declared under 8th Malaysian Plan (2001-2005)
  - National Biofuel Policy and Biofuel Industry Act 2005
  - World 1st integrated commercial normal and winter-grade biodiesel plant
- Current Status
  - 0.18 million tonnes of biodiesel exported in 2008
  - Employment for more than 590,000 direct workers
  - 91 biodiesel licenses being approved (10 million tonnes production capacity)
  - B5 Biofuels Programme starting June 2011
  - Key performace area under New Economic Model 2010

Source: MPOB

List of Major Biodiesel Plant in Malaysia

No.	Name of Production Company	Plant Location	Plant Capacity (tonnes/year)
1	Carotino Sdn. Bhd.	Pasir Gudang, Johor	120 000
2	Malaysia Vegetable Oil Refinery Sdn. Bhd.	Pasir Gudang, Johor	100 000
3	PGEO Bioproducts Sdn. Bhd.	Pasir Gudang, Johor	100 000
4	Vance Bioenergy Sdn. Bhd.	Pasir Gudang, Johor	100 000
5	Mission Biotechnology Sdn. Bhd.	Kuantan, Pahang	100 000
6	Carotech Bio-Fuel Sdn. Bhd.	Ipoh, Perak	150 000
7	Lereno Sdn. Bhd.	Setiawan, Perak	60 000
8	Golden Hope Biodiesel Sdn. Bhd.	Teluk Panglima Garang, Selangor	150 000
9	Global Bio-Diesel Sdn. Bhd.	Lahad Datu, Sabah	200 000
10	SPC Bio-Diesel Sdn. Bhd.	Lahad Datu, Sabah	100 000

Total combined annual capacity : 1.7 million tonnes
(~30% of world biodiesel demand in 2006)

Malaysia Biodiesel with Foreign Collaborations

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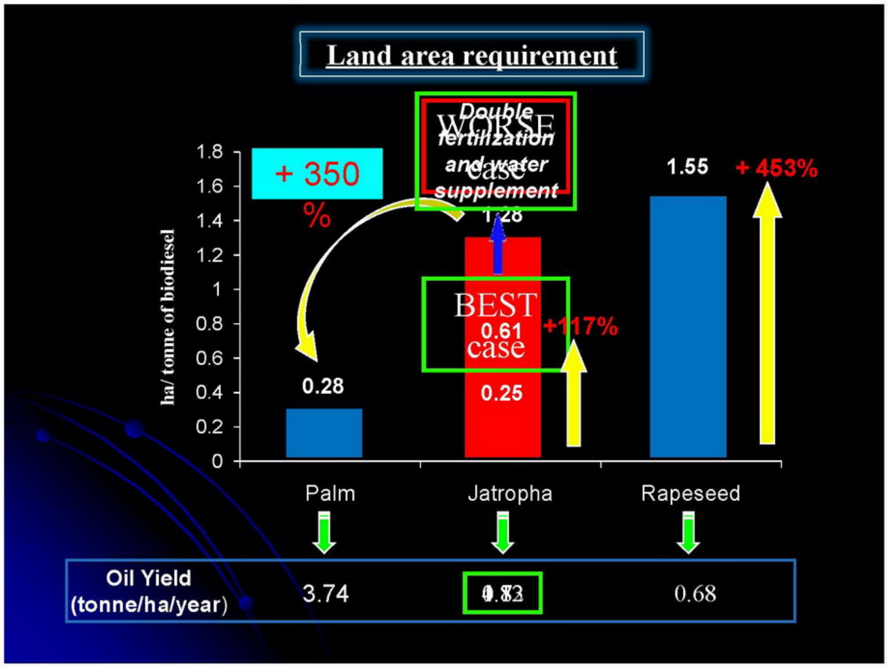
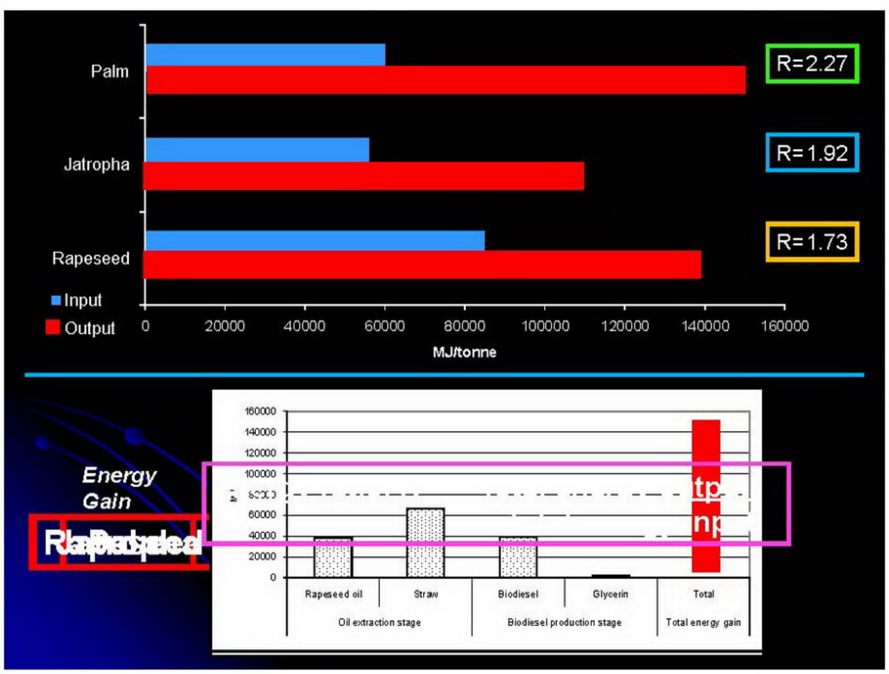

Land area requirement
ha/ tonne of biodiesel
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
+ 350 %
Double fertilization and water supplement
1.28
1.55
+ 453%
BEST case
0.61
+117%
0.28
0.25
Palm
Jatropha
Rapeseed
Oil Yield (tonne/ha/year)
3.74
0.68


Palm
Jatropha
Rapeseed
Input
Output
0
20000
40000
60000
80000
100000
120000
140000
160000
MJ/tonne
R=2.27
R=1.92
R=1.73
Energy Gain
Rapeseed oil
Straw
Biodiesel
Glycerin
Total
Oil extraction stage
Biodiesel production stage
Total energy gain

Challenges

- Sustainability debate
  - Deforestation, extinction of wildlifes and food vs fuel

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Issues

- Deforestation
  - Tropical forests cleared
  - Endangered animal species
- Orangutan Extinction
  - Sumatran & Bornean Orangutan (*Pongo abelii*)
  - Natural habitat degraded
  - Death rate increases
- Peatland Destruction
  - Natural carbon sink
  - Cleared for new plantations
  - Massive emission of CO_2

How true are the issues raised?

Claim :

- Deforestation

Real Scenario :

- Although Malaysia is currently the second largest producer of palm oil in the world, oil palm plantation only occupies 10% of the total land mass in Malaysia.
- Currently, more than 60% of land mass in Malaysia is still covered with virgin forest.
- Survey results revealed that palm oil plantation is rich with flora and fauna biodiversity

Changes in land use of selected tree crops in Malaysia (million ha)

Crop	1990	2005
Oil Palm	1.980	4.050
Rubber	1.823	1.250
Cocoa	0.416	0.033
Coconut	0.315	0.130
Total	4.534	5.463

How true are the issues raised?

Claim :

- Orangutan extinction

Real Scenario :

- Malaysia practices re-location of wildlife animals during land clearing
- Orangutan sanctuary has been establish in various locations in Malaysia
- There is still sufficient virgin forest as habitat for orangutans

\

How true are the issues raised?

Claim :

- Peatland destruction leading to depletion of "carbon sink"

Real Scenario :

- Oil palm plantations are actually good carbon sink.
- Better than virgin rainforests – the assimilation rate of CO_2 is 64.5 tonnes per hectare per year for oil palm plantation as compared to 42.2 tonnes per hectare per year for rainforest.

The Roundtable on Sustainable Palm Oil (RSPO)

- RSPO

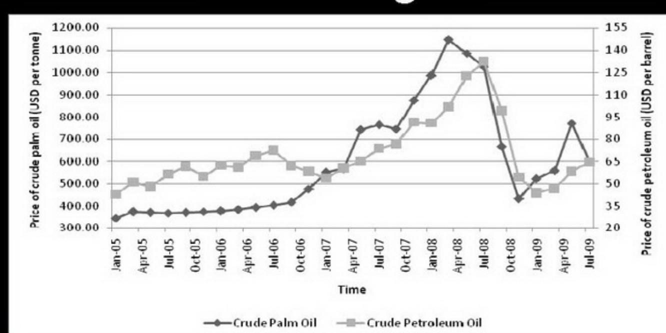
  - Promote growth and sustainable palm oil.

  - SUSTAINABLE definition:

  a legal, economically viable, environmentally appropriate and socially beneficial management and operations.

  - Hence, RSPO Principles and Criteria is introduced to ensure sustainability.

Challenges



- Pricing mechanism
  - Fluctuations in price of fossil fuels and uncertainty in demand

Source: IndexMundi

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Challenges

- Government policy
  - Legal, political, geographical and economical barriers

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Challenges

- Scientific research
  - Improving agricultural yield (harvesting and plantation)
  - Increase biofuels processing efficiency (milling and primary reaction process)
  - Better waste management for agro-industrial waste (POME and EFB)
  - Investigating feasibility of 2nd and 3rd generation of biofuels

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Challenges

- Raw material selection
  - Reduce over-dependency on single type of raw material
  - Transforming towards multi-feedstock biofuels production

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Outlook of 2nd Generation Biofuels in Malaysia

- Non-edible oils and agro-industrial waste
- Jatropha for biodiesel
  - Total plantation : 0.6 – 1.0 million hectares by end of 2010
  - On-going R&D for commercial jatropha biodiesel production
- Lignocellulosic biomass for bioethanol
  - Annual palm oil biomass generated : 55.73 million tonnes (2008)
  - On-going R&D for conversion of lignocellulosic biomass to bioethanol
- Palm oil mill effluents (POME) for biogas
  - Recoverable energy : 539 million Nm^3 CH_4
  - On-going R&D for process optimization

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Outlook of 3[rd] Generation Biofuels in Malaysia

- Cultivation of microalgae for biofuels
  - On-going R&D among academic researchers (USM) and private companies (AlgaeTech)
  - Pilot plant microalgae utilizing CO_2 from flue gas due to complete in 2010
  - Total recorded tally of Malaysian marine algae stands at 375 specific and intraspecific taxa
  - Large area of under-utilized rice lands and abundant supply of CO_2 from power generation plant

Source: Phang

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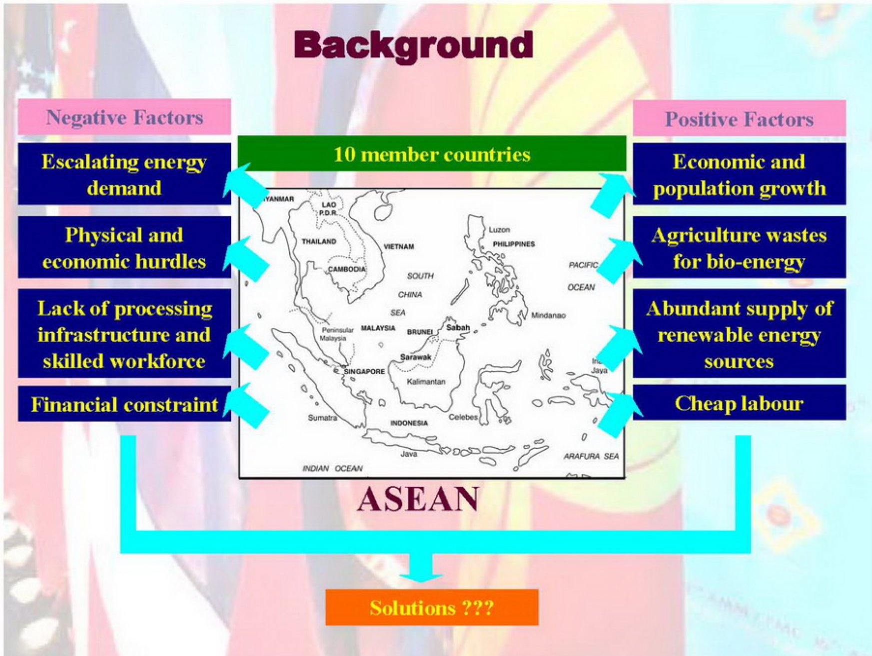
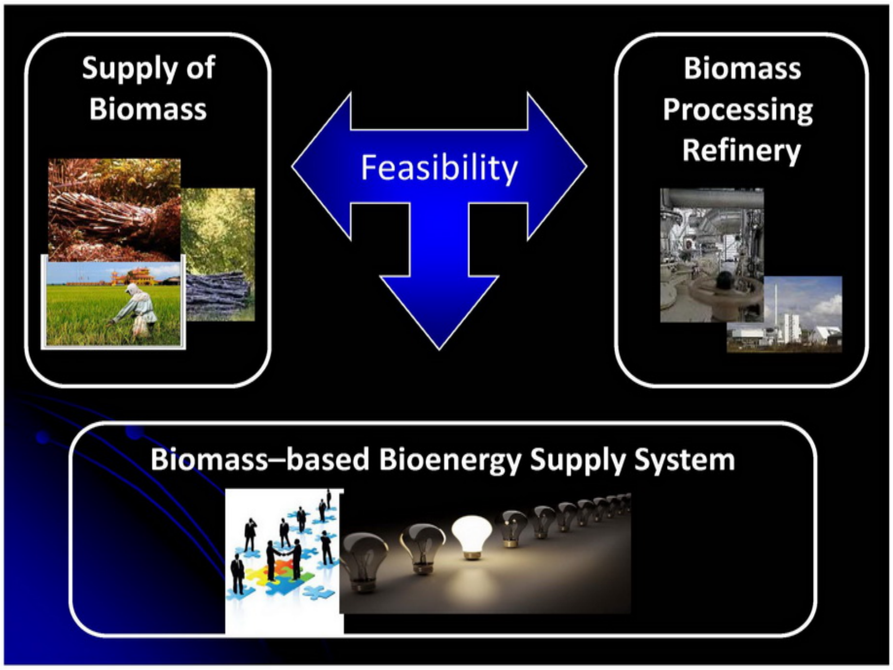
Fostering Co-operation Between ASEAN Countries Towards Biomass-Based Bioenergy System



Solutions

- Developing efforts as a unified body, not individuals
- Utilizing exclusive resources of each country
- Lao PDR, Cambodia, Myanmar-Supply of biomass
- Indonesia, Malaysia, Indonesia-centralized regional research centre or refinement of bio-energy technology and training providers
- Minimization of technological gap through knowledge and information sharing
- Concerted efforts in pooling resources to overcome financial barrier



Characteristic of Oil Palm Biomass

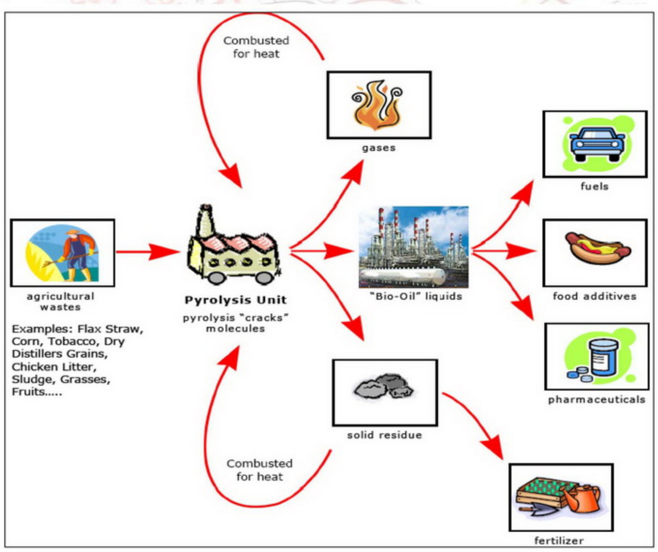
Types of Biomass Residues	Annual Quantity (million tons)	Approximate Moisture Content (%)	Energy Content MJ/kg
Empty Fruit Bunch	15.4	55	6.33
Mesocarp Fibers	9.5	40	1.064
Palm Kernel Shells	3.9	10	15.26
Palm Kernel Trunks	8.8	Dry Basis	18.50
Fronds	28.2	Dry Basis	19.81
TOTAL	**75.8**		

(Source: MPOB, FRIM, Singh, G. et.al. Oil Palm and the Environment: A Malaysian Perspective, 1999)

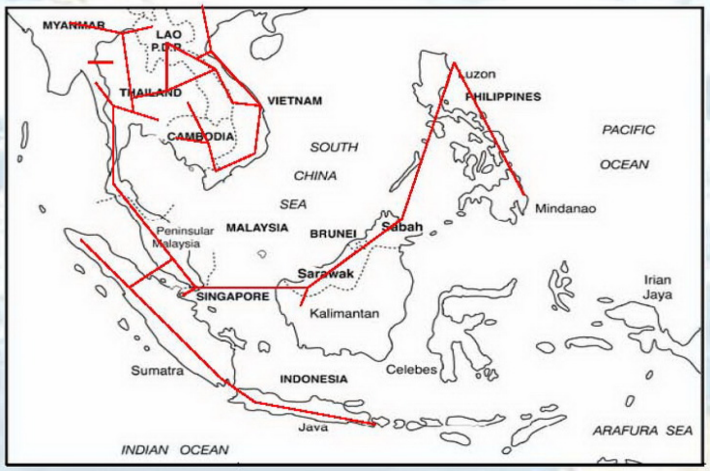
Supply of Biomass

Countries	Plantations	Total agricultural land (million hectares)	Area of plantations (million hectares)	Production (thousand tons)	Biomass generated (million tonnes/year)
Malaysia	Oil palm	7.87	4.49	-	55.73
	Rubber		1.25	-	1.65
	Rice		0.66	2,375	0.55
Indonesia	Rice	48.50	12.33	-	8.13
	Oil palm		6.77		84.03
	Rubber		3.41		4.49
Thailand	Rice	19.75	10.81	-	4.13
	Rubber		1.80		2.37
	Sugarcane		1.25		10.00
Philippines	Rice	11.50	4.27	-	4.06
	Coconut		3.36		10.40
	Sugarcane		0.38		3.04
Myanmar	Rice	11.98	8.20	20,923	8.15
Vietnam	Rice	10.07	7.21	25,867	8.97
Cambodia	Rice	5.46	2.57	6,264	1.68
	Corn (maize)		0.14	-	0.70
Lao PDR	Rice	2.13	0.78	1,963	0.68
Total		117.26	69.68	-	208.68

Biomass Processing Refinery



Biomass–based Bioenergy Supply System



Conclusions

- Solid foundation has been laid
- Worldwide frenzy on the search for a sustainable biofuels supply
- Cost effective technology and scheme needed to meet the future demand
- Robustness and versatility in dealing with the social issues
- Multi-feedstock production + Sustainable agricultural and agro-industrial waste management
- Key elements to reducing GHGs emissions and mitigate climate change

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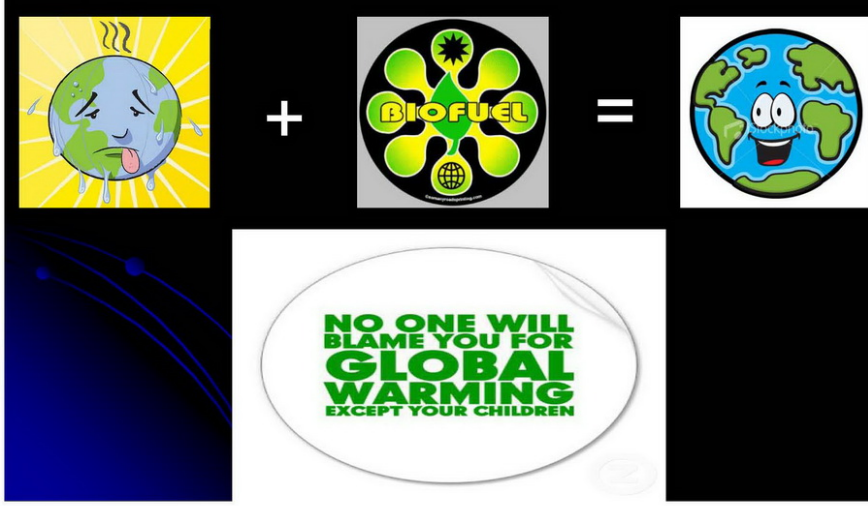
Acknowledgement

- Asia-Pacific Economic Cooperation (APEC)
- Faculty of Agro-Industry, Chiang Mai University
- Dr. Vorapat Sanguanchaipaiwong
- Dr. Noppol Leksawasdi
- Dr. Charin Techapun
- All the organizers of this Symposium

Thank you!



Session III

Session III: Keynote Speaker (Thailand); Professor Boonlom Cheva-Isarakul

Biogas Production as Substituted Energy and Pollution Reduction in Animal Farms

Suchon Tangtaweewipat, Ongart Songsee,
Boonlom Cheva-Isarakul
Dept. of Animal and Aquatic Science,
Fac. of Agriculture, Chiang Mai University

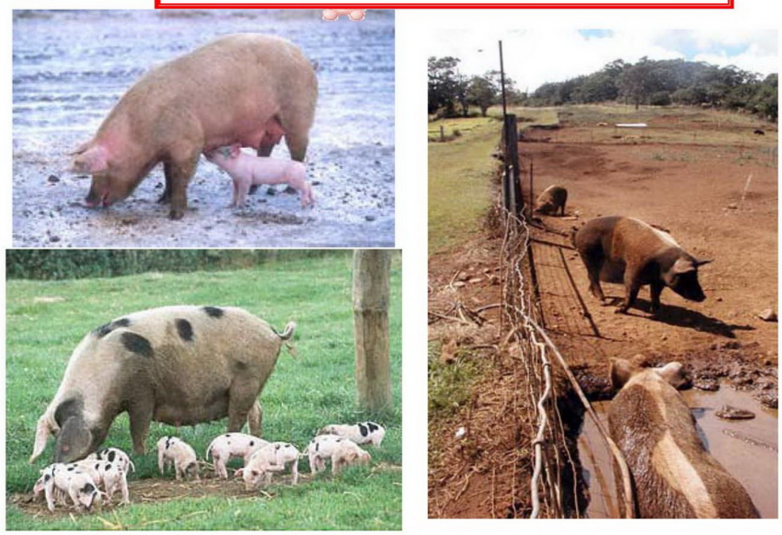
1

Assoc. Prof.
Dr. Suchon

Mr. Ongart

Assoc. Prof.
Dr. Boonlom

Animal production in former days



Backyard farming

4

Small holder farms


Local commercial
farm


Large scale farming
It is claimed by communities for
causing pollution problems
8

Problems caused by excreta:

*Unpleasant odor
- Ammonia
- Hydrogen sulfide

} Toxic

* Fly & Disease transmission

Methods for Problem Solving/Reduction

Use for fish production

- Use feces as direct feed to fish
- Use feces for plankton growth

Chicken raising on fish pond

12

3. Use as animal feed

4. Spray with EM (Effective micro-organisms)

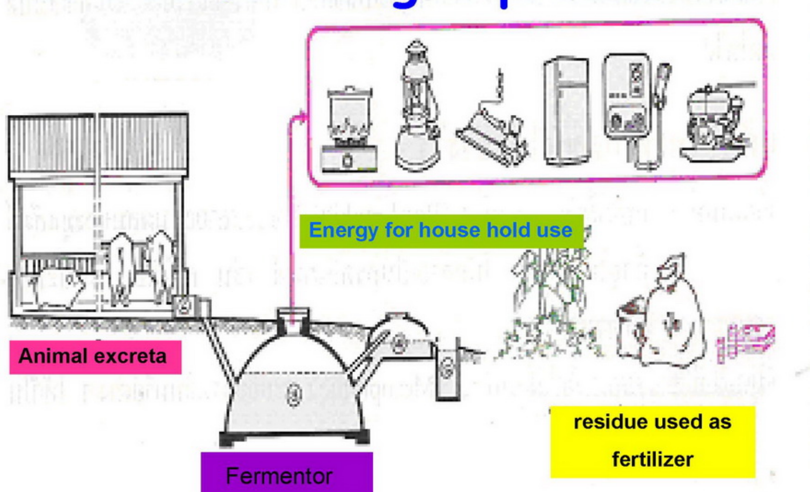
14

5. Using deep pit system

Excreta will be absorbed by the litter in the deep pit

15

6. Use for biogas production



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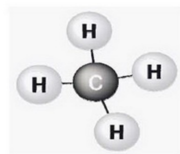
Biogas

is a natural gas, produced by fermentation of organic materials by micro-organisms under anaerobic condition



Composed of :

- Methane (CH_4) 50 - 70 %
- Carbon dioxide (CO_2) 30 - 50 %
- Others e.g. hydrogen sulfide (H_2S), ammonia (NH_4) 2 %

17

Organic matter (solid of large molecules)

⇩ **Hydrolysis**

Small molecule solid

⇩ **Acidogenesis**

Large molecule organic acid solution

⇩ **Acetogenesis**

Small molecule organic acid solution

⇩ **Methanogenesis**

Biogas

Products: NH_3, H_2S, VFA_s, CO_2, CH_4, CO_2

18

Amount of biogas from animal feces

Animals	Cubic meter/head
Swine	0.18
Cattle	0.16
Chicken	0.014
Human/ kitchen garbage	0.028

19

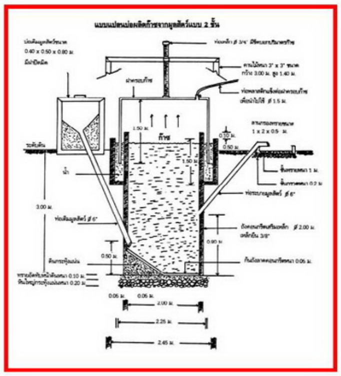
Factors affecting gas production

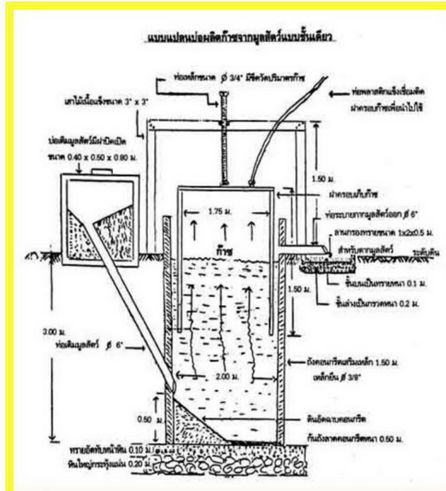
1. Temperature : 4-60 (30)ºC base on type of micro-organisms
2. pH : 6.6-7.5
3. Nutrient C:N = 25:1
4. Inhibitors e.g. ammonia, volatile fatty acids (VFA), EM, etc
5. Type and structure of organic matter : Material being digested e.g. feces can produce gas easily
6. Type of digester

20

Popular Biogas system

Floating dome





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Floating dome

Lahu village

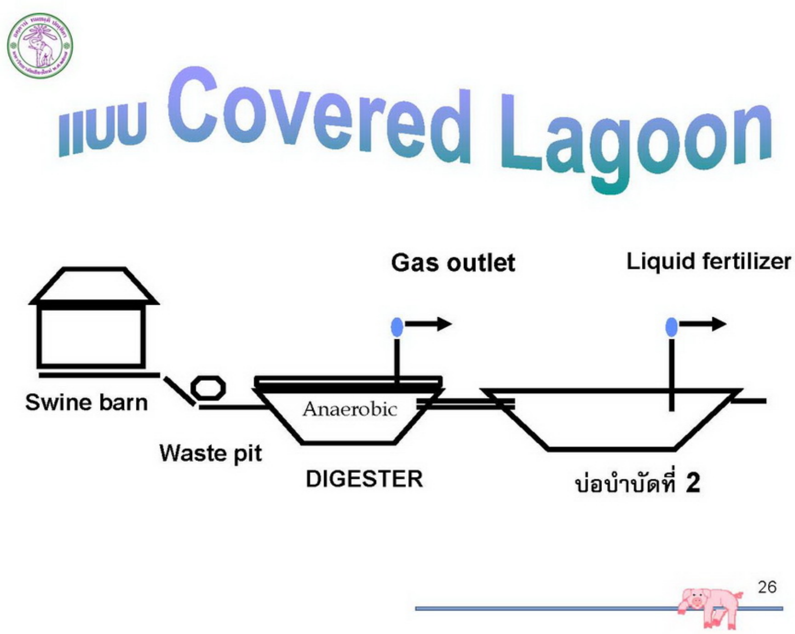
(Hill tribe)

Supported by Heifer international Project, Thailand

& Gifts for Life Foundation

22


Fix dome


แบบ Covered Lagoon
Gas outlet
Liquid fertilizer
Swine barn
Anaerobic
Waste pit
DIGESTER
บ่อบำบัดที่ 2
26

THE USE OF BIOGAS

For motor

For house hold cooking

Use as fertilizer

The project is supported by
Ministry of Science and Technology
Y2006 - present

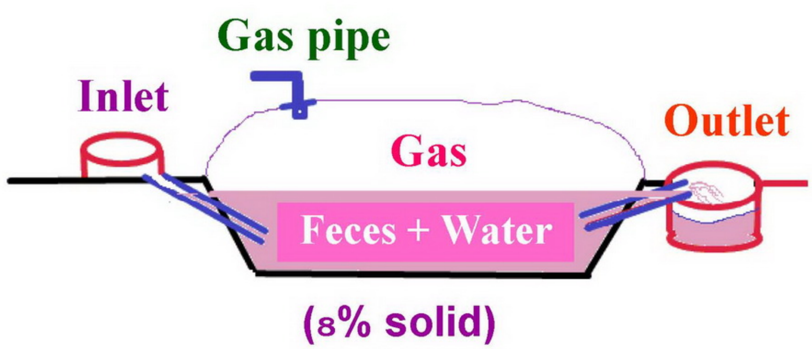
Aimed for small farms

*To reduce pollution problem
*To supply house hold energy
* Produce organic fertilizer
*Self reliance & Strengthen community
*Decrease global warming

30

Method

CMU sausage type digester



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Calculation

Amount of gas for cooking
= 20-25 cubic foot/ hour
or 1.4 cubic meter (2 hours)

Gas production 0.24 cubic meter/pig
= 1.4/ 0.18 = 8 heads

Number of pigs required for raising
= 8-20 heads/ family

Fermentation period = 17-55 days

33

Number of animals required

Animals	Heads
Cattle/buffalo	5 -15
Swine	8 -20
Chicken	100 - 200
Dairy cattle/beef	3 - 5

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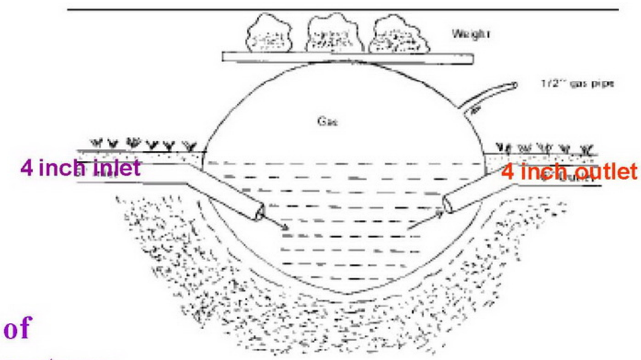


Advantage of CMU sausage type:

High elasticity (unbroken)

- **Low cost**
- **Easily to construct**
- **Easily to repair**
- **High gas production (under optimum temperature)**

35

Size of the pit

Materials

PVC sheet 0.25 mm. thick

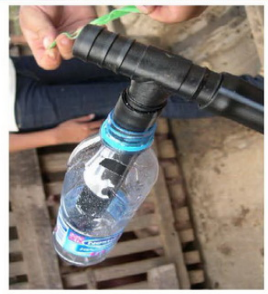
3 pieces of 1.8 m wide x 6 m long

Fixed them together with glue into a tube form

(3 inches overlapping)

Gas pipe with pressure adjuster & water trap

T- shape tube fixed to a gas pipe (PE) with an inner tyre of a bicycle



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Connecting the gas pipe to the digester

Tie 2 pieces of 1.2 m long, 4 inch
diameter PVC tubes
to both ends of the bags
with an old inner bicycle tyre

Air pumping

Any kinds of blowers can also work well

43

Carry to the pit


Add water to the digester
Fix a gas pipe
Fix a pressure adjuster &
water trap


Feces inlet
46


Using PVC
tube to close
the inlet
47


Sludge outlet

Connect a gas valve to a stove

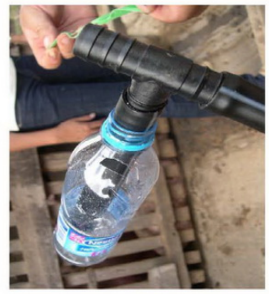
Cover with shading net, adjust the tension with an inner tyre

50

Gas purification

1. **Water trapping in gas pipe**

Biogas has high moisture. During flowing along a low temperature pipe, the moisture will be condensed to water and may block the pipe. Therefore water trap should be fixed



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Double digesters for a big farm

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The gas can be used
in animal farm &
Household cooking

Construction cost
of biogas unit
(not the house)
2,550 – 2,750 Baht
(excluding labor cost)

Possible problems:

Too much water in the digester
(washing the barn)

Not enough feces
(animals were sold out)

Obstruction in the gas pipe (T-shape)

Obstruction at the stove (rust)

55

Possible problems:

High concentration of solid

Too much water in the digester
(washing the barn)

Not enough feces
(animals were sold out)

Obstruction in the gas pipe (T-shape)

Obstruction at the stove (rust)

56


Safety valve: the end of the pipe should be 1 inch lower than water level
Water block in the gas pipe


Japanese quail farm, Doi saket, Chiang Mai


Japanese quail


Horse farms
- Mae sai, Chiang Rai
- Jun, Pa Yao

Jae hom, Lam Pang

Santisuk School, Doilor, Chiang Mai

Banpo, Chachengsao (April 6, 2009)

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Sanpoolei, May 2009

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Ban ta yiem, Sakon Nakorn

24 เทคโนโลยีชาวบ้าน

พลังงานทดแทน

ผลิตก๊าซชีวภาพ ด้วยถุงหมัก พีวีซี
แหล่งพลังงานทดแทนและลดมลภาวะ

Technology transfer through magazines

66

เกษตร มช. แนะชุมชนแปรรูปมูลสัตว์เป็นพลังงาน ผลิตแก๊สหุงต้ม-ตะเกียงชีวภาพ

2 local newspapers

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เจดีย์แม่ครัว

TV news

July 16, 2008

TV

March 3, 2009

March 10, 2009

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Science and Technology Fair

70

First prize award for Science and Technology Invention, Year 2008

Minister of Science and Technology

HRH Princess Chulabhorn
6th Northern Agricultural Fair (2009)

งานประชาสัมพันธ์ คณะเกษตรศาสตร์

Congratulation message from Fac. of Agriculture


Our lovely elephants are waiting for you
Korb Khun Ka
They need your kind support
75

International APEC Symposium on
"Biofuels from Agricultural and Agro-Industrial Wastes"
May 24th – 27th, 2010, Chiang Mai, Thailand

BIOFUELS POLICY AND SITUATION IN MEXICO

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ABSTRACT

Mexico is self-sufficient in terms of national energy security by being able to produce enough power to supply its internal primary energy demand and even export more than 30% of its primary energy production. Nevertheless, the origin of its energy production shows a significant bias towards hydrocarbons as its primary source. In this sense, through public policy focused on the promotion and development of biofuels, the Mexican government seeks to diversify its energy sources and respond to the need for agricultural development. This paper explores the Mexican energy context and its national energy policy with a particular focus in biofuels.

Keywords: energy security, biofuels, rural development and sustainability.

1 NATIONAL ENERGY CONTEXT

Primary energy corresponds to the array of sources that allow us to extract power from natural resources in many forms, both through direct or indirect ways.

In 2008, primary energy production amounted to 10,500 PJ, which compared to that of 2007 represents a .2% decrease.

In 2008 hydrocarbons were the main source for primary energy production, representing 89.1 % of all primary energy sources. 62.1% of the hydrocarbon production corresponded to crude oil, 26.2% to natural gas and 1% to condensates[2].

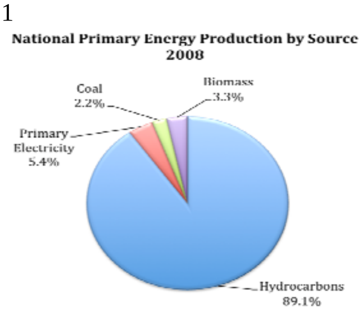
Electricity production represented 5.4% of total primary energy production. Its main sources were: Hydro Power which produced 368.8 Pj and represented 68.3%; Nuclear Power which produced 106.6 Pj and represented 18.8%; Geothermal Power which produced 70.1 Pj and represented 12.4% and Wind Power which produced 2.5 Pj and represented .5%[3] .

Coal production fell by .2 percentage points in relation to last year´s. Total coal production amounted to 2.2% of the national primary energy production[4].

Byomass production amounted to 345 Pj and represented 3.3%[5].

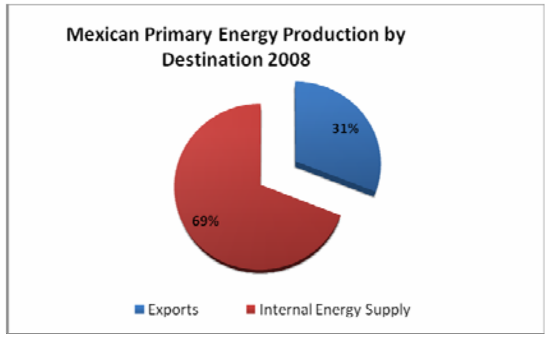
It is expected that byomass use for the production of biofuels will increase in Mexico, while the use of hydrocarbons will decrease in the production of primary energy. In this sense we will reduce our dependence on this energy source.

Fig. 1



The internal supply of primary energy amounted to 7,367 Pj.[6] This includes production, imports and inventory variation, discounts exports and unexploited energy.

In 2008, the internal supply of primary energy registered an increase of 1.6% compared to the previous year as a consequence of the growth in natural gas and electricity production and the decrease in crude oil exports[7].



Mexico is self-sufficient in terms of its capacity for supplying its internal demand of primary energy. This production also allows it to export 31% to the international market[8] (3,286 Pj)[9]. In this sense, the biofuels industry in Mexico will respond more to the need for agricultural development than to achieving energy security.

2 NATIONAL ENERGY POLICY

The current global energy situation requires the adoption of new concepts in national public policies; especially considering the volatility of oil prices that has occurred in recent decades, and has had strong effects on a wide range of national economies. This instability has complicated energy planning, and even economic planning in many economies worldwide. There are analysts who expect that the volatility will continue, especially when it is estimated that production has begun to decrease in some major oil producing economies.

Considering this, several economies have undertaken efforts to diversify energy sources, in order to reduce their present oil dependence and thus strengthen national energy security.

In the case of Mexico, the federal government has taken this as one of the main objectives of

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[2] National Energy Balance 2008, Ministry of Energy 2010, pg. 24.
3 Ibíd., Pág. 22.
4 Ídem.
5 Ídem.

6 Ibídem. Pág. 24.
7 Ídem.
8 Ídem.
9 Ibídem, Pág. 23.

the national energy policy, through the National Development Plan 2007 - 2012 (NDP), which seeks to promote the use of renewable energy and biofuels, with the purpose of diversifying energy sources and ensuring a reliable supply, as well as competitively priced energy inputs that guarantee quality[10].

Consistent with the PND, the Energy Sector Program 2007-2012 (PROSENER) states that energy security is a central goal for our economy, in response to the overwhelming dependence that our energy consumption has on oil. In this situation, there is a need to reduce the risks of high consumption of hydrocarbons[11], and to boost the participation of alternative sources of primary energy such as renewables and biofuels in the national energy matrix.

Therefore, the PROSENER incorporated within its objectives the need to ensure the economy's energy security in hydrocarbons (Goal I.1); balance the portfolio of primary energy sources (Objective II.2), and promote the use of renewable energy and biofuels that are technically, economically, environmentally and socially viable (Objective III.2).

The objectives mentioned above are converted into instruments for their own achievement. The balance of the options for primary energy sources contributes in the strengthening of national energy security. The promotion of renewable energy and biofuels propels that balance through diversification of sources.

3 NATIONAL BIOFUELS POLICY

3.1 Motivations Towards Biofuels

The promotion and development of biofuels in Mexico is motivated by three factors: (i) the achievement of greater national energy security, (ii) the reduction of greenhouse gas emissions and (iii) the achievement of greater development in the economy's rural areas.

Biofuels are aimed at reducing Mexico's reliance on hydrocarbons. Thus, it is essential that biofuels have a positive energy balance, which means that the energy obtained from biofuels is higher than that used for its production.

In the environmental sphere, it is estimated that the potential for emission mitigation of greenhouse gases by the use of biofuels will be of approximately 2.5 million tons of CO_2 by 2012[12]. However, to achieve this, we must ensure that the greenhouse gas emissions that derive from biofuels production chain are lower than those from the use of hydrocarbons.

Finally, rural development will undoubtedly be the biggest driver of bioenergy policy in Mexico, since, on one hand, it generates economic development in marginal areas through job creation, and on the other it will diversify the income of producers through the use of biomass, as this source of input will be destined for a strong and profitable industry.

3.2 Biofuels Promotion and Development Law

The Biofuels Promotion and Developmen Law (LPDB), published on February 1 2008, marks the beginning of the national policy on biofules. In accordance with the nature of the biofuel industry, this Law aims for the promotion and development of biofuels in order to contribute to energy diversification, sustainable development and the improvement of life conditions in rural areas; all of these, without risking food security, the environment and natural resources.

The LPDB endowed a number of different agencies to ensure the compliance of the motivations behind biofuels.

Therefore, this Law empowers the Ministry of Energy (SENER) to make a regular assessment of the energy balance of the programs that it foresees[13], which will ensure their efficiency and enhance national energy security; the Ministry of Environment and Natural Resources (SEMARNAT) to regularly evaluate that the programs are environmentally sustainable[14], including the balance on

[10] Presidency of the Republic, 2007. National Developmnent Plan 2007 – 2012, Pg. 134. Available at : http://pnd.calderon.presidencia.gob.mx/index.php?page=documentos-pdf.

11 Ministry of Energy, 2007. Sectorial Energy Plan 2007-2012, Pg. 6. Disponible en: http://www.energia.gob.mx/webSener/res/0/Programa%20Sectorial%20de%20Energia%202007-2012.pdf

[12] CICC, 2007. National Strategy for Climate Change. Intersecretarial Comission for Climate Change, SEMARNAT, México. Pg. 66.

13 12th Article, fraction XI from the Biofuels Promotion and Development Law.

14 13th Article, fraction V from the Biofuels Promotion and Development Law.

emissions of greenhouse gases; and the Ministry of Agriculture, Livestock, Rural Development, Fisheries and Food (SAGARPA) to assess the impact they generate on food security, as well as rural development, due to the production of feedstocks for biofuels.

According to the above, it is clear that LPDB is a fundamental step for our economy to enter an industry and, particularly, a market that has been developed in recent years, but that has caused a global discussion on its sustainability.

3.3 Instruments that complement the Law

Like any legal mandate, the LPDB requires a series of tools that complement its norms; therefore, it foresees the following instruments:

a) Regulatory related:

The norms contained in the LPDB are of a general nature and therefore require administrative regulations that develop its instruments and procedures in this respect.

At the moment the administrative regulation is integrated by a Bylaw on the Promotion and Development of Biofuels (RLPDB), which was published on June 18, 2009; and the Guidelines for permission granting, which were published on November 13, 2009.

b) Program related:

Regarding the program related instruments, the LPDB establishes the development of two major programs: on the one hand, (i) SAGARPA has to design the Sustainable Production of Feedstocks for Biofuels Program; and on the other, (ii) SENER is responsible of the Biofuels Introduction Program.

c) Coordination related:

Considering the diversity of agencies that have responsibilities in this area, the Inter-Ministerial Commission for Biofuels Development, was created through the LPDB, as a body composed of the heads of the Ministries of (i) SAGARPA, (ii) SENER, (iii) SEMARNAT, (iv) Economy and (v) Finance and Public Credit.

This Commission aims to coordinate the policies of the Federal Government on biofuels.

The RLPDB orders the Inter-Ministerial Commission for Biofuels Development to elaborate a strategy for the coordination of actions between agencies, which was published on November 5 2009, in the websites of SENER, SAGARPA and SEMARNAT.

3.4 The Sustainable Production of Feedstocks for Biofuels Program

The Sustainable Production of Feedstocks for Biofuels Program (PROINBIOS) aims to enhance the sustainable production of biofuels by the diversification of the Mexican farmers income sources, attending the food matrix and the energetic diversification of our economy. It was published on October 7 of 2009 on the SAGARPA web site

The comprehensive policy for the sustainable production of feedstocks for biofuels is synthesized in the following points:

a) Establish actions to enable the sustainable human, social and economic development of rural areas.

b) Promote the diversification of productive activities.

c) Ensure feedstocks production and supply of biomass, under sustainability criteria.

d) To consider new arrangements for field-industry organization.

In order to achieve the former goals, 5 strategies have been established. Out of these strategies a number of actions have emerged: the generation of technological packages; the production and reproduction of seeds and vegetative materials; the identification and establishment of pilot projects; and the analysis and approval of productive projects.

The PROINBIOS foresees the following as potential crops for the production of biofuels: sugarcane, sweet sorghum and sugar beet for ethanol production; and jatropha, castor and palm oil for biodiesel production.

According to the LPDB, corn, being a staple in Mexican agriculture, may be used as an ethanol feedstock only under very strict national surplus market conditions.

The National Institute for Crops, Livestock &

Forestry Research (INIFAP) has developed several studies to estimate the production potential of crops and regions, in order to boost production of biomass for biofuels.

INIFAP has 120 research projects in process geared to determine and select the genotypes with high yield and agroindustrial quality for some of the selected feedstock. The studies will also contemplate which regions have better conditions for the production of feedstock for biofuels.

3.5 Biofuels Introduction Program

The Biofuels Introduction Program aims to provide certainty for the development of the production and consumption chain of biofuels as an alternative in the fuel mix. It was published on October 7 of 2009 on the SENER web site.

This program foresees five action lines through which the stated objective will be achieved; these are:

a) Promoting information:

Throught the promotion of information it is intended to establish a biofuel information system for continuous communication between the various actors in the production chain. Within the achieved actions, two documents stand out: the publication of the "Feasibility Study on Biofuels in Mexico", which was prepared by the Inter-American Development Bank, German Cooperation (GTZ) in November 2007; and the compendium entitled "Legal Framework for Biofuels", which contains all the regulations that apply to the activities related to biofuels and was published on the SENER web site in December 2009.

b) Promoting research:

Research and technology will aim to the development of second and third generation technologies.

In this sense, the sector focused trust fund named "CONACYT-SECRETARIA DE ENERGIA-SUSTENTABILIDAD ENERGETICA" was established to propel scientific research and applied technologies, through the adoption and innovation regarding technological development in:

- Renewable sources of energy.
- Energy efficiency.
- The use of clean technologies.
- The diversification of primary energy sources.

The main institutes involved in the assessment of biofuel technologies are: The Mexican Petroleum Institute (IMP), the Electric Research Institute (IIE), The National Autonomous University of Mexico (UNAM) and the Polytechnic National Institute (IPN).

c) Promoting partnerships for the development of biofuels:

This line is intended to promote interaction and understanding of the various players of this multidisciplinary industry. One of the actions that have been made for this purpose is the Second International Conference on Biofuels, which took place on October 6 2009, in León, Guanajuato, bringing together experts from around the world who shared knowledge, technologies and experiences in the field.

d) Generating market certainty:

It seeks to give certainty to the production of consumer needs and consumption on production capabilities. Given this, SENER has led the coordination of mechanisms and the linkages between different sectors related to this new industry.

In this sense, on September 29 2009 PEMEX published the first national bid for the purchase of anhydrous ethanol in 2011, for the oxygenation of gasoline that is distributed in the metropolitan area of Guadalajara; thus creating a potential market of 176 million litters of anhydrous ethanol per year.

Also, the first 12 permits for the commercialization of biofuels were granted by SENER in December 2009.

e) Promoting the implementation, capacity and production:

This strategic line aims at building capacities in different sectors, allowing increased participation of biofuels in the national energy balance.

In order to generate experience in ethanol handling; evaluate the performance of gasoline-ethanol blends in car engines, and assess their gas emissions, PEMEX conducted a pilot introduction of anhydrous ethanol at the Cadereyta refinery in Nuevo León from December 11 2008 to February 6 2009.

This test consisted in replacing MTBE, the current gasoline oxygenizer, with anhydrous ethanol at a 6% mixture level by volume. For this purpose a batch of gasoline was mixed with 151, 600 litters of anhydrous ethanol produced from sugar cane. From this mixture a total of 2.53 million litters of gasoline-ethanol were distributed to 4 stations, through retail sales, with satisfactory results.

After the pilot test, the incorporation of anhydrous ethanol, at a 6% mixture level by volume, in the gasoline that is distributed in the three main metropolitan areas of the economy (Guadalajara, Monterrey and Mexico City) is foreseen; therefore replacing the MTBE that is used to oxygenate the gasoline in these metropolitan areas.

In a first stage, around 3 thousand barrels per day of anhydrous ethanol will be introduced to Guadalajara gasoline. This means approximately 176 million litters of anhydrous ethanol annually. The estimated necessary investment in infrastructure is of around 215 million pesos (17.34 million US Dollars).

In a second stage in 2012, anhydrous ethanol will be added to gasoline in the metropolitan areas of Monterrey and Mexico City, adding 133 and 493 million litters per year respectively. For this purpose the required investment in infrastructure will be of around 660 million pesos (53.23 million US Dollars).

Regarding biodiesel, the short-term strategy will be based on its use as an additive to ultra low sulphur diesel (UBA), in order to regain lubricity. Therefore, PEMEX has defined a strategy for the integration of biodiesel to the production of diesel UBA, at a 0.3% mixture level by volume, in two phases.

The first consisted in testing it as an additive over 30 thousand daily barrels of diesel UBA. The second phase would integrate biodiesel as an additive to the total national production of diesel UBA, requiring 105 million litters per year.

CONCLUSIONS

Biofuels represent an opportunity to increase energy security, reduce the dependence on fossil sources and encourage rural sustainable development.

Moreover, technologies that allow the production of 2nd and 3rd generation biofuels must be developed, because they do not compete with food security and help reduce negative impacts on the environment.

However, it is required to:

a) Increase information regarding the availability of feedstocks for biofuels.
b) Diversify the possible feedstocks for the production of biofuels.
c) Guarantee the supply and quality of biofuels.
d) Establish a price formula that makes the production of biofuels attractive when compared to its substitutes in production (i.e. ethanol vs. sugar), without compromising the public finances.

When promoting biofuels, environmental aspects must be taken into account, particularly avoiding:

a) Land use change.
b) The expansion of the agriculture frontier.
c) The use of exotic and invasive species as feedstock for biofuels.
d) Unsustainable water consumption.
e) Excessive use of pesticides and fertilizers.

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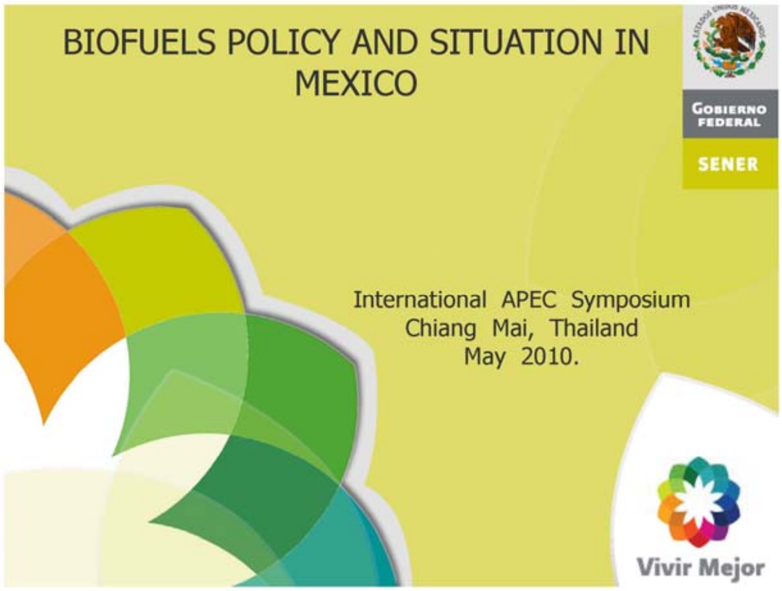
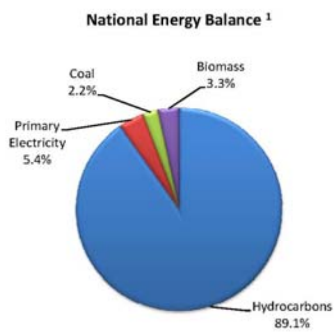
Session III: Active participants (Mexico); Mr. Roberto de la Maza



Mexican Energy Context

National energy balance:



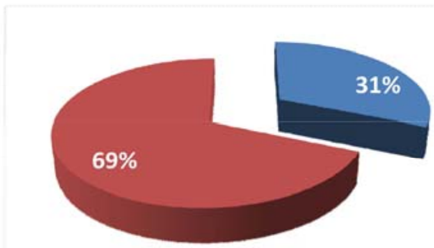
National Energy Production: 10,500 Pj	
Coal	**2.4%**
Hydrocarbons	**89.1%**
• Crude Oil	62.1%
• Natural Gas	26.2%
• Condensates	0.9%
Primary Electricity	**5.4%**
• Nuclear Power	1.0%
• Hydro Power	3.7%
• Geothermal Power	0.7%
Biomass	**3.3%**
• Sugarcane Biomass	0.9%
• Firewood	2.3%

[1] "National Energy Balance 2008", Ministry of Energy, Mexico, Pg. 22.

2

Mexican Energy Context

Energy destination:



■ Exports ■ Internal Energy Supply

[1] "National Energy Balance 2008", Ministry of Energy, Mexico, Pg. 24.

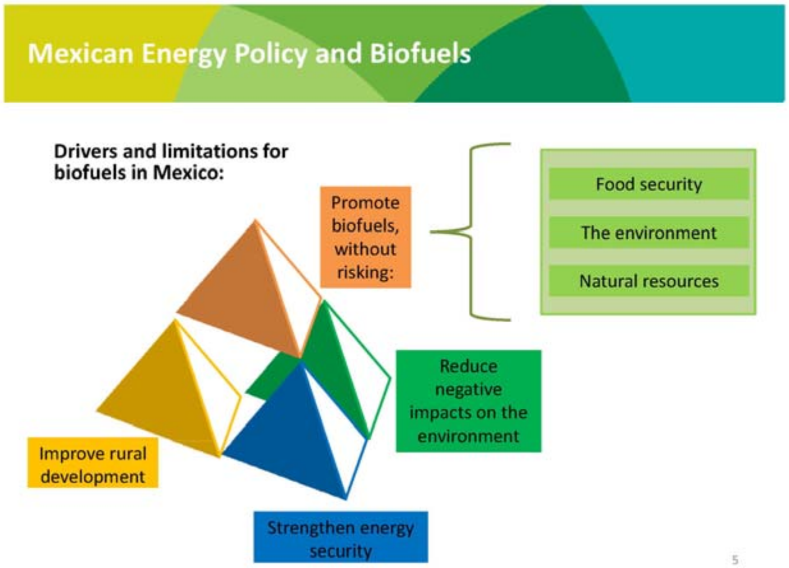
3

Mexican Energy Policy and Biofuels

Main goals:

- Energy security.
- Quality supply.
- Energy efficiency.
- Technological diversification.
- Sustainable development.

4



Biofuels National Policy

Mexican Biofuels Promotion and Development Law:

- Published on February 1st 2008.
- This law is focused on:
  - Feedstocks production without compromising food security.
  - Production, commercialization and use of biofuels, maintaining a positive energy balance.
  - Environmental protection and reduction of greenhouse gas emissions.

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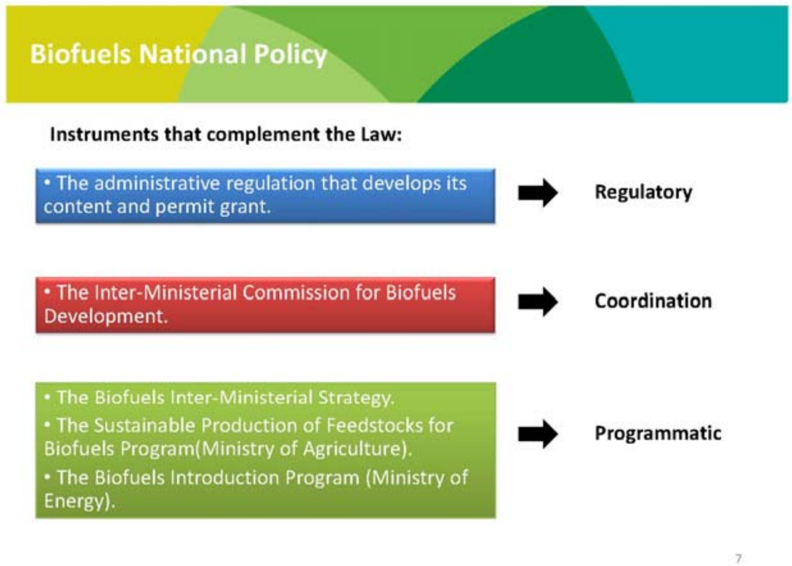
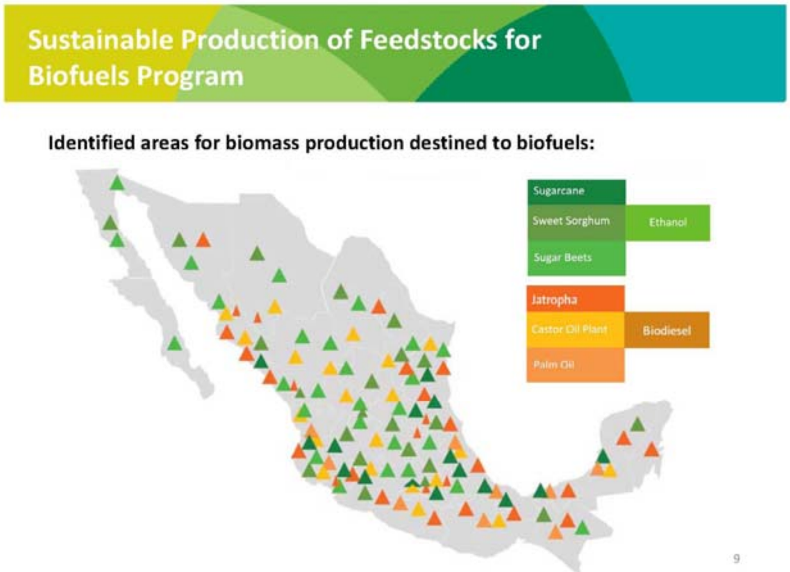
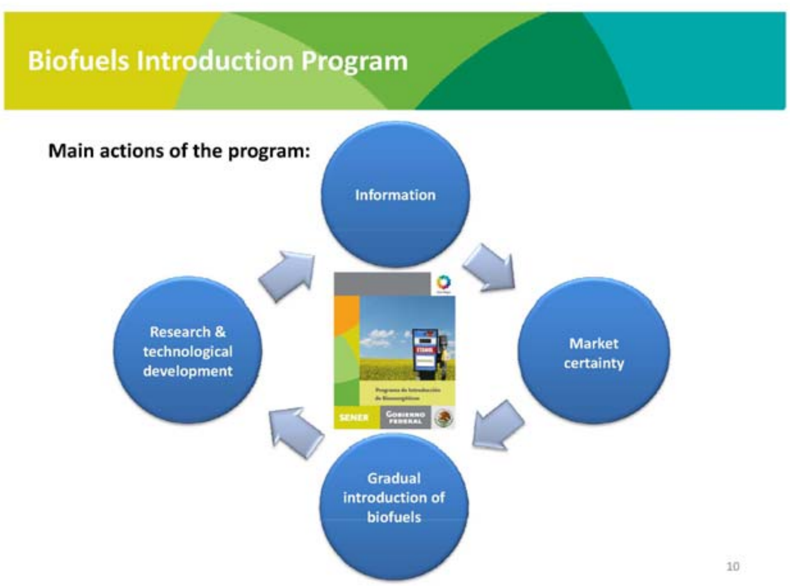

Biofuels National Policy
Instruments that complement the Law:
• The administrative regulation that develops its content and permit grant.
Regulatory
• The Inter-Ministerial Commission for Biofuels Development.
Coordination
• The Biofuels Inter-Ministerial Strategy.
• The Sustainable Production of Feedstocks for Biofuels Program(Ministry of Agriculture).
• The Biofuels Introduction Program (Ministry of Energy).
Programmatic
7


Biofuels National Policy
Inter-Ministerial Commission for Biofuels Development:
• Collegiate body integrated by the Ministries of Energy; Agriculture, Livestock, Rural Development, Fisheries and Food; Environment and Natural Resources; Economy; and Treasury and Public Credit.
• Its main duty is to coordinate the policies of the different ministries of the Federal Government, regarding biofuels, through the Biofuels Inter-ministerial Strategy.
Gobierno Federal
SAGARPA
SE
SEMARNAT
SENER
SHCP
8


Sustainable Production of Feedstocks for Biofuels Program
Identified areas for biomass production destined to biofuels:
Sugarcane
Sweet Sorghum
Sugar Beets
Ethanol
Jatropha
Castor Oil Plant
Palm Oil
Biodiesel
9


Biofuels Introduction Program
Main actions of the program:
Information
Market certainty
Gradual introduction of biofuels
Research & technological development
SENER
Gobierno Federal
10

Biofuels Introduction Program

Biodiesel introduction pilot test:

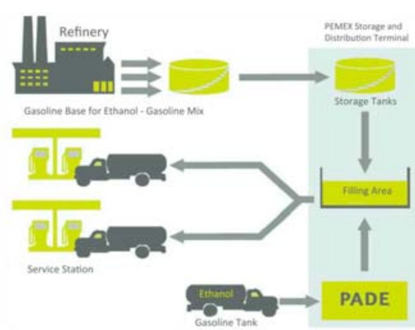
- In November 2008, the Cadereyta Refinery started the production of ultra low sulphur diesel.
- 0.5 and 0.3 % of biodiesel was added to regular diesel to test its performance as a lubricant.
- The use of biodiesel is also been assessed in the public transportation fleet of the city of Tuxtla Gutiérrez.

11

Biofuels Introduction Program

Ethanol introduction pilot test:

- Gasoline mixed with 6% of ethanol at 4 service stations in a period of 58 days, in order to:
  - Generate experience in ethanol handling.
  - Evaluate the performance of gasoline-ethanol blend in car engines.
  - Assess gas emissions from the use of gasoline-ethanol blend in cars.



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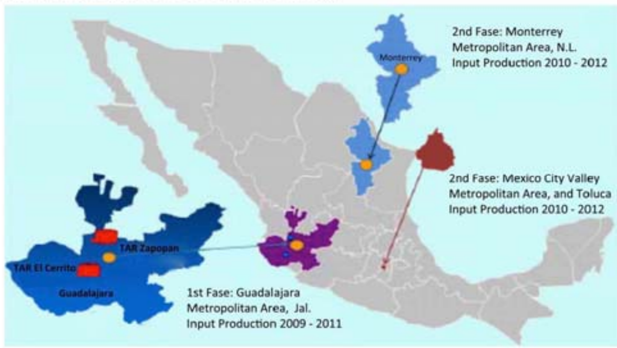
Biofuels Introduction Program

Gradual introduction of ethanol:

• The program considers replacing MTBE with ethanol as a 6% component of gasoline in the main cities of the country.



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Biofuels Introduction Program

Gradual introduction of ethanol:

• Its first stage will start in 2011, in Guadalajara, requiring 176 million liters of ethanol per year.

• On September 2009, PEMEX published a national bid to acquire the ethanol required to oxygenate the gasoline in Guadalajara.

• The selected proposal was presented by a consortium of three companies, but the contract was not signed because of the high prices of sugar.

• A new bid is being prepared by PEMEX.

14

Biofuels Introduction Program

Gradual introduction of ethanol:

• The second stage will take place in 2012, in Monterrey and Mexico City, requiring 133 and 493 million liters of ethanol per year, for each city.

• According to the Ministry of Agriculture, in these stages the main feedstocks for the production of ethanol will be sugar cane and sorghum.

15

Biofuels Introduction Program

Research and technological development:

- The program promotes research and technological development for 2nd and 3rd generation biofuels.
- There are several research projects regarding the production of ethanol through cellulosic material.

16

Conclusions

- Biofuels represent an opportunity to increase energy security, reduce the dependence on fossil sources and encourage rural sustainable development.
- Moreover, technologies that allow the production of 2nd and 3rd generation biofuels must be developed, because they do not compete with food security and help reduce negative impacts on the environment.
- However, it is required to:

  a) Increase information regarding the availability of feedstocks for biofuels.

  b) Diversify the possible feedstocks for the production of biofuels.

  c) Guarantee the supply and quality of biofuels.

  d) Establish a price formula that makes the production of biofuels attractive when compared to its substitutes in production (i.e. ethanol vs. sugar), without compromising the public finances.

17

Conclusions

- When promoting biofuels, environmental aspects must be taken into account, particularly avoiding:

  a) Land use change.

  b) The expansion of the agriculture frontier.

  c) The use of exotic and invasive species as feedstock for biofuels.

  d) Unsustainable water consumption.

  e) Excessive use of pesticides and fertilizers.

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Session III: Active participants (Mexico); Ms. Irasema Infante

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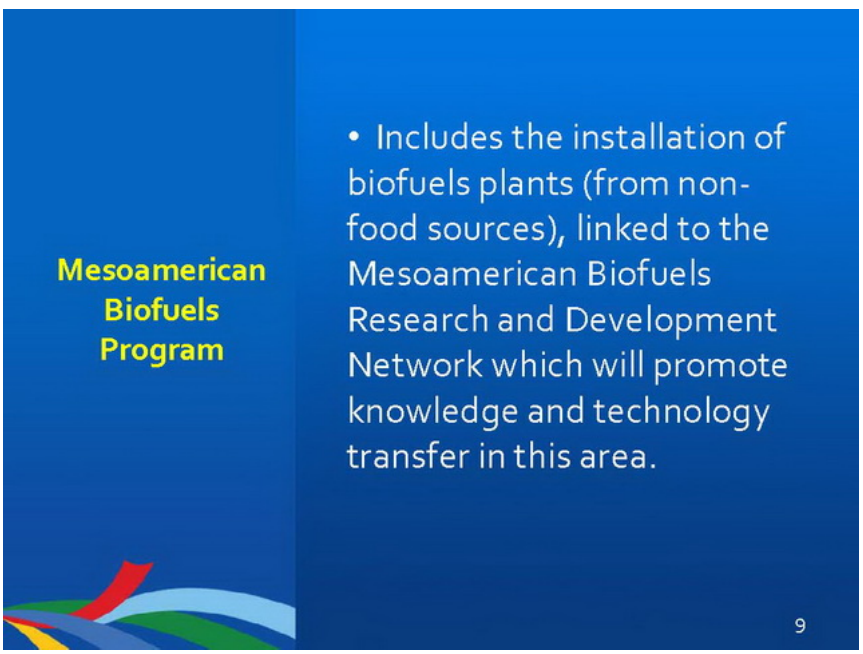
Project Mesoamerica is…
Dialogue and coordination mechanism that articulates cooperation, development and integration efforts amongst the Mesoamerican region in order to improve the quality of life of its citizens.
4


Added Value
Political Dialogue
Regional Integration
Common Priorities Definition
Resource Management (financing and cooperation)
Regional Public Goods
5


Main Projects:
Social:
• Mesoamerican Public Health System
• Mesoamerican Environmental Sustainability Strategy
• Mesoamerican Territorial Information System
• Social Housing Development Program for Central America
Economic :
• Highway Infrastructure (RICAM)
• Energy (electrical interconnections and biofuels)
• Telecommunications Integration
• Modernization of Customs and Border Crossings
6


Mesoamerican Biofuels Program
PROYECTO
Integración y Desarrollo
MESOAMÉRICA
7


Motivations
• Address concerns such as the depletion of proven oil reservoirs and oil price fluctuations
• Strengthen energy security by diversifying energy sources, without compromising food security in the region
• Promote sustainable development and natural resources preservation, contributing to climate change mitigation actions
• Create jobs and increase income in the region's rural areas by enhancing biofuels feedstock production
8


Mesoamerican Biofuels Program
• Includes the installation of biofuels plants (from non-food sources), linked to the Mesoamerican Biofuels Research and Development Network which will promote knowledge and technology transfer in this area.
9

Mesoamerican Biofuels Program

a) Biofuels Plants:

Country	Feedstock	Status
El Salvador	Jatropha, palm oil,	Operational
Honduras	Palm oil	Operational
Mexico	Jatropha, palm oil,	Under Construction
Dominican Republic	pending	Under Technical Studies
Panama	used oil	Under Licitation
Colombia	Palm oil	Operational

b) Conformation of the Mesoamerican Biofuels Research and Development Network.

10

Project in Chiapas, Mexico

- Production plants with different technologies:

1st **Phase**: Experimental using 2 FuelPod reactors

2nd **Phase**: Small scale production- Swedish technology plant- 2,000 daily lts.

3rd **Phase**: Industrial Production -British technology plant of 20,000 daily lts.

- 4th **Phase**: Development of Mexican-Colombian technology plant-8,000 daily lts.

Research and Technology Center in Biodiesel Production

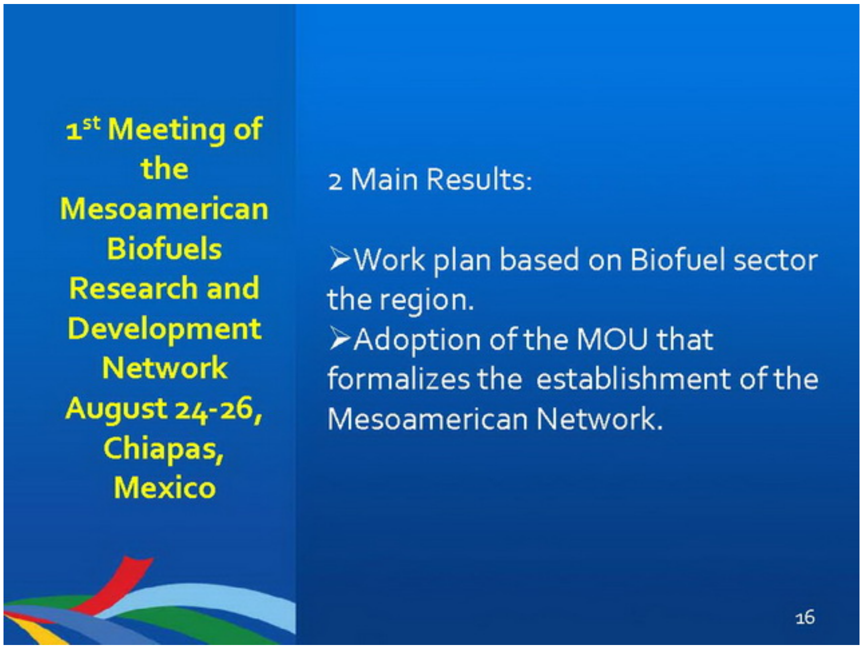
11


Expected Impacts of the Project
•Creation of jobs in rural areas in the production of biofuels feedstock (jatropha and oil palm) and the operation of the plant.
•Generation, validation and technology transfer
•Production of 7.2 million liters of biodiesel per year (minimum capacity)
•Supply biodiesel to Chiapas's public transport system
•Reforestation due to the production of biofuels feedstock with perennial crops and the use of temporary and marginal lands
12

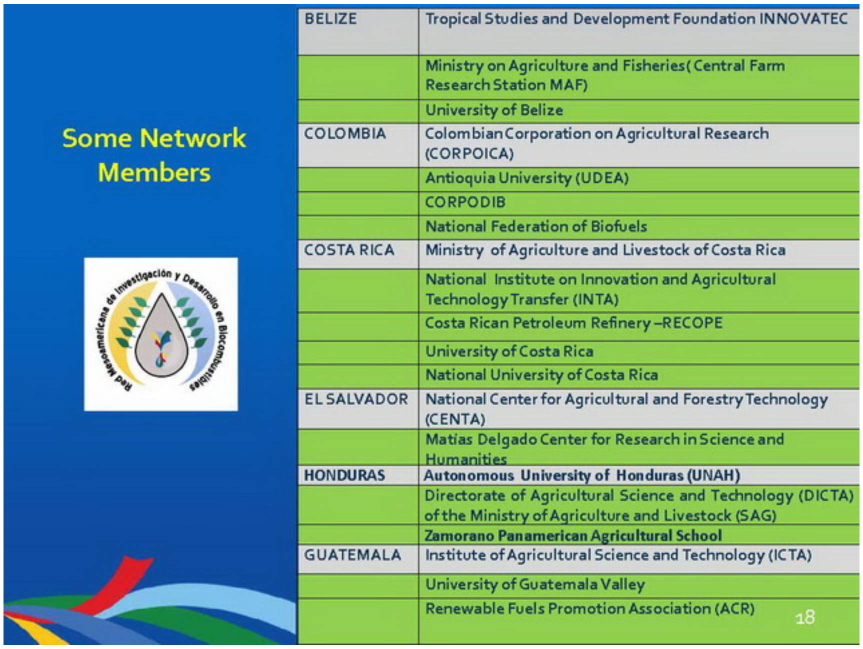

XI Summit of the Heads of State and Government of the Tuxtla Dialogue and Agreement Mechanism
Guanacaste, Costa Rica
July 29, 2009
Declaration of Guanacaste:
"To strenghthen the Mesoamerican Biofuels Research and Development Network, which will contribute to energy and food security in the region, and to hail the progress in the Mesoamerican Biofuel Program, especially the installation of two pilot plants for biodiesel production in El Salvador and Honduras, as well as the progress achieved in Dominican Republic, Mexico and Panama. "
13


The Mesoamerican Biofuels Research and Development Network is…
A regional instrument to facilitate the development of technology, capacity building and strengthening of research institutions.
General Objective:
Promote research, knowledge sharing, development of technology, human resources and best practices among the Mesoamerican countries with the purpose of assisting in the formulation of biofuels' policies, scientific validation, and information transference.
14

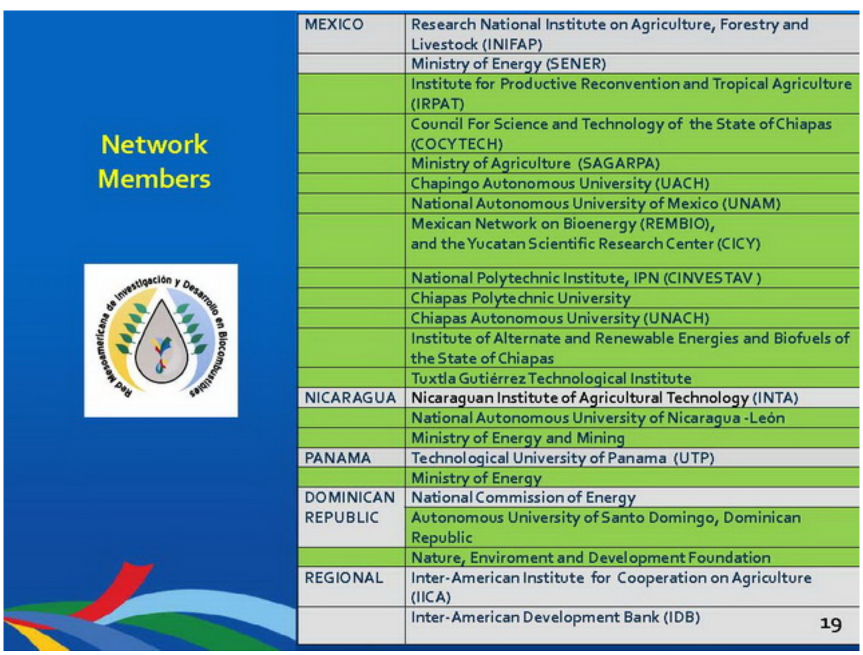

Specific Objectives:
•Develop plans and programs with regional impact
•Develop and implement interdisciplinary and interinstitutional projects
•Promote training and capacity building among the members of the Network
•Promote the exchange of knowledge and experience
•Promote a direct link between users and beneficiaries of specific projects
•Contact funding sources and participate in the resources management
15


1st Meeting of the Mesoamerican Biofuels Research and Development Network August 24-26, Chiapas, Mexico
2 Main Results:
➢Work plan based on Biofuel sector the region.
➢Adoption of the MOU that formalizes the establishment of the Mesoamerican Network.
16

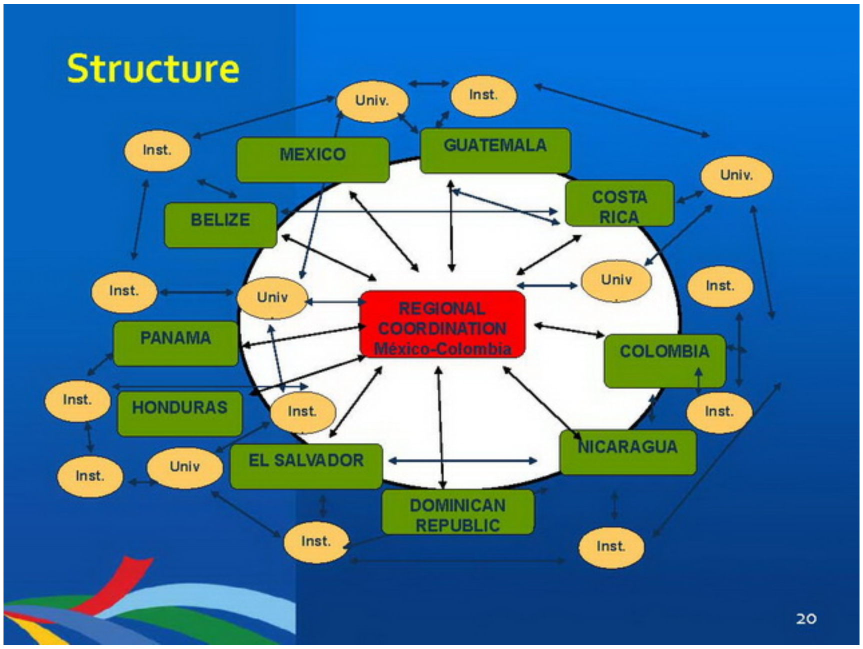

Work Plan Content:
1. Regional Project for the Genetic Improvement of Jatropha.
2. Regional Project for a study on micro-organisms as biofuels supply.
3. Create a website containing reliable technical information that allows online discussion forums and links to other networks.
4. Human resources management and training.
5. Mesoamerican graduate program.
6. Environmental and Food Security Diagnosis.
7. Process technology development .
17



BELIZE	Tropical Studies and Development Foundation INNOVATEC
	Ministry on Agriculture and Fisheries(Central Farm Research Station MAF)
	University of Belize
COLOMBIA	Colombian Corporation on Agricultural Research (CORPOICA)
	Antioquia University (UDEA)
	CORPODIB
	National Federation of Biofuels
COSTA RICA	Ministry of Agriculture and Livestock of Costa Rica
	National Institute on Innovation and Agricultural Technology Transfer (INTA)
	Costa Rican Petroleum Refinery –RECOPE
	University of Costa Rica
	National University of Costa Rica
EL SALVADOR	National Center for Agricultural and Forestry Technology (CENTA)
	Matías Delgado Center for Research in Science and Humanities
HONDURAS	Autonomous University of Honduras (UNAH)
	Directorate of Agricultural Science and Technology (DICTA) of the Ministry of Agriculture and Livestock (SAG)
	Zamorano Panamerican Agricultural School
GUATEMALA	Institute of Agricultural Science and Technology (ICTA)
	University of Guatemala Valley
	Renewable Fuels Promotion Association (ACR)



MEXICO	Research National Institute on Agriculture, Forestry and Livestock (INIFAP)
	Ministry of Energy (SENER)
	Institute for Productive Reconvention and Tropical Agriculture (IRPAT)
	Council For Science and Technology of the State of Chiapas (COCYTECH)
	Ministry of Agriculture (SAGARPA)
	Chapingo Autonomous University (UACH)
	National Autonomous University of Mexico (UNAM)
	Mexican Network on Bioenergy (REMBIO), and the Yucatan Scientific Research Center (CICY)
	National Polytechnic Institute, IPN (CINVESTAV)
	Chiapas Polytechnic University
	Chiapas Autonomous University (UNACH)
	Institute of Alternate and Renewable Energies and Biofuels of the State of Chiapas
	Tuxtla Gutiérrez Technological Institute
NICARAGUA	Nicaraguan Institute of Agricultural Technology (INTA)
	National Autonomous University of Nicaragua -León
	Ministry of Energy and Mining
PANAMA	Technological University of Panama (UTP)
	Ministry of Energy
DOMINICAN REPUBLIC	National Commission of Energy
	Autonomous University of Santo Domingo, Dominican Republic
	Nature, Enviroment and Development Foundation
REGIONAL	Inter-American Institute for Cooperation on Agriculture (IICA)
	Inter-American Development Bank (IDB)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DOMINICAN REPUBLIC
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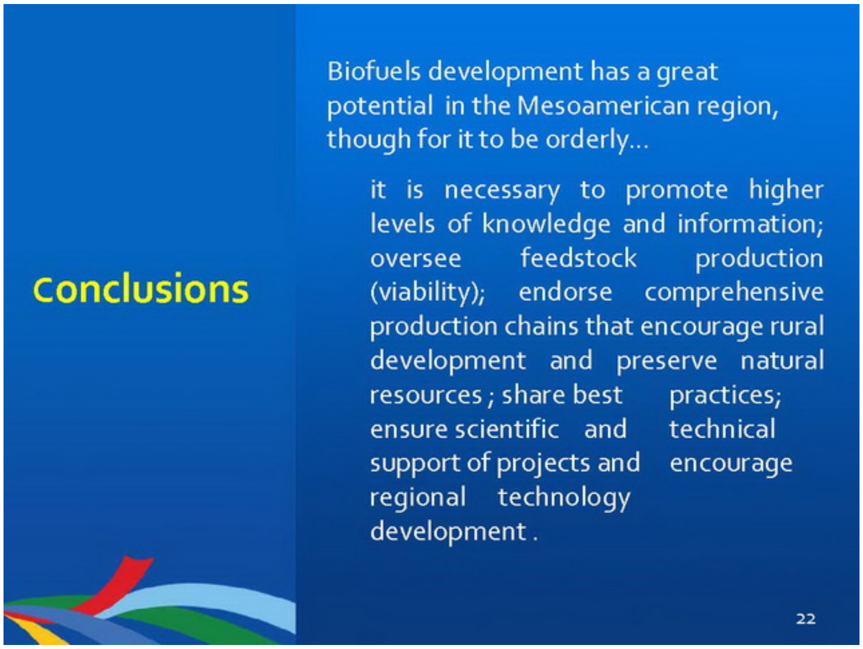
Mesoamerican Biofuels Research and Development Network website:
Menú principal
Calendario
Usuarios en línea
Mensajes
No hay mensajes en espera
Biodiesel
Programa de Trabajo
Administración del sitio


Conclusions
Biofuels development has a great potential in the Mesoamerican region, though for it to be orderly…
it is necessary to promote higher levels of knowledge and information; oversee feedstock production (viability); endorse comprehensive production chains that encourage rural development and preserve natural resources ; share best practices; ensure scientific and technical support of projects and encourage regional technology development .
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MESOAMÉRICA
www.proyectomesoamerica.org
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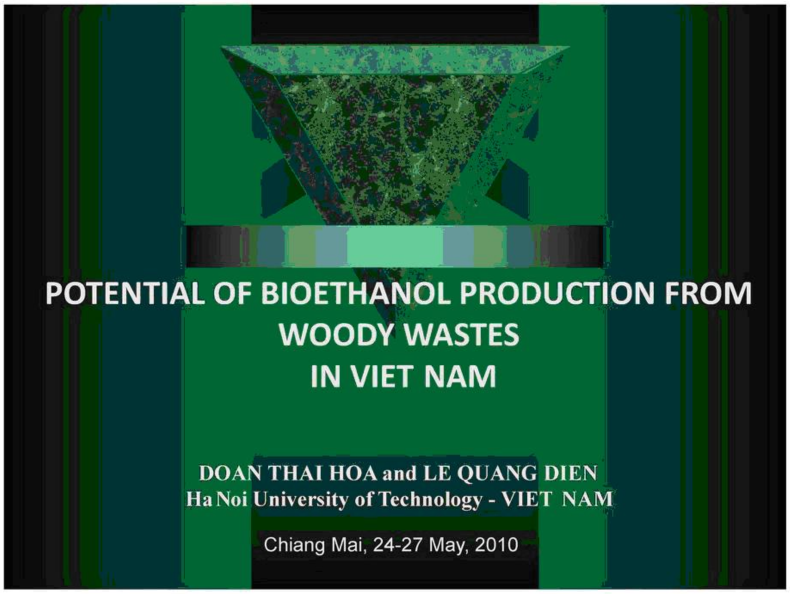
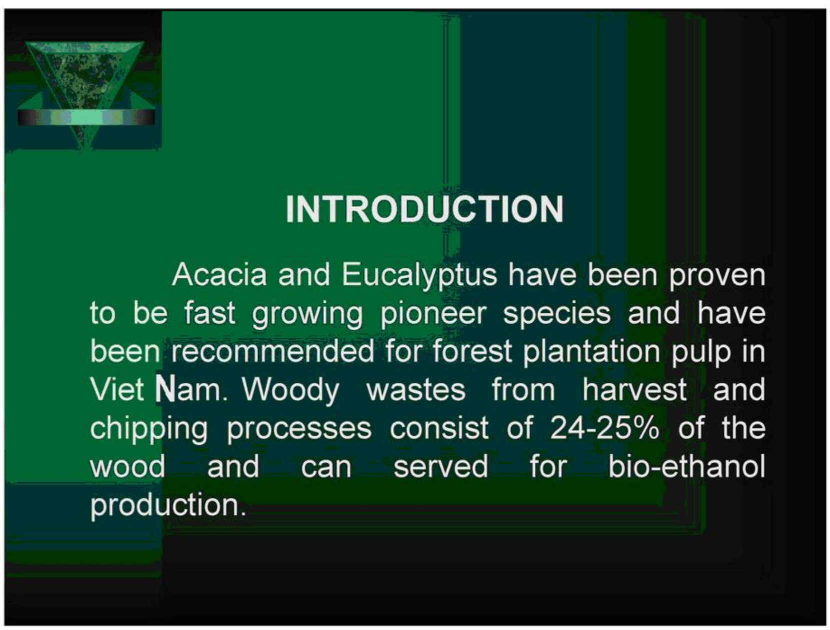
Active participants (Viet Nam);
Associate Professor Dr. Doan Thai Hoa





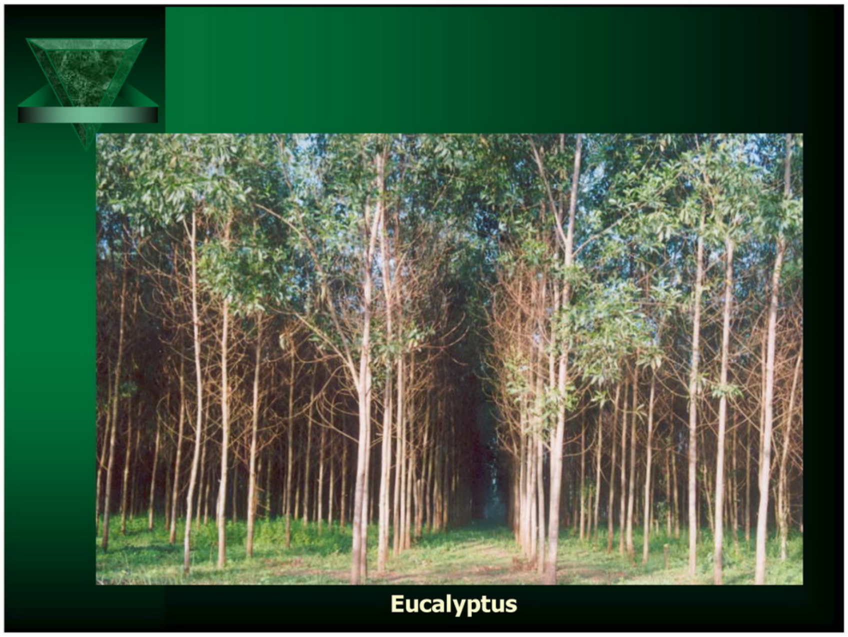
Area of Forest in Viet Nam

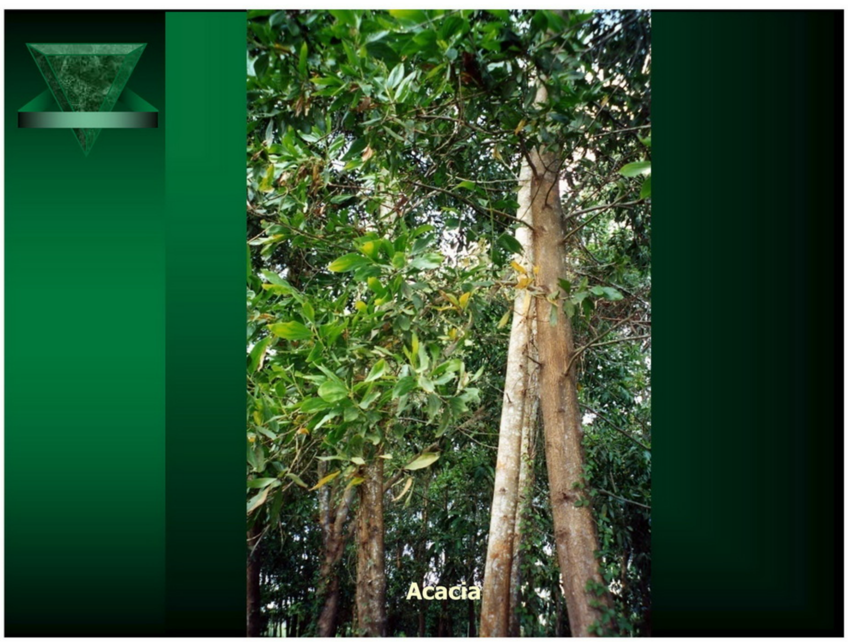
(by 31 December 2008)	Area of Forest, 10^3 ha	*Planted Forest, 10^3 ha*
Whole Country	**13118.8**	***2770.2***
Red River Delta	416.4	*203.6*
Northern Midlands and Mountain Areas	4558.4	*983.9*
North Central Area and Central Coastal Area	4497.4	*1007.4*
Central Highlands	2928.7	*197.3*
South East	419.9	*139.6*
Mekong River Delta	298.5	*238.5*

(Source: Statistical Yearbook of Vietnam 2008, Statistical Publishing House)

Area of concentrated planted forest was about 670.000 ha, (mainly *Acacia mangium* and *Eucalyptus urophylla*), increasing rate of more than 5%.

With production of wood 10 - 12 m^3/ha, the yield may be more than 6 million m^3/year, or more than 3 million tons/year.


Eucalyptus


Acacia

Pulp and paper industry in Viet Nam annuallly used around one million tons of timber. The wood residues extimated 200 thousand tons/year.

In 2009, chips (mainly acacia and eucalyptus) exported to Japan, China... was around 1.5 million tons.

So, annually, 70-80 thousand tons of woody wastes can be utilized for bioethanol production.

Chemical Compositions of Woody Wastes

Constituents	*Acacia mangium*			*Eucalyptus urophylla*		
	Timber	Branches	Saw Dust	Timber	Branches	Saw Dust
Cellulose, %	49.7	46.3	41.5	46.3	40.1	43.1
Lignin, %	26.8	27.1	29.6	23.94	25.3	28.5
Extractives, %	3.4	3.5	5.8	2.67	2.98	-

ETHANOL PRODUCTION FROM BIOMASS IN VIET NAM

- The first generation bioethanol from starch (rice, maize, cassava etc.) and molasses is popular.
- The second bioethanol from lignocellulosics has not yet been developed. So, cellulosic bioethanol production became one of important issue for sustainable development.

Some results of bioethanol production from agricultural wastes (rice straw, sugar canes, elephant grass...) have been obtained.

Utilization of woody residues are perspective due to the use of renewable resources and can be applied in a large scale.

Cellulose can be hydrolyzed by using either acids or enzymes.

To convert lignocellulosic biomass to glucose for ethanol fermentation, enzymatic hydrolysis is an attrative option.

Development of an effective pretreatment method for lignocellulosic biomass is the most important aspect of the enzymatic saccharification process.

In this study, woody wastes were pretreated by dilute sulfuric acid and hot water.

Dilute sulfuric acid pretreatment and enzymatic saccharification

Pretreatment:

- Acid concentration: 0.1-0.5%
- Temperature: 125-165°C
- Duration: 5-25 min

The optimization condition: 0.25% H_2SO_4, 150°C, 15 min. Dissolved 22.2% of dried biomass.

Enzymatic hydrolysis:

- Novozymes 50013 (cellulase mixture), Novozymes 50014 (hemicellulase) and Novozymes 50010 (β-glucosidase).
- Hydrolysis: 50°C, citric acid buffer, pH 4.8, 96 h

Cellulose conversion was 30-32%

Hot water pretrea tment and enzymatic saccharification

Hot water pretreatment:

- Temperature: 190-200°C
- Duration: 20 min

Dissolved 12.6-21.2% of dried biomass

Alkaline treatment:

- 1% NaOH, 70°C, 4 h

Enzymatic hydrolysis:

- Novozymes 50013 (cellulase mixture), Novozymes 50014 (hemicellulase) and Novozymes 50010 (β-glucosidase)
- Hydrolysis: 50°C, acidcitric buffer, pH 4.8, 96 h

Cellulose conversion was around 62%

Ethanol fermentation

No	Sugar solution	Fermentive ability				
		D3 (Bac.)	D5 (Bac.)	Y24 (Yeast)	Mixture of D5 and Y17	*Zymomonas mobilis*
1	Pentose sugars	++	++	-	++	++
2	Hexose sugars	+++	+++	-	+++	-

++ good
+++ very good
- Nonfementive

CONCLUSION

- The woody wastes from pulp and paper industry can be use as feedstock for bioethanol production in Vietnam.
- The hot water pretreatment, followed by alkaline treatment could improve enzymatic saccharification. More than 60% of cellulose or 83% of cacbohydrate was converted to fermentable sugars.
- Dilute sulfuric acid pretreatment could converted 32% cellulose or 54% of cacbohydrate to fermentable sugars.
- Additional treatment could be apply for improving cellulose conversion to fermentable sugars.


Thank you!

Session III: Active participants (Viet Nam);
Mr. Nguyen Van Thong
(on behalf of Dr. Pham Khanh Toan)

APEC International Symposium
"BIOFUELS FROM AGRICULTURAL AND AGRO-INDUSTRIAL WASTERS"
May 24-27, 2010 in Chiang Mai-Thailand

CURENT STATUS AND TREND OF BIOFUEL DEVELOPMENT IN VIET NAM

Economy Report

By: Dr. Pham Khanh Toan
Director of Institute of Energy - Ministry of Industry and Trade

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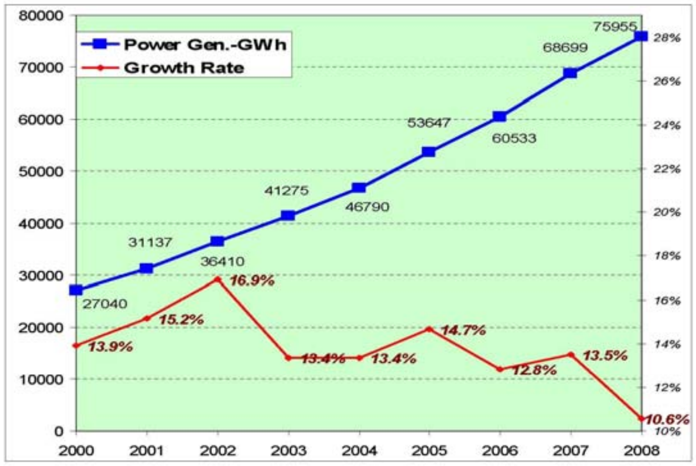
CONTENTS OF PRESENTAION

1. An Overview: Viet Nam Energy
2. National Program for Biofuel Development
3. Potential of Biofuel in Viet Nam
4. Current and Trend of Biofuel Development in Viet Nam
5. Conclusions

1. An Overview: Viet Nam Energy

power generation 2001-2008



Power Gen. 2006-2008 grew: 12.3%/ann.

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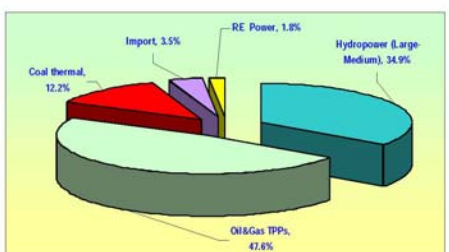
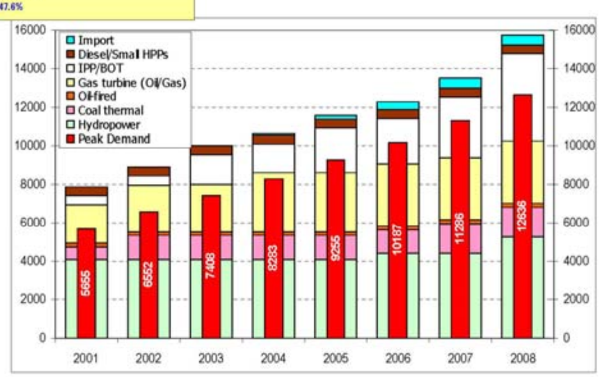
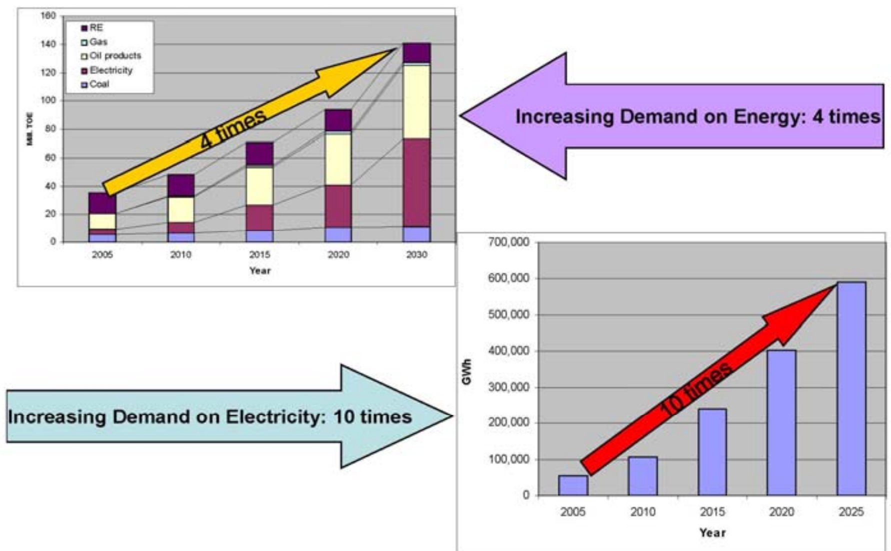
generation fuel mix in 2008





Demand of Energy & Electricity Increasing Rapidly



Limited availability of Indigenous primary energy resources

- Large hydropower sites in the south will be fully developed in the coming decade
- Gas and coal resources are limited
- Have to import coal for electricity generation.
- Viet Nam is more dependent on the international energy prices.

Energy Security Issues and Sustainable Development

2. National Program for Biofuel Development

The Program started from 2007

General Goal of the Program

- Biofuels to replace partial conventional fuels, to attend energy safety and environment protection

Detailed goals of the Program

Period to the year 2010

- Establishment of legal framework for investment, production, and usage of biofuel at industrial level. Public awareness of biofuel benefits.
- Development of roadmap for use of biofuels
- Studying for appropriate technology approach to produce biofuels from biomass, blending technology.
- Building biofuel distribution infrastructure in some selected cities, provinces.
- Human resources development for production. Running of production trial module of 100000tons E5 and 50000 tons B5 to meet 0.5% of oil product demand.

Period 2011-2015

- Expansion of biofuel production facilities, distribution infrastructure.
- Introduction of new varieties developed by generation technology.
- Application of modern fermentation technology in order to diversify raw biomass sources.
- Mastering of additives and molecular mesh production.
- Production would reach 250 thousand tons, equivalent to 1% of oil product demand.

Outlook to 2025

- Viet Nam would have modern biofuel production technology. Production would reach 1.8 million tons, equivalent to 5% of petroleum product demand.

Recent legal framework for biofuel development

- Decision No 1855/QD-TTg dated 27 December, 2007 signed by The Prime Minister about the national strategy on energy development to the year 2020, and outlook to 2050.
- Decision No 177/2007/QD-TTg dated 20 November, 2007 signed by Prime Minister about National program for the biofuel development in Vietnam to the year 2015, and outlook to 2025.
- Decision No 1842/ QD-BNN- LN signed by Minister of Agricultural and Rural development approving The Project of "Research, development and using products from Jatropha Curcas in Viet Nam on the periods 2008-2015, and outlook to 2025.
- Inform of Goverment Office No 83/TB-VPCP, dated 16 Mach 2009 on conclusions of Deputy Prime Minister for national program for the biofuel development.
- Circular No 147/2009/TTLT-BTC-BCT dated 21, July, 2009 regulated the use and administrative the state budgets to implement Bio-fuels development projects.

Governmental Organization and Framework to Promote Biofuel Development Program

- Ministry of Industry, Program Leader
- Ministry of agricultural & Rural Development (Policy, Land use, Cultivation)
- Ministry of Science & Technology (Policy on technology and R &D)
- Ministry of Finance (arrange budget)
- Ministry of Education & Training (Capacity building)
- Ministry of Planning & Investment (planning for development)
- Other Ministries
- Provinces & Research Institutes, and Companies

3. Potential of Bio-fuels in Viet Nam

- Agricultural country
- Diversified in geographic conditions, climate and plant system.
- High price of petroleum products.
- Easy to import high technology for manufacture of biofuels.

- Viet Nam has high potential for developing large area of raw materials for alcohol production.
- Present cultivation area does not allow to produce alcohol in large scale. But medium and small scale production are suitable.
- It is advisable to develop large scale cultivation area of tapioca and sugar cane, using high yield varieties, new cultivation technology.

- Raw material for production of Ethanol:
  - Rice
  - Maize
  - Potatoes (sweet potato)
  - Tapioca
  - Sugar cane
- Raw material for plant oil:
  - Soya beans,
  - Ground nuts
  - Coconuts.




- Roughly estimated shown that Viet Nam could produce about 5 billions liters of alcohol just by re-adjust the plantation areas of rice, cassava, corn and sugar-cane.

- Viet Namese agriculture are able to mobilize about 01 million hectare of oil bearing crop (coconut, soybeans, peanuts …)

- The Viet Namese government encourages and partly supports for enterprises to grow jatropha tree in order to reach 30,000 ha for producing 30,000 tons jatropha oil per year in the year 2010 and to reach 300.000ha in the year 2015.

- Other oil-bearing industrial crops in northern area.

Standards and technical regulation

- TCVN 7716-2007: Denatured fuel ethanol for blending with gasoline for use as automotive spark-ignition engine fuel. Specification
- TCVN 7717-2007: Bio-diesel fuel blend stock (B100). Specification
- TCVN 8063: 2009 **for E5**
- TCVN 8064:2009 **for B5**
- QCVN 1 : 2009/BKHCN - National technical regulation on gasoline, diesel fuel oils and biofuels

4. Current and Trend of Biofuel Development in Viet Nam

- In 2008 and 2009, under the support of MOIT and MOST, PetroVietnam Biofuels Company was running a pilot program to supply gasohol (E5) and biodiesel (B5). E5 has been completely tested and could be used as comercial fuel in Vietnam.
- As planed R&D activities in 2009, there are 11 projects for R&D and 01 pilot project of manufacturing bio-fuels are being implemented. The State budget allocated for 2009 fiscal years is 7,060 million VND.
- In 2010, there will be more 04 R&D projects and 03 production projects.

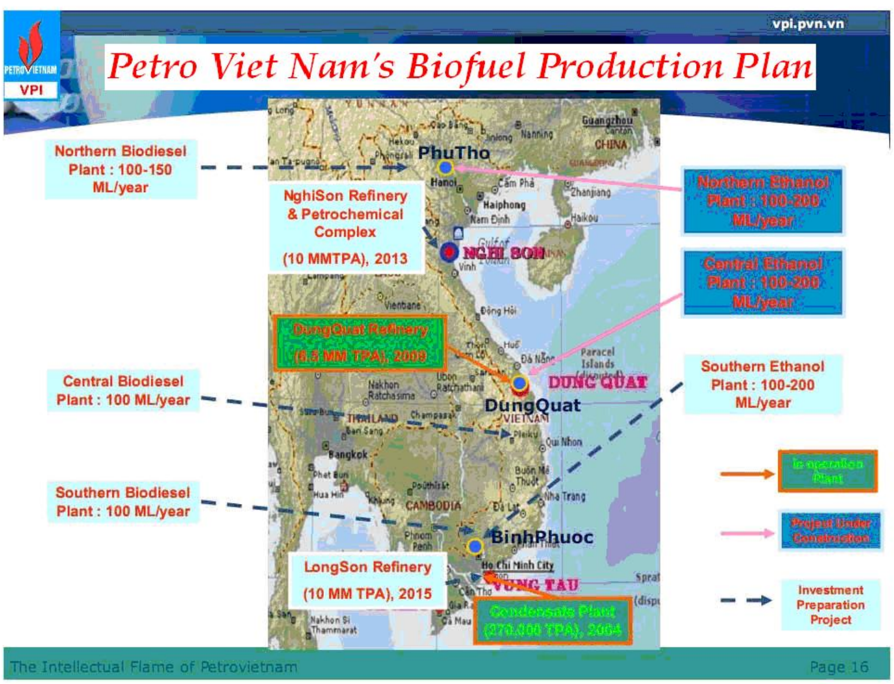
Bio-fuel industry in Viet Nam

Up to date, there are 03 projects has been approved and under construction in Viet Nam to produce ethanole for E5:

- Dong Xanh Joint Stock Company in Quang Nam province. The capacity is 100,000 tones/year. This production started in September 2009.
- Petro Viet Nam Bio-fuels (PVB) has invested in a factory in Tam Nong, Phu Tho province to produce 100,000 tones of ethanol per year from 21 June, 2009. As planned, it could be come into production in December 2010
- Other factory is in Dung Quat with the capacity of 100 million liters/year. The Owner is Petro Center of Biofuels (PCB). The factory will start production at beginning of 2011.

Other activities:

- Petro Viet Nam has considered to invest an ethanol factory in Binh Phuoc province, South of Vietnam.
- MOIT and Dong Nai province support Tung Lam Company Ltd to set up 60,000 tones/year factory in Xuan Loc, Dong Nai province.
- MOIT has verified 05 projects of planting and processing bio-diesel



Conclusion

- Legal framework for Bio-fuel development has been established.
- Standards and technical regulations were set up for basic development of bio-fuels market
- R&D activities have been started with the small amount of State budget
- Bio-fuel industry begins to take a shape
- Institutional and policy issues
  - Further regulation and policy to express the high commitment of the government for bio-fuels development
  - More incentive mechanism for bio-fuel manufacturers and users
- Technology and R&D activities
  - More support from government to develop the technology of producing and using bio-fuel products.
  - Standard development needs more attention of authorities to control the market and ensure the good attitude of users.
- Market
  - Need more support from government to develop the distribution system for bio-fuels
  - Official propaganda to increase public awareness of bio-fuels

The presidents of Viet Nam and Brazil approved the cooperation to produce bioethanol from sugar-canes in Viet Nam

- Cassava is waiting for processing in Viet Nam

Movement of growing Jatropha in Viet Nam

- Big event in Hanoi
*"Selling gasohol E5
for taxi
in a pilot project"*

R & D activities

- Scale use of gasoline mixed with Ethanol for internal combustion engines, use of Methyl Ester as biodiesel in lab scale.
- Trials on agro-machines
- Family electricity generation

Session IV

International APEC Symposium on
"Biofuels from Agricultural and Agro-Industrial Wastes"
May 24th – 27th, 2010, Chiang Mai, Thailand

BIOFUEL COMMERCIALIZATION IN THE U.S.: A RACE TO THE STARTING LINE

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ABSTRACT

The U.S. is widely regarded as a leader in the development of advanced biofuels from agricultural and agro-industrial wastes and purpose grown feedstock e.g., algae. Through aggressive policy, the U.S. has set an ambitious goal of producing 36 billion gallons of biofuels per year by 2022 and a short term goal of producing 100 million gallons of advanced biofuels per year by 2014. A number of companies are currently demonstrating technologies producing cellulosic ethanol, biobutanol and drop-in fuels and have stated target production capacities that will exceed the short-term goal. However, significant challenges are yet to be overcome to achieve commercialisation.

Keywords: biofuels, policy, cellulosic, drop-in fuels, commercialisation

1 INTRODUCTION

Globally, the U.S. is recognized as a nation with a high economic performance and substantial consumption of energy (IEA, 2009). The U.S. consumes approximately 20 million of the 85 million barrels of oil consumed globally per day, but produces less than 7 million barrels per day (BP, 2009). To address the production gap, the U.S. must rely on foreign sources of oil, requiring it to import the bulk of its supply from nations including Canada, Saudi Arabia, Mexico, Venezuela, Nigeria and Russia (EIA, 2010). The Obama administration has declared that it has “a moral, environmental, economic, and security imperative to address dependence on foreign oil and tackle climate change in a serious, sustainable manner.” It has set an ambitious target of producing at least 60 billion gallons of advanced biofuels by 2030 and has committed to invest federal resources, including tax incentives and government contracts in developing the most promising technologies and building the infrastructure to support them (BIWG, 2010).

1.1 Overview of the U.S. Biofuels Policy

The Renewable Fuels Standard (RFS1) was adopted by the Environmental Protection Agency to implement the provisions of the Energy Policy Act of 2005 which specified a goal of producing 7.5 billion gallons of biofuels by 2012 (EPA, 2005). The Energy Independence and Security Act (EISA) was enacted in December of 2007 and set a goal of producing 36 billion gallons of renewable fuel by 2022 (**Error! Reference source not found.**). Subsequently, the RFS2 was adopted, which lays the strategy for reaching the provisions of the EISA (EPA, 2010). The RFS2 prescribes new specific volume standards for cellulosic biofuel, biomass-based diesel, advanced biofuel, and total renewable fuel that must be used in transportation fuel each year (**Error! Reference source not found.**).

Table 1: Renewable Fuel Volume Requirements in the Renewable Fuel Standard 2 (billion gallons)

Year	Cellulosic	Biomass-Based Diesel	Advanced Biofuel	Total Renewable Fuel[a]
2009	n/a	0.5	0.6	11.1
2010	0.1	0.65	0.95	12.95
2011	0.25	0.8	1.35	13.95
2012	0.5	1	2	15.2
2013	1	a	2.75	16.55
2014	1.75	a	3.75	18.15
2015	3	a	5.5	20.5
2016	4.25	a	7.25	22.25
2017	5.5	a	9	24
2018	7	a	11	26
2019	8.5	a	13	28
2020	10.5	a	15	30
2021	13.5	a	18	33
2022	16	a	21	36

a – Includes grain-based biofuels
b – to be determined through future rule making

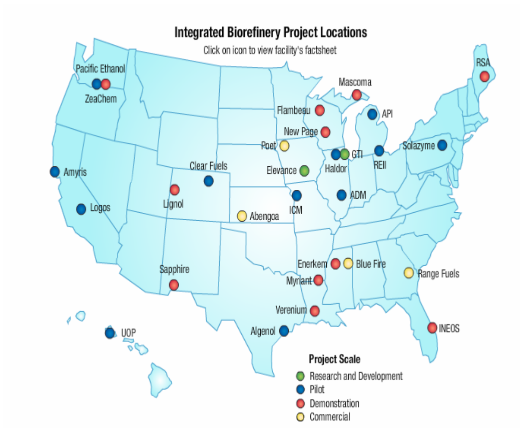
Other significant goals of the RFS2 are:

- Deploy up to 100 million gallons of biofuel capacity by 2014;
- Make cellulosic ethanol cost competitive, at a modelled cost for mature technology of $1.76/gallon by 2012;
- Make biofuels cost competitive, at a modelled cost for mature technology of $2.85/gallon gasoline, $2.84/gallon diesel and $2.76/gallon jet fuel by 2017;
- Help create an environment conducive to maximizing production and use of biofuels;
- Reach 21 billion gallons of advanced biofuels per year by 2022 (EPA, 2010).

1.2 The Existing Situation

Currently, the U.S. produces about 12 billion gallons of renewable fuel per year, mostly corn-based ethanol. RFS2 revised the 2010 volume standard for cellulosic ethanol to 6.5 million ethanol equivalent gallons from 100 million gallons prescribed in RFS1. This change was based on an updated market analysis which indicated that this target would not be achieved in 2010 (EPA, 2010). To address this situation, the government has mandated additional federal funds from the American Recovery and Reinvestment Act of 2009 to fund pilot, demonstration and commercial scale biorefineries. Biorefineries are analogous to the petroleum refineries in that multiple products are targeted based on market demand, contractual agreements and plant operating limits. The biorefinery concept is a means of improving economics by 1) use of various biomass feedstock options 2) producing a mix of fuels, power, and high-value co-products and 3) optimisation of feedstock and product mix. This flexibility and maximisation of feedstock utilisation could potentially accelerate recovery of capital costs and reduce operational costs as well as reduce the carbon and energy footprint. **Error! Reference source not found.** shows projects that have received federal funding totalling over $1 billion. Many of these projects are still in early stage development or validation stage and have not achieved continuous integrated economic operations at scale.

Figure 1: DOE Funded Integrated Biorefineries



Source: http://www.eere.energy.gov/

1.3 Methodology

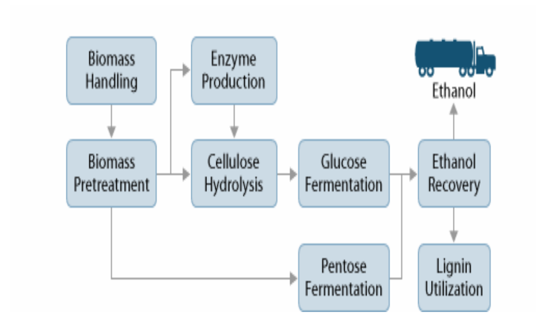
This paper provides a status of current production capacity and the projections for selected advanced biofuels companies against the goal of deploying up to 100 million gallons of advanced biofuel capacity by 2014. It should be noted that since most of the companies in the industry are privately held, public information is limited. The paper's focus is on companies that have existing pilot or demonstration operations with stated current and target capacity. Analysis presented here were built in part from information in the public domain (Lane, 2010), company websites and personal communications with the companies. Due to the long-range nature of the company production projections and the nascent stage of biofuel commercialisation, the information presented is dynamic as changes in capacity can be influenced by a number of factors including project financing and technology robustness at scale. This paper utilises the term "advanced biofuel" as defined in the EISA as "fuel other than ethanol derived from corn starch, that has lifecycle greenhouse gas emissions, as determined by the Administrator, after notice and opportunity for comment, that are at least 50 percent less than baseline lifecycle greenhouse gas emissions" (EISA, 2010).

2 CELLULOSIC ETHANOL

In recent years, cellulosic ethanol commercialisation has sustained criticism as perpetually being 'five years away' since the mid 1980's. As discussed previously, the RFS 2 revised the volume standard for cellulosic ethanol to reduce the initial 2010 target to 6.5 million ethanol equivalent gallons from 100 million gallons because of the slow rate of commercialisation. Table 2 presents data from the top 10 cellulosic ethanol producing companies in the U.S. by stated target capacity greater than 10 million gallons a year by the year 2014 based on successful commercialisation of technologies currently being validated at existing pilot and demonstration biorefineries.

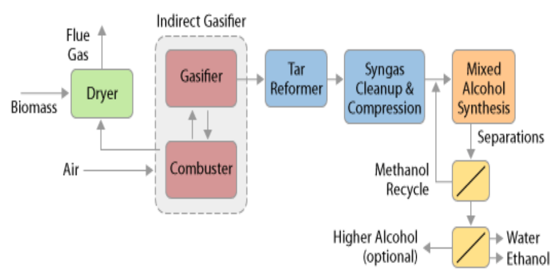
There are two main routes for producing cellulosic ethanol; biochemical and thermochemical (**Error! Reference source not found.** and **Error! Reference source not found.** respectively**)**. Of the potential top 10 cellulosic ethanol producers, 30% utilise the thermochemical route, while the biochemical/fermentation pathway remains the most popular process.

Figure 2: Schematic of a Biochemical Cellulosic Ethanol Production



Source: DOE Biomass Program

Figure 3: Schematic of a Thermochemical Cellulosic Ethanol Production Process



Source: DOE Biomass Program

Table 2: Top U.S. Companies Producing Cellulosic Ethanol (million gallons per year)

	Company	2010	2014
1	Algenol	0.30	750
2	Coskata	0.05	55
3	Verenium	1.40	37
4	POET	0.02	25
5	BlueFire Ethanol	0.01	23
6	Mascoma	0.20	20
7	Range Fuels	20.00	20
8	Abengoa	0.00	15
9	Fulcrum	0.01	11
10	AE Biofuels	10.00	10
	Total	31.99	967

Range Fuels is the only company in the 'top 10' that is scheduled to begin commercial production by 2010 despite the fact that the DOE has funded 4 commercial plants since 2006 (

Figure 1). Range Fuels uses a two-step thermochemical process using forest wood waste as feedstock (Range Fuels, 2010). Algenol has declared the most aggressive target using their proprietary 'Direct-to Ethanol™' process that 'links photosynthesis with the natural enzymes to produce ethanol inside each algae cell' (Algenol, 2010). Algenol claims that its prototype production strains can produce ethanol at a rate of 10,000 gallons/acre/year. The algae are metabolically enhanced to produce ethanol while being resistant to high temperature, high salinity, and high ethanol levels. Coskata employs a unique approach combining thermochemical and biochemical processes. Syngas from the gasification step is fermented using proprietary microorganisms. Coskata claims to produce up to 100 gallons of ethanol from a tonne of dry biomass. The advantage of this process is that it eliminates the need for hydrolytic enzymes and the potential to produce various end-products from syngas. Fulcrum Bioenergy claims to have completed demonstration efficient conversion of Municipal Solid Waste (MSW) to syngas, and syngas conversion to ethanol and is poised to commence commercial operations converting 90,000 tons of post-recycled MSW – the amount of trash produced by a city with a population of 165,000 – into 10.5 million gallons of ethanol per year. Verenium Corporation is poised to begin construction of its 36 million gallon a year biochemical ethanol facility in 2010. The facility is designated to operate on diverse regional feedstocks including sugarcane bagasse and specially-bred energy cane. POET is progressing towards commencing operations on its 25 million gallon a year biorefinery in 2011 processing corn cobs. Abengoa is studying various routes for the thermochemical conversion of the biomass with the goal of selecting the technology with the most promising technical and economical attributes, a demonstration plant a demonstration plant will be erected in 2010 and used to study the syngas cleaning and conditioning and its use for alcohol synthesis, utilising multiple feedstocks. Abengoa targets to begin commercial production by 2012. AE Biofuels utilises an Integrated Plant Approach that allows for the use of cellulose, corn and sugar feed stocks, increasing efficiencies. AE Biofuels technology facilitates the upgrading of existing corn ethanol plants to use both corn and cellulosic feedstock and enables sugar cane ethanol plants to convert bagasse into fuel. Most of the companies progressing towards commercialisation claim to have achieved favourable production costs without the $1.00/per gallon blending tax credit for cellulosic ethanol allocated in the EISA. Assuming that these top 10 and other companies in this space can overcome commercialisation challenges in the next 3 years, the U.S. will achieve 9 times the 100 million gallon a year advance biofuel milestone by 2014 with just cellulosic ethanol.

3 BIOBUTANOL

Biobutanol offers distinct advantages over bioethanol due to high energy content, miscibility with gasoline, low volatility and octane rating (Knoshaug, et al., 2008). In general, biobutanol fermentations suffer from problems of low yield and productivity and low titer. Further, few micro-organisms are able to tolerate butanol concentrations higher than 2-3% which cause significant energy costs of recovery. Two U.S. companies have targeted production of greater than 10 million gallons per year by 2014 (Table 3). They currently have operational pilot biorefineries with demonstration units under construction (Table 3).

Table 3: Table 1: Top U.S. Companies Producing Biobutanol from lignocellulosic feedstocks million gallons per year (MGY)

	Company	2010 (MGY)	2014 (MGY)
1	Gevo	1.00	300
2	Cobalt	0.01	102
	Total	**1.01**	**402**

Gevo, using its 'Integrated Fermentation Technology' (GIFT™), is retrofitting an ethanol demonstration plant to produce one million gallons of biobutanol per year. The process will utilise much of the existing ethanol production system, but uses cellulosic yeast strains engineered to produce butanol instead of ethanol. Cobalt is focussing on optimizing fermentation productivity, yield, and titer at its pilot unit. It is developing production monitoring technologies that will enable continuous fermentation. Similar to the cellulosic ethanol producers discussed previously, achieving target 2014 production of biobutanol will exceed the RFS2 goal for total advanced fuels.

4 DROP-IN FUELS

A category of fuels that has gained significant traction in the U.S. energy landscape is fuels that are chemically indistinguishable from their petroleum counterparts and referred to as "drop-in" fuels (DIFs) or 'infrastructure-ready fuels'. These fuels are compliant with the existing $12 trillion U.S. network of pipelines, refineries, tankers, gas stations and vehicles. DIFs can be produced from a variety of feedstock including sugars hydrolysed from grain or sugarcane as well as lignocellulosic material. Significant progress has been achieved in producing oil-derived DIF from algae and non-food seeds including jatropha and camelina. A significant feature of oil based DIFs is the ability to be co-processed in existing petroleum biorefineries. The recent proliferation of algae-based companies is due to the superior biomass productivity on smaller land area than other feedstocks (Table 4).

Table 4: Renewable Fuel Feedstock Land Area Required to Displace 15% of U.S. transportation fuel (million acres)

Biofuel feedstock	Land area on a Btu basis
Algae	7
Tree farming	70
Corn	90
Switchgrass	90
Corn stover	150
Forest waste	500

(CARD, 2009), (Walters, 2010)

Figure 4 shows the basic process for producing drop-in fuels from algae. Algae and other non-food oils can be refined following deoxygenation in a conventional petroleum refinery to produce and distribute DIFs. UOP and Dynamic Fuels have developed the refining technologies for utilising these oils in a petroleum refinery. UOP has developed catalytic Ecofining™ for producing renewable diesel (first unit on-stream in 2010). Dynamic Fuels has developed the Bio-Synfining™ process to produce on-specification diesel and jet fuel (Hydrotreated Renewable Jet, HRJ) synthetic fuels from animal fats, greases, and vegetable oil via a three steps process: pre-refining, refining, and hydrocracking.

Figure 4: Process for Producing Drop in Fuels from Algae

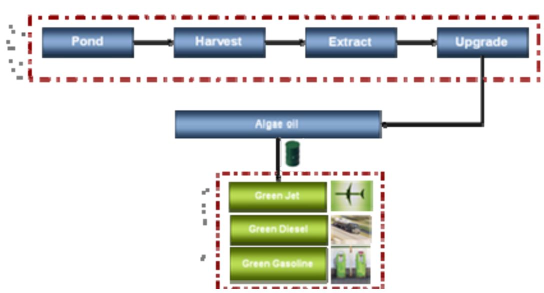


Table 5 presents top DIF producing U.S. companies (by projected 2014 production targets). Sapphire Energy, Petro-algae and Solazyme use algae oil as feedstock while Amyris, LS9 and Rentech utilise sugars derived from starch, sugarcane or cellulosic feedstock while Dynamic Fuels has developed technology to refine tallow. Petroalgae and Sapphire Energy use open ponds to grow micro-algae for producing fuel and animal feed protein products as shown in **Error! Reference source not found.**. There are significant challenges to overcome with this approach including minimising contamination from competitor micro-organisms and developing efficient harvesting and extraction technologies and optimisation of specific DIF production processes. Solazyme has adopted a unique diversified approach using algae to produce oils and biomaterials in standard fermentation facilities. The oils are refined to fuel as replacements for fossil-derived petroleum as well as natural plant oils and compounds for use in other products including oleochemicals, cosmetics and foods. LS9 utilise a proprietary 1-step fermentation process (similar to Consolidate Bioprocessing) to produce renewable fuels and sustainable chemicals from grain or cellulose-derived sugar. They have engineered enzymes to convert fatty acid intermediates into diesel in a biphasic fermentation that offers advantages with product recovery. A challenge to economic production of DIFs via the sugar refining approach would be the controlling the cost of feedstock. Rentech, Inc., uses municipal solid waste, lignocellulosic material and pet coke to produce power, jet fuel, diesel, chemicals and waxes though a gasification process. AltAir Fuels is dedicated to producing renewable jet from camelina oil. Camelina is which is an oil producing plant already widely grown on marginal land throughout the U.S. and Canada for cattle feed. A number of flights including the U.S. Air Force have been tested successfully using a 50% blend of camelina–derived jet fuel. By-products from the production of DIFs are targeted at animal feed markets or for the production of heat and power. Similar to cellulosic ethanol and biobutanol producers, companies in the DIF space claim production cost parity with petroleum at scale. With almost 800 million gallons targeted for production in 2014 by the selected companies, the short term RFS2 goal will be easily met by DIFs alone.

Table 5: Top U.S. Companies Producing Drop in Fuels (million gallons per year)

	Company	2010	2014
1	Rentech	0.15	259
2	PetroAlgae	0.12	210
3	Solazyme	0.1	100
4	AltAir Fuels, LLC	0.00	100
5	Dynamic Fuels	75	75
6	Amyris	0.01	27
8	LS9	0.10	10
9	Sapphire Energy	0.20	1
	Total	75.78	798

5 CONCLUSION

The biofuels markets represent an enormous opportunity but many obstacles must be overcome on the way to commercialization. Some of the obstacles include barriers to private sector capital financing and investment following the global financial crisis caused by the banking industry; lack of investor confidence as a result of losses sustained during the corn-ethanol boom; inherent technical challenges present in any rapid scale-up of new technologies and challenges in matching existing fuel distribution infrastructure with biofuels Ultimately, the companies that employ strategies that achieve profitability quickly by 1) focusing on high margin markets first, 2) developing technology at smallest scale and scaling up once capital and operation costs are proved cost competitive and 3) minimizing design complexity while demonstrating favourable return on investment while producing fuel at a cost parity with petroleum (without government subsidies) will lead the pack. Given the size of the potential U.S. and global biofuel market, the future looks bright for many winners in the biofuels race.

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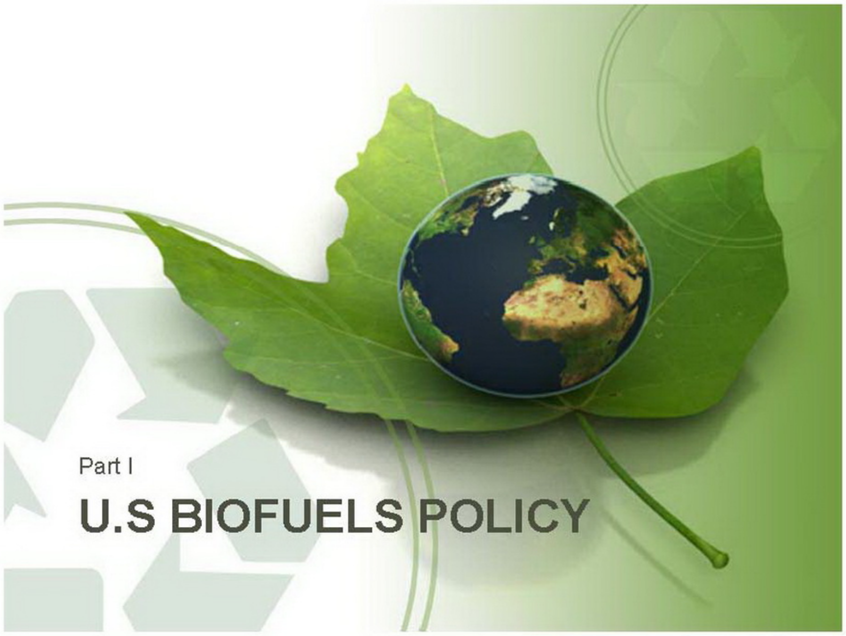
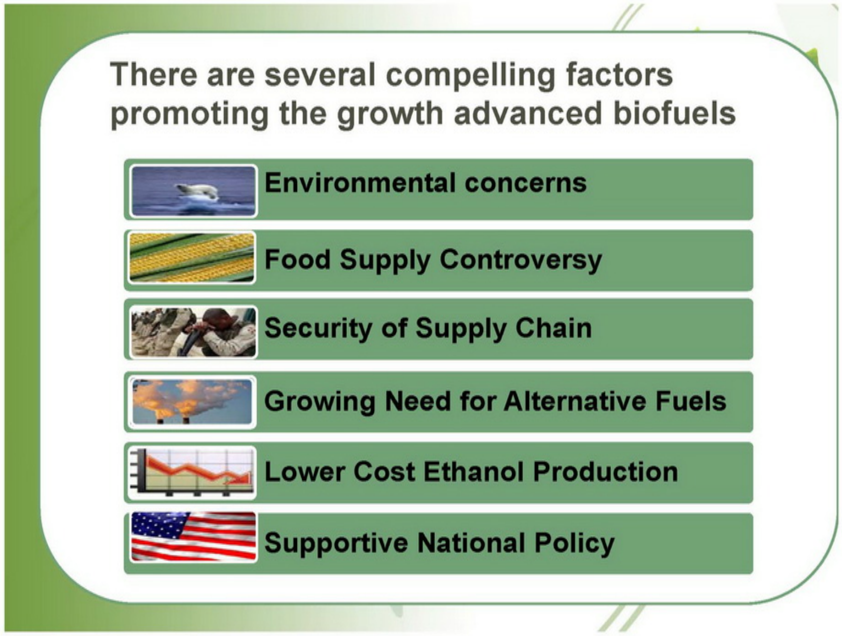
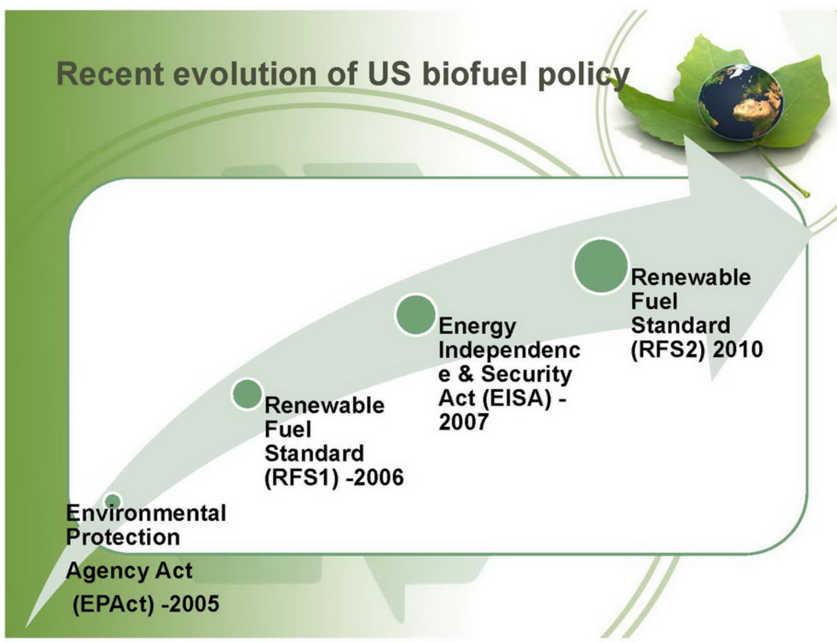
Session IV: Keynote Speaker (USA);
Dr. Kulinda Davis

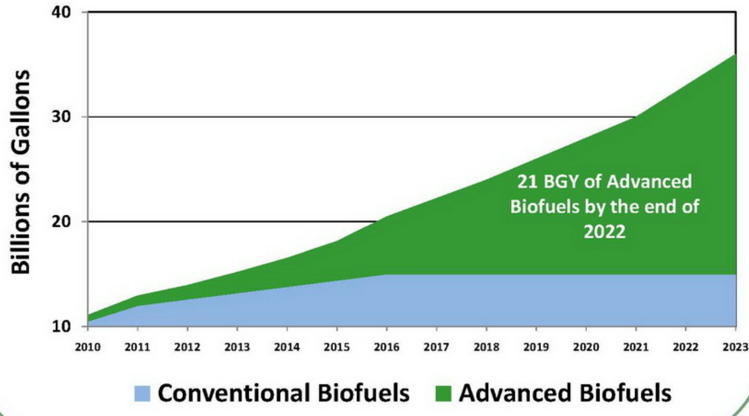

Part I
U.S BIOFUELS POLICY


"No beaches have been closed due to ethanol spills: ethanol,
America's CLEAN fuel;
Ethanol has not shipped a single job overseas: ethanol,
America's ECONOMIC fuel;
No U.S. soldiers have been deployed to defend our ethanol reserves: ethanol,
America's INDEPENDENT fuel;
No wars have been fought over ethanol: ethanol,
America's PEACE fuel;
We won't have to wait millions of years to replenish our ethanol reserves: ethanol,
America's RENEWABLE fuel;
Ethanol has contributed 0$ to the governments of Iran, Saudi Arabia and Venezuela: ethanol,
America's SENSIBLE fuel."
– Ad sponsored by Growth Energy


There are several compelling factors promoting the growth advanced biofuels
Environmental concerns
Food Supply Controversy
Security of Supply Chain
Growing Need for Alternative Fuels
Lower Cost Ethanol Production
Supportive National Policy


Recent evolution of US biofuel policy
Environmental Protection
Agency Act
(EPAct) -2005
Renewable Fuel Standard (RFS1) -2006
Energy Independenc e & Security Act (EISA) - 2007
Renewable Fuel Standard (RFS2) 2010

An enormous market has been created by the Renewable Fuel Standard 2



The RFS2 has set ambitious goals for the biofuel industry

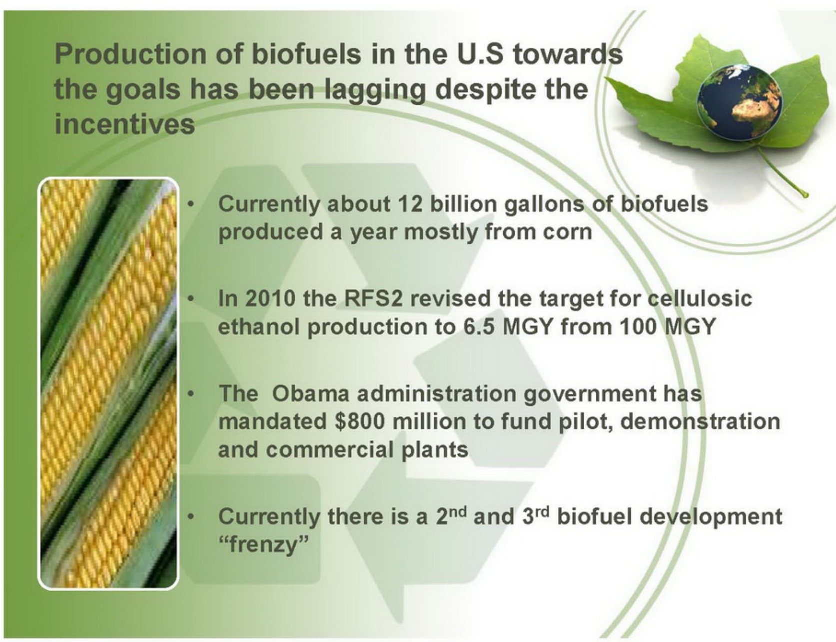
Capacity

- Deploy up to 100 million gallons of *advanced* biofuel capacity by 2014;
- Reach 21 billion gallons of advanced biofuels per year by 2022; 16 billion from cellulosic sources

Cost

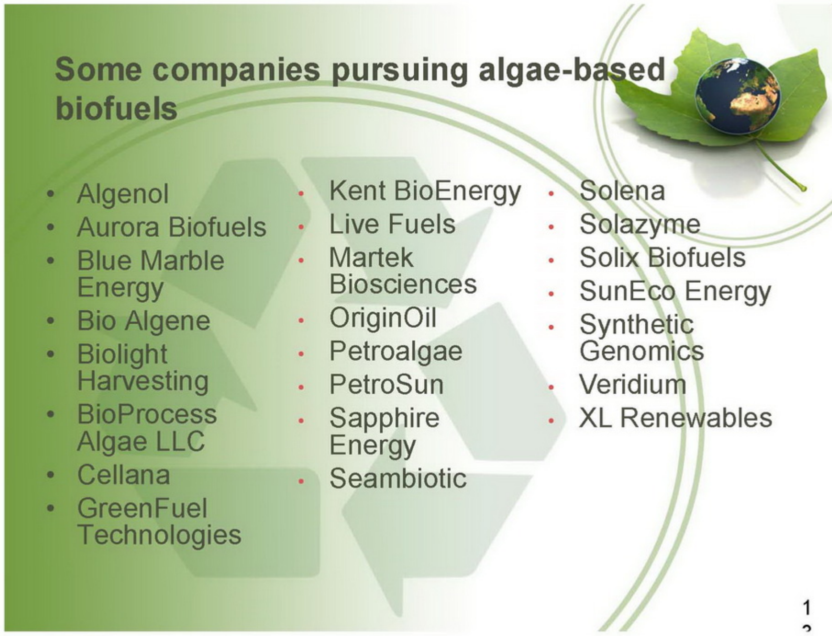
- Make cellulosic ethanol cost competitive, at $1.76/gallon by 2012;
- Make other biofuels cost competitive, at $2.85/gallon gasoline, $2.84/gallon diesel and $2.76/gallon jet fuel by 2017

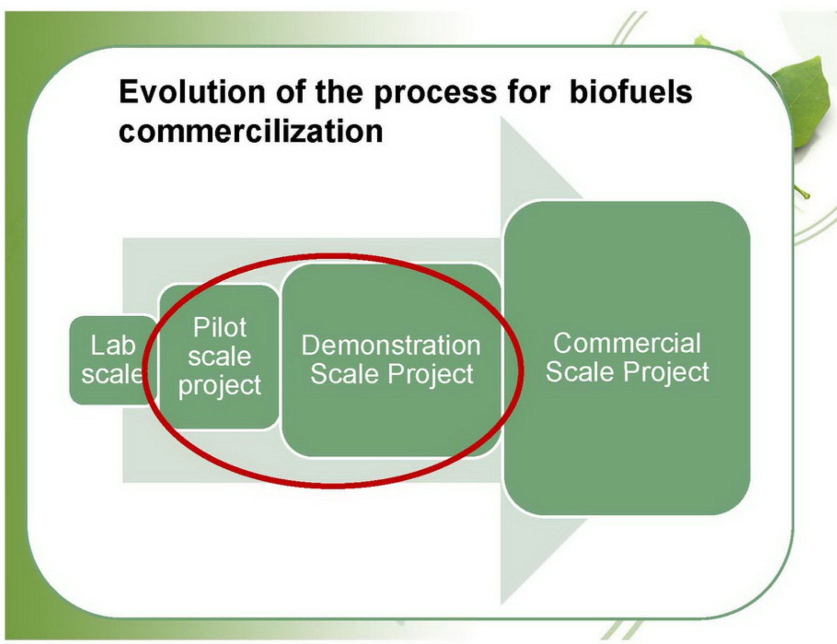

Part II
THE EXISTING SITUATION

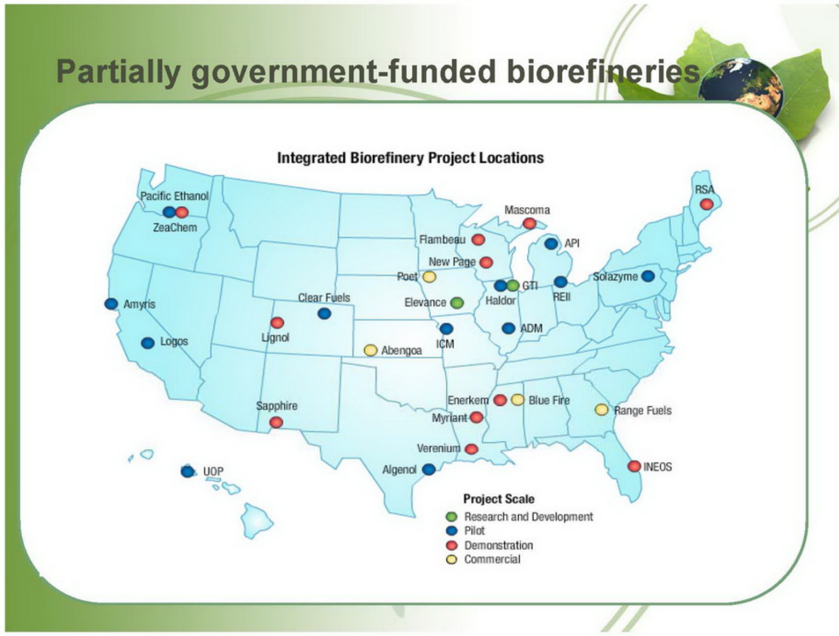

Production of biofuels in the U.S towards the goals has been lagging despite the incentives
• Currently about 12 billion gallons of biofuels produced a year mostly from corn
• In 2010 the RFS2 revised the target for cellulosic ethanol production to 6.5 MGY from 100 MGY
• The Obama administration government has mandated $800 million to fund pilot, demonstration and commercial plants
• Currently there is a 2nd and 3rd biofuel development "frenzy"


There are > 45 companies pursuing cellulosic ethanol & other alcohols
Abengoa
ADM
AE Biofuels
AEE Distilleries
Agresti Biofuels
American Process Inc.
Auburn/Masada
BlueFire
Biobutanol LLC.
BPI/Evolution Resources
Chemrec & Weyerhaeuser
Central Minnesota Cellulosic Ethanol Partners (CMCEP)
Clearfuels Technology
Cobalt Biofuels
Cornell BRL
Coskata
DuPont Danisco
EdenIQ/Logos Tech
Enerkem
Fiberight
Florida Crystals
Fulcrum Bioenergy
Gevo
Gulf Coast Energy
ICM
Inbicon/Great River Energy
INEOS Bio
Iogen
KL Energy
Lignol Energy
Mascoma
Pacific Ethanol WCB
Pan Gen Global
Pearson Technologies
Pencor/Masada
POET
PureVision Technology
Qteros
Range Fuels
Raven Biofuels
Terrebon
Verenium
Vercipia
Western Biomass
Zeachem
1

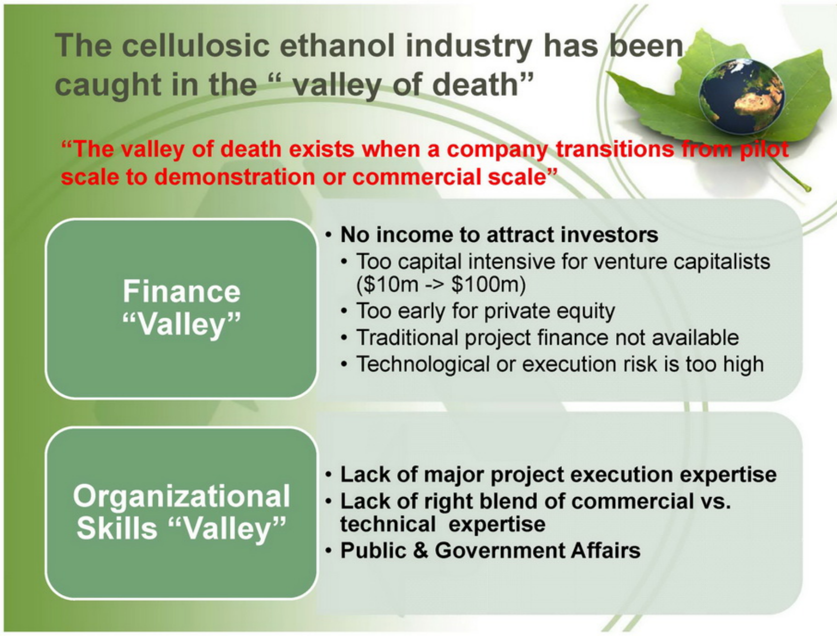

There are over 23 companies pursuing cellulosic hydrocarbons
Amyris
Baard
Bell Bioenergy
Cello
Choren
Clearfuels Technology
Envergent (UOP/Ensyn)
Dynamotive
Flambeau River Biofuels
Gas Tech Inst
Gulf Coast Energy
Haldor Topsoe
KiOR
LS9
New Page
Petrobras
SunFuels
Swift Fuels
Renewable Energy Inst
Rentech
Terrabon
TRI
Virent
1


Some companies pursuing algae-based biofuels
Algenol
Aurora Biofuels
Blue Marble Energy
Bio Algene
Biolight Harvesting
BioProcess Algae LLC
Cellana
GreenFuel Technologies
Kent BioEnergy
Live Fuels
Martek Biosciences
OriginOil
Petroalgae
PetroSun
Sapphire Energy
Seambiotic
Solena
Solazyme
Solix Biofuels
SunEco Energy
Synthetic Genomics
Veridium
XL Renewables


Evolution of the process for biofuels commercilization
Lab scale
Pilot scale project
Demonstration Scale Project
Commercial Scale Project

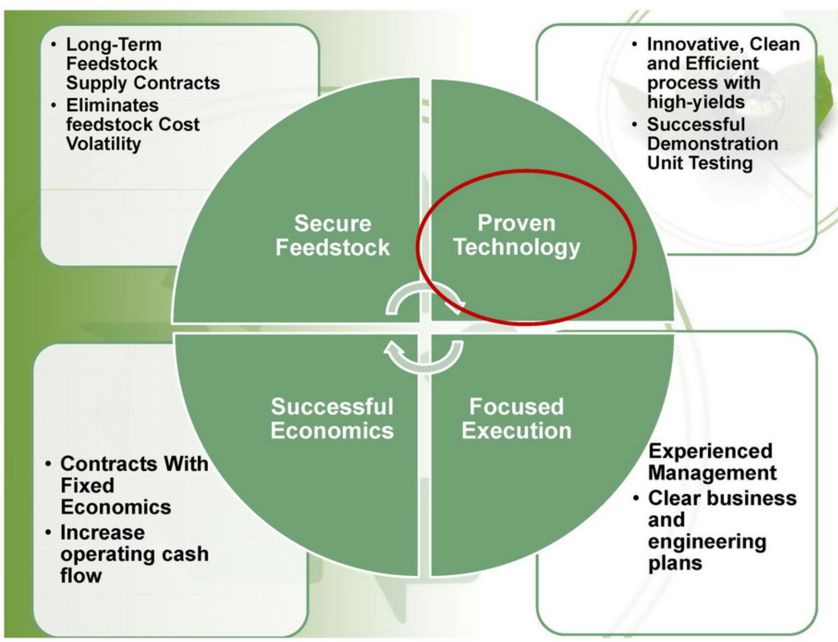

Partially government-funded biorefineries
Integrated Biorefinery Project Locations
Pacific Ethanol
ZeaChem
Amyris
Logos
Clear Fuels
Lignol
Sapphire
UOP
Poet
Elevance
Abengoa
ICM
Flambeau
New Page
Mascoma
API
GTI
Haldor
REII
ADM
Solazyme
RSA
Enerkem
Blue Fire
Myriant
Verenium
Algenol
Range Fuels
INEOS
Project Scale
Research and Development
Pilot
Demonstration
Commercial


Part III
THE CHALLENGES


The cellulosic ethanol industry has been caught in the " valley of death"
"The valley of death exists when a company transitions from pilot scale to demonstration or commercial scale"
Finance "Valley"
• No income to attract investors
• Too capital intensive for venture capitalists ($10m -> $100m)
• Too early for private equity
• Traditional project finance not available
• Technological or execution risk is too high
Organizational Skills "Valley"
• Lack of major project execution expertise
• Lack of right blend of commercial vs. technical expertise
• Public & Government Affairs


The valley of death will select the real players in the industry from the rest
No fully functioning commercial reference plant
• Construction schedule
• Capital cost
• Performance guarantees
• Operating costs
Reliable access to biomass feedstocks
• Costs
• Collection
• Processing
• Logistics
Legislative weariness
• Build Credibility – Execute, Don't Overpromise
• More Precise and Uniform Messaging

Part IV
THE WINNERS



• Long-Term Feedstock Supply Contracts
• Eliminates feedstock Cost Volatility
• Innovative, Clean and Efficient process with high-yields
• Successful Demonstration Unit Testing
Secure Feedstock
Proven Technology
Successful Economics
Focused Execution
• Contracts With Fixed Economics
• Increase operating cash flow
Experienced Management
• Clear business and engineering plans

Top US ethanol companies utilising lignocellulosic feedstocks (million gallons)

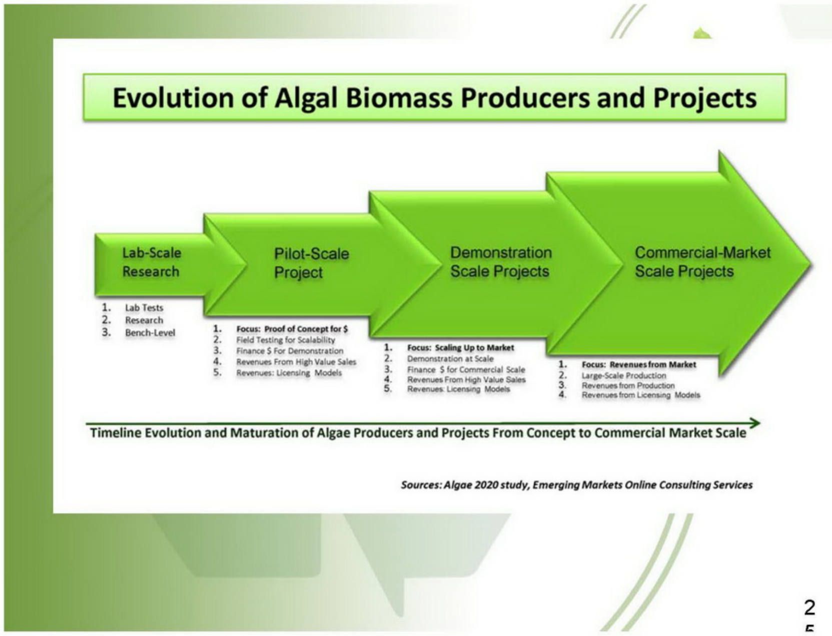
	Company	2010	2014	Technology
1	Algenol	0.30	750	Algae fermentation
2	Coskata	0.05	55	Thermochemical
3	Verenium	1.40	37	Biochemical
4	POET	0.02	25	Biochemical
5	BlueFire Ethanol	0.01	23	Biochemical Acid Hydrolysis
6	Mascoma	0.20	20	Biochemical Consolidated BioProcessing
7	Range Fuels	20.00	20	Thermochemical
8	Abengoa	0.00	15	Biochemical
9	Fulcrum	0.01	11	Thermochemical
10	AE Biofuels	10.00	10	Biochemical
	Total	32	967	

US companies utilising algae and other feedstocks to produce hydrocarbons (million gallons)

#		2010	2014	Technology
1	Rentech	0.15	259	Fischer Tropsch
2	PetroAlgae	0.12	210	Coking
3	Solazyme	0.10	100	Hydroprocessing
4	AltAir	0.00	100	Hydroprocessing
5	Dynamic Fuels	0.00	75	Fischer Tropsch
6	Amyris	0.01	27	Consolidated BioProcessing
7	Clearfuels	0.10	16	Steam reform
8	LS9	0.10	10	Consolidated BioProcessing
9	REII	0.02	0.35	Gasification
10	Sapphire Energy	0.20	0.2	Hydroprocessing
	Total	0.8	797	

The winners will have a clear understanding of the risk and have robust mitigating strategies

Risk	Mitigation Strategy
Demo. Capital Cost	Freeze Design; Provide explicit project definition
Scale-up	Establish clear performance goals for each level of scale up; Design for process flexibility
Integration	Use established technologies in deployment if possible to minimize potential of integration issues
Technology	Keep plant #1 based on known technology and processes to reduce complexities
Operations	Partner with an experienced operator
Economics	Fix feedstock costs and sell to credible 3rd parties - Fix the margin for given period of time
Funding	Ensure business has adequate funding accessing a variety of different sources
Engineering	Use experienced knowledgeable EPC, but maintain tight supervision on daily basis



Evolution of Algal Biomass Producers and Projects
Lab-Scale Research
Pilot-Scale Project
Demonstration Scale Projects
Commercial-Market Scale Projects
1. Lab Tests
2. Research
3. Bench-Level
1. Focus: Proof of Concept for $
2. Field Testing for Scalability
3. Finance $ For Demonstration
4. Revenues From High Value Sales
5. Revenues: Licensing Models
1. Focus: Scaling Up to Market
2. Demonstration at Scale
3. Finance $ for Commercial Scale
4. Revenues From High Value Sales
5. Revenues: Licensing Models
1. Focus: Revenues from Market
2. Large-Scale Production
3. Revenues from Production
4. Revenues from Licensing Models
Timeline Evolution and Maturation of Algae Producers and Projects From Concept to Commercial Market Scale
Sources: Algae 2020 study, Emerging Markets Online Consulting Services
2

International APEC Symposium on
"Biofuels from Agricultural and Agro-Industrial Wastes"
May 24th – 27th, 2010, Chiang Mai, Thailand

EFFECTS OF LIGHT INTENSITY AND NITROGEN CONCENTRATION ON GROWTH AND LIPID PRODUCTION OF *Chlorella vulgaris*

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ABSTRACT

Increasing oil prices and environmental concerns associated with the use of fossil fuels serve as the impetus in finding alternative sources of energy like biofuels from microalgae. The ability of microalgae to grow in non-arable lands, their high photosynthetic efficiency, and their potential to produce carbon neutral fuels make them better fuel source than current land-based energy crops. The viability of microalgae as an alternative fuel source depends on their lipid content and biomass that are affected by environmental and culture conditions. This work focused on examining the effect of light intensity and nitrogen concentration on the growth and lipid production of *C. vulgaris*. Results show that different levels of light intensity significantly affected growth and lipid production ($p<0.05$). The highest optical density, highest proliferous rate (0.08), and shortest generation time (3.79 days) were observed at 2700 lux while the highest lipid yield was observed at 800 lux (42%). Although nitrate concentrations did not significantly affect growth and lipid production, it is worth noting that highest lipid yields were at 1.5 g/L and 0.15 g/L of nitrate. Results also show that it was in the stationary phase that the most biomass and highest amount of lipids were harvested. Given these results, the optimum conditions for growth and lipid production of *C. vulgaris* are at 800 and 2700 lux, 1.5g/L and 0.15g/L nitrate.

Key Words: Biofuels, Microalgae, *Chlorella vulgaris*

Human activities are heavily dependent on fossil fuels but the political and environmental concerns associated with its use drive us to find an alternative energy source that is both renewable and sustainable. Biofuels could potentially meet this demand because chlorophyllous organisms are essentially a renewable resource. Although other renewable energy sources such as wind, solar, and geothermal are available, only plant biomass has the ability to produce liquid fuels. Moreover, biofuels can be carbon neutral if suitable methods are used in its production Huber *et al.,* 2006).

Land-based oil producing crops yield 6.8 to13.6 boe/ha-year while biofuels produced by microalgae can produce 390-700 boe/ha-year which is 45 to 255 times higher than the terrestrial oil crops (Huber, Iborra, and Corma, 2006). The high growth rates of the microalgae, ability to utilize a larger fraction of solar energy (up to 10%), and capacity to grow in non-arable lands which eliminates the threat to food production make the oil production from microalgae favorable (Schenk *et al.,* 2008).

The objective of this study was to determine the optimum environmental and culture conditions for growth and lipid production of the green algae *Chlorella vulgaris*. Specifically, this study examined the effects of light intensity and nitrogen concentration on growth and lipid production of *C. vulgaris*. The total lipid content of the microalgae was compared in two growth phases – the exponential and the stationary phase.

METHODOLOGY

Materials: The microalga, *Chlorella vulgaris*, was obtained from the National Insititute of Molecular Biology and Biotechnology (BIOTECH), University of the Philippines Los Baňos. *C. vulgaris* was cultured in cotton plugged glass bottles with the modified BG-11 as growth medium. The inoculum alga was incubated at room temperature (27±2°C) with a photoperiod of 12h hours light and 12 hours dark and a light intensity of 1500 lux or 139.4 feet-candle (ft-c). The culture was shaken three times daily and the experiment was done in triplicates.

Growth monitoring: Six milliliters (mL) of *C. vulgaris* inoculum in logarithmic phase (9-day old) was transferred to sterile bottles with 150mL BG-11 medium. The growth monitoring was done for 41 days, starting immediately after inoculation. Wavelength determination for optical density measurements was done by scanning the microalgae with a Shimadzu UV-1601 UV-vis spectrophotometer from 300 to 700 nm. Cell count (cells/mL) was obtained using the Neubauer haemocytometer.
Growth rate (K) and average generation (G) time were calculated based on the following equations (Quinn, 2005):

$$K = [(\log OD_t - \log OD_0) \times 3.322]/T \qquad (1)$$
$$G = 0.301/K \qquad (2)$$

Optical density measurements were taken at λ = 445.5nm. OD_t represents the final optical density while OD_0 is the initial optical density. T is the time in days.

Light Intensity Manipulation: White fluorescent lights (regular tube type, 40W and 18W) were used as a light source. The light intensity was measured from the top, middle and bottom of the glass bottles using the Xtech 401025 light meter. Three levels of light intensity were examined, 800 lux, 1500 lux (control), and 2700 lux.

Nitrogen Concentration Manipulation: Nitrogen as nitrate (NO_3^-) from the salt sodium nitrate was used. The experimental design was adopted from Piorreck *et al. (*1984) whereby only the initial concentrations were varied. The following $NaNO_3$ concentrations were used: 1.5 (control, BG-11), 0.15, 0.015, and 0.0015 g/L.

Lipid Content: The biomass was harvested during the logarithmic phase and the stationary phase. The lipid extraction followed the procedure described by Lee, Yoon, and Oh. (1989). Cells were first harvested by pelletizing the algal cells in the centrifuge at 5000 revolutions per minute (rpm). The pelletized algal cells were dried at 100°C for one hour. The algal cells were crushed with a mortar and pestle and sonicated with 30mL of chloroform/methanol (2:1 v/v) for 1 hour. The lipids were recovered in the lower chloroform phase and washed with 20mL of 5% (w/v) NaCl. The solution was evaporated to dryness, weighed gravimetrically, and recorded as total lipid. The total lipid content of the algae relative to its dry weight was obtained using the equation below:

$$\% \text{ lipid} = (\text{total lipid}/\text{dry weight})*100 \qquad (3)$$

RESULTS AND DISCUSSION

Relationship between the optical density and cell count: Optical densities taken at 445.5 nm and cell counts are strongly correlated. (R^2 = 0.990). Hence, the obtained regression equation was used to estimate the cell densities and algal growth from the optical density measurements. Y represents the optical density and X is the actual cell density (algal cells per milliliter culture).

$$y = 3.0E\text{-}8x + 0.286 \qquad (4)$$

Growth curve of C. vulgaris: Figure 1 below shows that the microalgae had a lag phase of 7 days prior to the onset of the 21-day logarithmic growth. *C. vulgaris* has a short stationary phase of 3 to 5 days. At the death phase, the decline in optical density was accompanied by the browning and agglutination of algal cells at the bottom of the glass bottles.

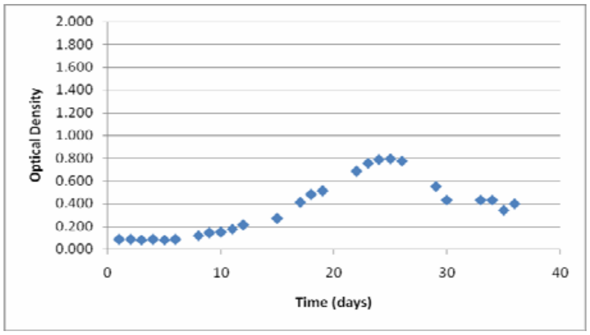

Fig. 1 The growth curve of *C. vulgaris* under control conditions with light intensity at 1500 lux and nitrate concentrations at 1.5g/L

Growth of C. vulgaris under different light intensities and nitrate regimes: There is a significant interaction between the effects of light intensity (800, 1500, and 2700 lux) and nitrate concentration (1.5, 0.15, 0.015, and 0.0015 g/L of $NaNO_3$) on the growth of *C. vulgaris* ($p < 0.05$). This is consistent with the report of Lewin (1962) wherein light stimulates nitrate reduction and nitrogen assimilation, in *Chlorella* spp. Specifically, the nitrate-light interaction could be any of the following: (1) light increases the permeability of the cells to nitrate or a (2) by product of photosynthesis is produced that can readily reduce nitrate to a form that is easily used by the cell.

Statistical results show that the growth rate and generation time of *C. vulgaris* grown in various light intensities are not significantly different ($p < 0.05$). However, Table 1 shows that growth rate increases with increasing light intensity. Light intensities used in the experiment still belong to the growth dependent portion of the light intensity curve wherein most of the photons are utilized for photosynthesis and growth (Kommareddy and Anderson, 1994; Sorokin and Krauss, 1958). Table 1 shows that the highest growth rate (0.08 day^1) and the shortest generation time is at 2700 lux.

Table 1 The average generation time and growth rate of *C. vulgaris* under different light intensities.

Light Intensity (lux)	Growth Rate (K)	Generation Time (G)
2700	0.08	3.66
1500	0.06	4.88
800	0.03	10.22

The growth rate and the generation time of *C. vulgaris* at 0.0015g to 0.15g/L of $NaNO_3$ is comparable to the growth of the control at 1.5g/L of $NaNO_3$ (Table 2). The different nitrate levels did not result to significant differences in growth because there was sufficient nitrogen in the growth medium. The growth of *C. vulgaris* is inhibited when the nitrogen level is below 0.001M or 0.0014g/L of Nitrogen (Lewin 1962; Fogg, 1952). Since the selected nitrate levels were above the growth-limiting N concentration, similar growth responses were noted. The presence of another nitrogen source in the form of ferric ammonium citrate in the BG11 medium also supports the claim that the nitrogen levels in the medium were above the growth limiting concentrations. Ferric ammonium citrate contributed 0.03g/L of nitrogen in the medium thereby making the growth medium nitrogen-rich.

Table 2 Average generation time and growth rate of *C. vulgaris* under different nitrate concentrations.

Nitrate Concentration	Growth Rate (K)	Generation Time (G)
0.0015 g/L	0.05	6.02
0.015 g/L	0.06	4.64
0.15 g/L	0.06	5.13
1.5 g/L	0.06	5.22

The findings on the growth rate and generation time were consistent with the growth curves of *C. vulgaris* under different nitrate concentrations and light intensities. Fig. 2 shows the average optical densities of set-ups with different nitrate concentrations. The growths of *C. vulgaris* at different nitrate levels were almost similar. A two-way ANOVA of the final biomass (optical density at the 41^{st} day) confirmed this observation ($p < 0.05$).

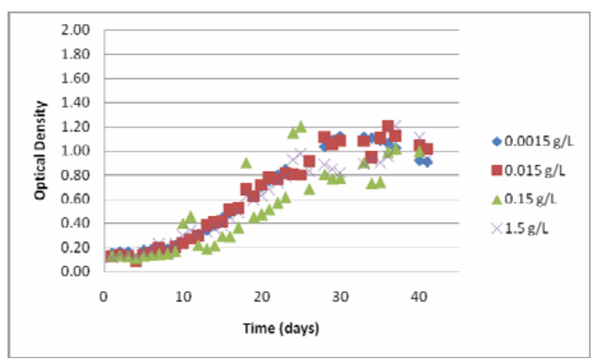

Fig.2 Growth curve of *C. vulgaris* in different nitrate concentrations measured for 41 days with 1.5g/L as the control.

Fig. 3 shows that the algal biomass at 2700 lux was significantly different from other light treatments ($p<0.05$). When the set-up was terminated, the algal cells at 800 lux agglutinated rather than being distributed evenly after shaking. The algal cells at 1500 also exhibited agglutination to a lesser degree and some of the cells were slightly brown.

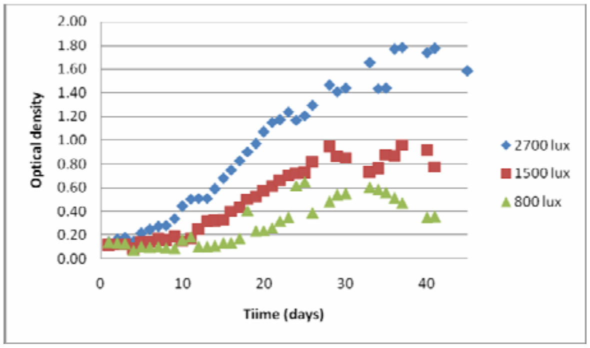

Fig. 3 Growth curve of *C. vulgaris* under different light intensities for 41 days with 1500 lux as the control.

Fig. 3 also shows that growth increased with the increasing light intensity. It can be noted that: (1) the lag phase at 2700 lux is shorter than the lag phase at 1500 lux and 800 lux; (2) both set-ups at 800 and 1500 lux reached stationary phase at the same time; (3) the logarithmic phase at 2700 is longer (up to the 35^{th} day) than the logarithmic phase at 1500 and 800 lux (up to the 30^{th} day). Thus, the light intensity levels belong to the light dependent portion whereby most of photons were used for photosynthesis and growth (Kommareddy and Anderson, 1994). The highest growth at 2700 lux is consistent with the study of Sorokin and Krauss (1958) wherein the photosaturation of *C. vulgaris* was observed at 2690 lux. Hence, 2700 lux is most effective at promoting growth regardless of nitrate concentrations.

Effect of nitrate and light intensity on the total lipid content of C.vulgaris in the logarithmic phase: There is a significant interaction between the effects of light intensity and nitrate concentration on the lipid production of *C. vulgaris* in the logarithmic phase ($p<0.05$). Lewin theorized that light influences nitrate reduction and nitrogen assimilation in the cell (1962). Hence, it is difficult to infer about the individual effects of nitrate and light intensity because light influences nitrate reduction.

At the logarithmic phase, the total lipid content of *C. vulgaris* among different nitrate levels is almost the same ($p<0.05$). Fig. 4 shows that the lipid content varies from 28% to 42% among different nitrate concentrations. This is consistent with the ability of *Chlorella* spp. to synthesize lipids instead of starch and carbohydrates when the nitrogen concentration of the medium is altered (Dickson, Galloway, and Patterson, 1969; Liu, Wang, Zhou, 2007). At 0.0015 g/L of nitrate, the total lipid content (42%) is relatively higher than the lipid content of algae grown in unmodified growth medium which varies from 13 to 30% (Liu, Wang, Zhou, 2007). Similar results were reported by Piorreck, Baasch, and Pohl (1983) wherein the highest lipid content occurred at 0.001 to 0.003% KNO_3.

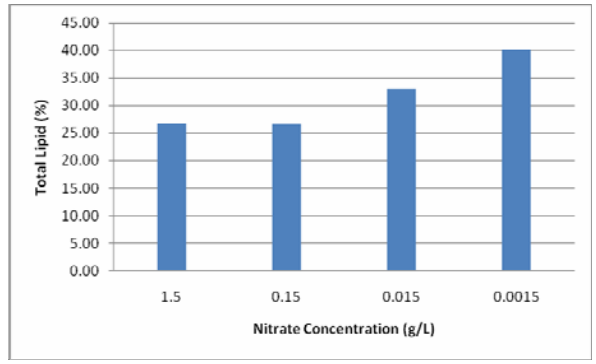

Fig. 4 Total lipid content of *C. vulgaris* in different nitrate levels in the logarithmic phase.

It is evident in Fig. 5 that there is no significant difference in total lipid content among varying light intensities ($p<0.05$). However, it can be observed that the total lipid content is slightly higher in 2700 lux than in the other two light intensities. This could be due to the increased capacity of illuminated photosynthetic tissues stimulate nitrate reduction and lipid synthesis (Yung and Mudd, 1965).

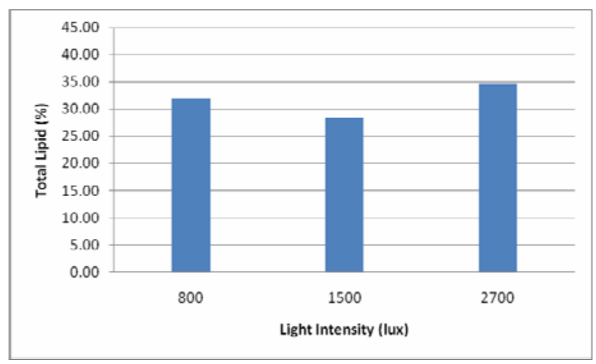

Fig. 5 Total lipid content of *C. vulgaris* at different light intensities in the logarithmic phase.

Effect of nitrate and light intensity on the total lipid content of C. vulgaris in the Stationary Phase: At the stationary phase, the decreased nitrate concentrations did not increase the total lipid content of *C. vulgaris* ($p>0.05$). It can be observed in Fig. 6 that the lipid content varied from 15 to 30% which is similar to the lipid content of *C. vulgaris* grown in unmodified growth medium (Liu, Wang, Zhou, 2007). The result is consistent with the findings of the United States National Renewable Energy Laboratory (1998) that nitrogen deprived conditions did not lead to increased lipid production. It is also probable that there was a sufficient level of nitrogen in the growth medium because of the presence another nitrogen source: ammonium-N from ferric ammonium nitrate which supplemented 0.03g/L of nitrogen in the growth medium. Since lipid accumulation is usually associated with nitrogen deprivation, high levels of nitrogen in the growth medium would not result to significant changes in the lipid content (McGinnis, Dempster, Sommerfeld, 1997; Dickson, Galloway, Patterson, 1969; Liu, Wang, Zhou, 2007; Piorreck, Baasch, and Pohl, 1984).

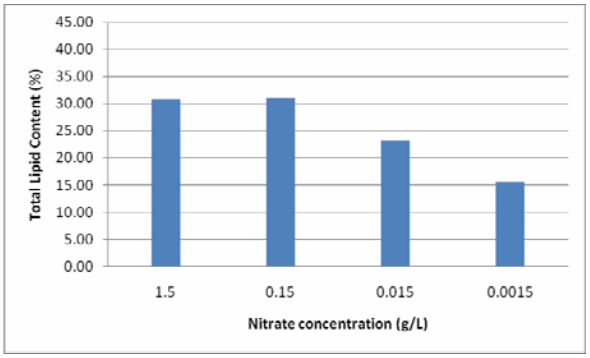

Fig.6 Total lipid content of *C. vulgaris* in different nitrate levels in the stationary phase.

It should be noted that the effect of nitrogen on fatty acid metabolism is unknown. It is theorized that its effect might be a secondary one wherein the drop in chlorophyll contents, which were observed during nitrogen starvation, leads to the simultaneous breakdown of the chlorophyll apparatus and lipid catabolism (Piorreck, Baasch, and Pohl, 1984)

The total lipid content of *C. vulgaris* in the stationary phase at 800 lux is significantly higher than the other light intensities ($p<0.05$). The microalgal lipid content at 800 lux is 42%, while the lipid content at 1500 lux and 2700 lux are 18% and 15%, respectively (Fig. 7). The effect of light intensity on the lipid content is the inverse of its effect on growth: while 2700 lux promoted the highest growth, 800 lux promoted the lipid accumulation. This is because greater amount of carbon can be diverted to lipid storage when the cell division or growth is suppressed (McGinnis, Dempster, Sommerfeld, 1997).

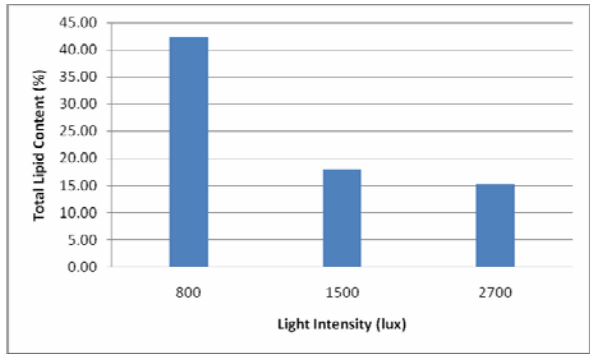

Fig. 7 Total lipid content of *C. vulgaris* in different light intensities in the stationary phase.

Total oil yield in grams: Sheehan, et al. (1998) stated that a balance between oil production and growth must be achieved. The results in previous sections show that high total lipid content (42%) was observed in the set-up with the lowest growth (800 lux, stationary phase), whereas in the set-up with the highest growth (2700 lux,logarithmic phase) the total lipid content was only 35%. The total oil yield was assessed to account for both the growth and total lipid content.

Although the amount of oil extracted from the algae at different nitrate concentrations were not significant ($p<0.05$), it can be observed that the highest amount of lipid extracted were at 1.5 and 0.15 g/L of nitrate at the stationary phase with 0.182g and 0.184g of oil, respectively (Fig. 8).

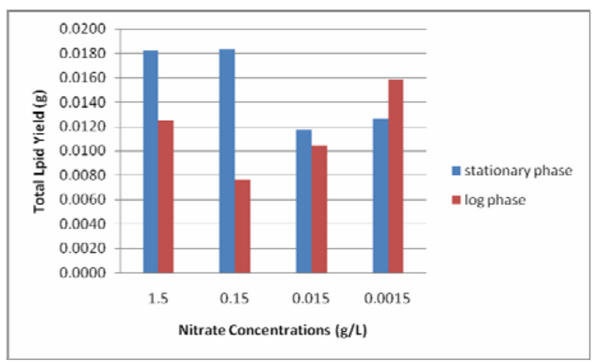

Fig. 8 Amount of oil extracted from *C. vulgaris* in different nitrate concentrations at stationary and logarithmic phase.

Although previous results show that the lipid content and growth at different nitrate concentrations not significantly different at the stationary phase, the relatively higher lipid yields at 1.5 and 0.15 g/L of nitrate could be attributed to the bigger cell sizes in those concentrations (Fig. 9). It is also notable that the cells in the stationary phase are bigger than the cells at the logarithmic phase. This could also be a factor why high amounts of oil was extracted in the stationary phase than in the log phase. Generally, cells at the the logarithmic phase contain fewer lipids because the light energy harnessed is used for cell division. At the stationary phase wherein the cells already stopped dividing because of limiting culture conditions, the energy harnessed are used for the synthesis of storage lipids (Dunstan et al., 1993; Guckert and Cooksey, 1990; Chiu et al., 2008).

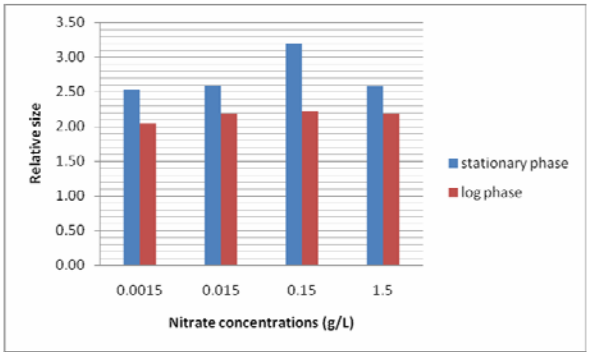

Fig. 9 Relative size of the cells of *C. vulgaris* in different nitrate concentrations at stationary and logarithmic phase.

The amount of oil extracted from *C. vulgaris* at different light intensities for both the stationary and the logarithmic phase were not significant ($p<0.05$). However, it can be observed that high oil yields were obtained from cells in the stationary phase at 800 lux and 2700 lux with 0.0185g and 0.0174g of oil respectively (Fig. 10). The oil yield at 800 lux is due to the high total lipid content of the cell (Fig. 11) while the the oil extracted from 2700 lux is due to its high biomass. Bigger cells at the stationary phase could also be a factor in the high oil yields at the stationary phase.

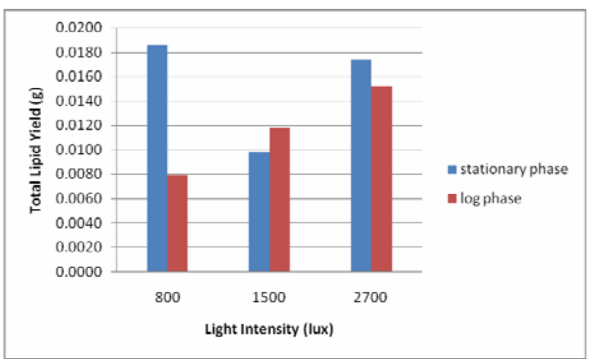

Fig. 10 Amount of oil extracted from *C. vulgaris* in different light intensities at stationary and logarithmic phase.

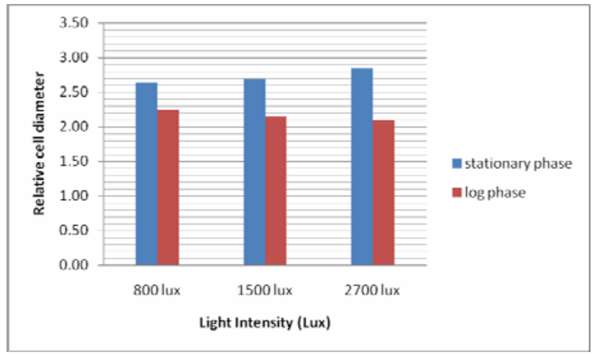

Fig. 10 Relative size of the cells of *C. vulgaris* in different light intensities at stationary and logarithmic phases.

CONCLUSION

Only light intensity had a significant effect on the lipid production and growth of *C. vulgaris* ($p<0.05$): 2700 lux promoted growth and 800 lux produced the highest amount of lipid. The total lipid yield (g) which integrates both the growth and lipid content showed that both 800 lux and 2700 lux yielded significant amounts of lipid. Moreover, it showed that nitrate levels at 1.5g/L and 0.15g/L produced the most number of oil. Given these results, it can be concluded that the optimum conditions for the growth and lipid production of *C. vulgaris* are at 800 and 2700 lux with 1.5 and 0.15 g/L of nitrate. Moreover, lipid harvesting is ideal at the stationary phase.

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Session IV: Active participant (Thailand);
Dr. Gumpanart Bumroonggit

EGCO GROUP

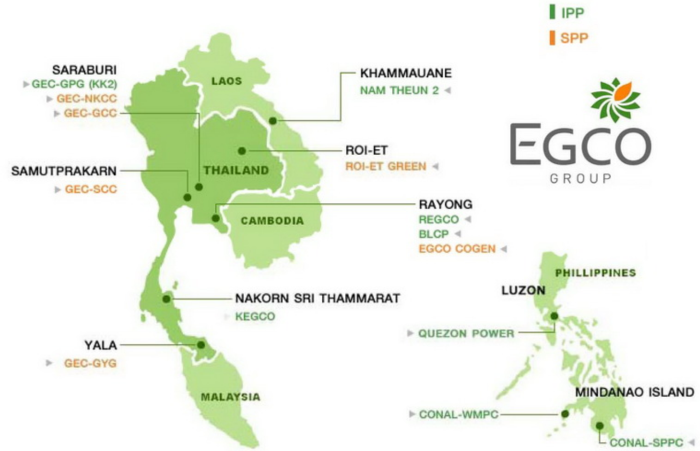
Asia-Pacific Economic Cooperation

Electricity Generation from Agricultural Waste in Thailand

Dr. Gumpanart Bumroonggit
Electricity Generating Public Company Ltd.

25 May 2010
Chiang Mai University

EGCO — Energy for life



EGCO

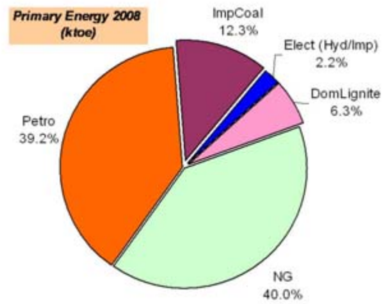
Energy for life

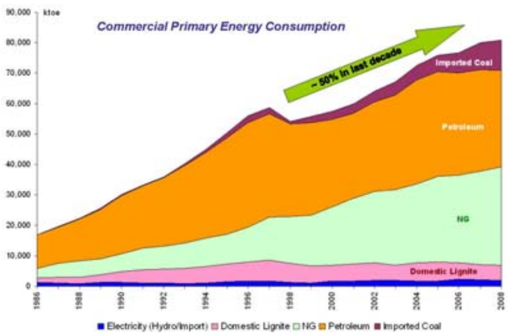
Thailand's Energy Consumption

Thailand's total commercial primary energy consumption increased rapidly, nearly 50%, in the last decade. The average annual growth rate was 6.7% during the period of 1986 to 2008.

In 2008, total commercial primary energy consumption was 80,971 ktoe. Majority of the energy consumed were Natural Gas, Petroleum, and Imported Coal, of which the majority were imported. Approximately more than 90% of petroleum, and 23% of natural gas were imported.

Value of energy import heavily goes to crude oil import, especially in the last few years where the crude oil price increased very strongly. Total value of energy import was 1,161,699 million Baht in 2008, a jump of almost 100% from 2004.





Value of Energy Import (mB)

Type	2004	2005	2006	2007	2008
Crude Oil	486,627	644,933	753,783	715,789	1,002,355
Petroleum Product	41,533	55,680	62,350	48,317	29,940
Natural Gas	46,053	62,827	77,843	78,901	88,414
Coal	12,275	15,422	18,896	29,656	36,456
Electricity	5,659	7,114	8,294	7,414	4,534
Total	592,148	785,976	921,166	880,078	1,161,699

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Source: Energy Policy and Planning Office (EPPO)

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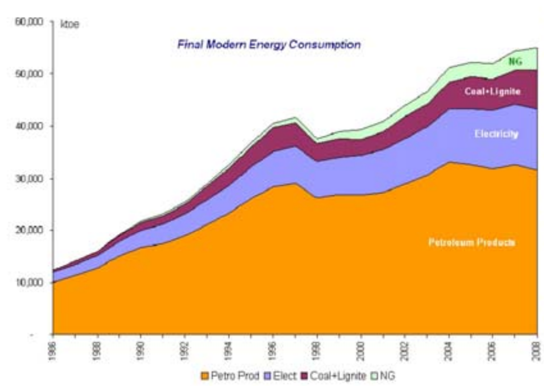
Thailand's Energy Consumption



In terms of Final Modern Energy Consumption, petroleum products and electricity were the two main form of energy used in the country since 1986. In 2008, petroleum products and electricity were consumed for 53% and 21%, respectively. While the growth of petroleum products was 20%, that of electricity was as high as 68% in the last decade.

Petroleum products were used mainly as fuel for transportation, especially high speed diesel and unlead gasoline, although the skyrocket oil price and economic downturn have slowed down the consumption a little bit.

The peak demand of electricity generation has been increasing continuously since 2000 at the average growth rate of around 5%. However, due to the economic slow down in the world and in the region, the peak demand in the last two years dropped as much as 2.3%.

The government policy clearly indicates the effort to utilize energy more efficiently, and promotes the use of renewable energy for both fuel and electricity generation through various programs and some subsidy measures.

Year	Peak (MW)	Increase (MW)	Growth
2000	14,918	1,206	8.79%
2001	16,126	1,208	8.10%
2002	16,681	555	3.44%
2003	18,121	1,440	8.63%
2004	19,326	1,204	6.65%
2005	20,538	1,212	6.27%
2006	21,064	527	2.56%
2007	22,586	1,522	7.23%
2008	22,568	(18)	-0.08%
2009	22,045	(523)	-2.32%

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Source: Energy Policy and Planning Office (EPPO)

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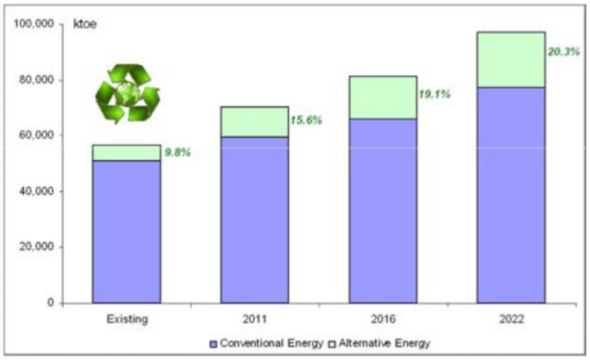
15-year Alternative Energy Plan

TARGET :
Increase the use of alternative energy to 20% of country's final energy consumption by 2022



Energy (ktoe)	*Existing*	*2011*	*2016*	*2022*
Alternative Energy	5,535	10,961	15,579	19,799
Conventional Energy	51,152	59,339	65,922	77,501

กระทรวงพลังงาน
MINISTRY OF ENERGY

To reduce the dependency and the expenses on imported energy, the Thai Government tries to promote the utilization of alternative energy in the country. It is the energy security enhancement for the country and is also the main part of green energy policy to limit the greenhouse gas emission.

The 15-Year Alternative Energy Plan is formulated by the Ministry of Energy, and it covers the 15-year period of 2008 to 2022. However, the information and figures used here for "Existing" is updated to September 2009.

The Alternative Energy includes
- Renewable energy in forms of Electricity, Thermal, Biofuel, and
- Natural Gas for Vehicle (NGV).

Source: Ministry of Energy (MoE)

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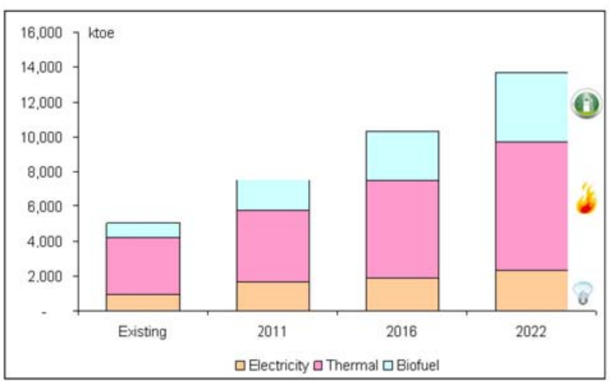
Renewable Energy in the Future



1

Electricity
Solar
Wind
Mini-Hydro
Biomass
Biogas
Waste

2

Thermal
Solar
Biomass
Biogas
Waste

3

Biofuel
Ethanol
Biodiesel

In the 15-Year Alternative Energy Plan, Alternative Energy includes
- Renewable Energy in forms of Electricity, Thermal, Biofuel, and
- Natural Gas for Vehicle (NGV).

Here, focusing on Renewable Energy, the energy in the form of NGV will be excluded.

Total amount of renewable energy is expected to increase from existing 5,020 ktoe to 13,709 ktoe in 2022, or approximately 2.7 times.

The plan shows that Thermal energy covers a large portion both at present and in the future.

Biofuel is also being promoted in the form of Ethanol and Biodiesel. The plan expects that biofuel energy would cover up to 3,986 ktoe in 2022, or about one-third of total renewable energy utilization.

Renewable energy may derive from various sources such as solar, wind, hydro, biomass, biogas, biofuel, etc.

Source: Ministry of Energy (MoE)

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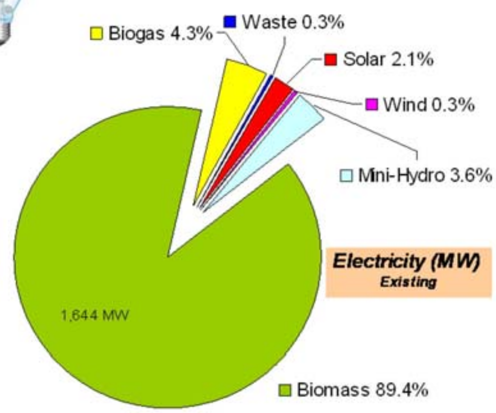
1 Electricity Generating Capacity from Renewable Energy

	Potential	Existing
Electricity	MW	MW
Solar	50,000	39
Wind	1,600	5
Mini-Hydro	700	67
Biomass	4,400	1,644
Biogas	190	80
Waste	400	6
Hydrogen		
Total		1,840



Solar energy has the largest potential for electricity generating capacity from renewable energy. But due to high unit cost of electrical energy produced, the utilization is limited at present.

Although its potential for electricity generating capacity is the second largest from solar energy, Biomass is the largest source for electricity generation capacity from renewable energy in Thailand at present day. The electricity generation from biomass is supplied for own use of the plant owners and is also purchased to the grid under Small Power Producer (SPP) program and Very Small Power Producer (VSPP) program, which are part of renewable energy promotion policy of the government.

Various kinds of biomass are being utilized as fuel for electricity generation. Those include agricultural material such as rice husk, bagasse, wood chips, etc.

Source: Ministry of Energy (MoE)

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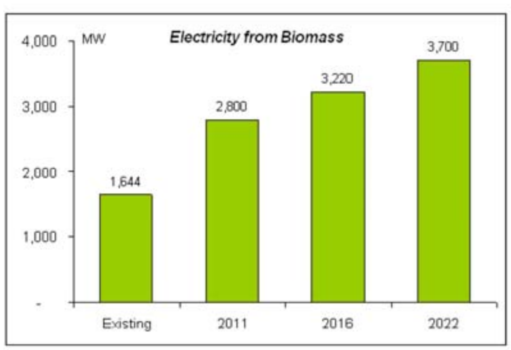
1 Electricity Generating Capacity from Renewable Energy

Electricity (MW)	Existing	2011	2016	2022
Solar	39	55	95	500
Wind	5	115	375	800
Mini-Hydro	67	165	281	324
Biomass	1,644	2,800	3,220	3,700
Biogas	80	60	90	120
Waste	6	78	130	160
Hydrogen	-	-		4
Total	1,840	3,273	4,191	5,608



The 15-Year Alternative Energy Plan expects that the total electricity generating capacity from renewable energy will increase and reach 5,608 MW in 2022.

Among various sources of renewable energy, the electricity generation from Biomass will play important part. Its generating capacity would be double by 2016.

The total generating capacity from Biomass should reach 3,700 MW by the year 2022, equivalent to 125% growth.

In terms of electricity generation from agricultural and agro-industrial wastes, the combined capacity from biomass and biogas should finally reach 3,820 MW by the end of the plan.

Data from Renewable Energy Projects of EGAT estimates that investment cost of biomass power plant is 40,000 - 70,000 Baht/kW. The electric energy cost is approximately 3.00 – 3.50 Baht/kWh. The cost of biomass fuel is the important factor determining the electric energy cost.

Source: Ministry of Energy (MoE)

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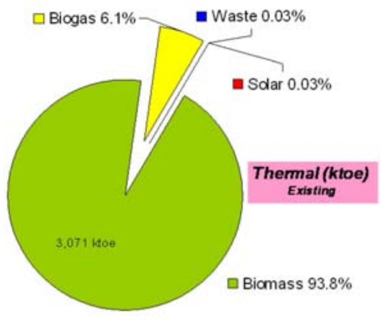
2 Thermal Energy from Renewable Energy

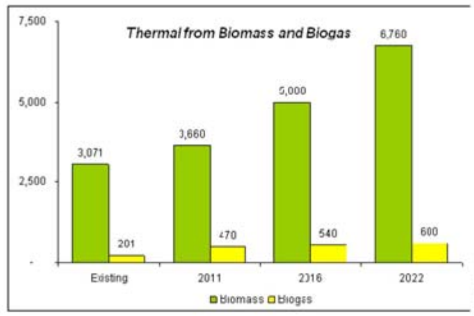
Thermal (ktoe)	Potential	Existing	2011	2016	2022
Solar	154	1	5	18	38
Biomass	7,400	3,071	3,660	5,000	6,760
Biogas	600	201	470	540	600
Waste		1	15	24	35
Total		*3,274*	*4,150*	*5,582*	*7,433*

As shown earlier, thermal energy plays the largest part of renewable energy utilization at present and in the future. It is being promoted for use both in industry and community.

The major source is biomass, more than 90% at present. The plan expects that biomass will be utilized for thermal energy almost up to its potential by the end of the plan, or 120% growth.

Biogas utilization derived from a) animal waste, and b) industrial waste water. It is being expanded fairly well at the moment and is expected to triple by 2022, or 199% growth.





Source: Ministry of Energy (MoE)

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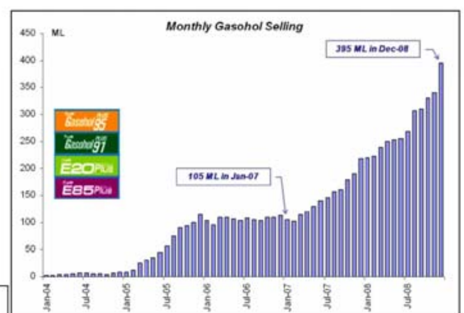
3 Biofuel Energy

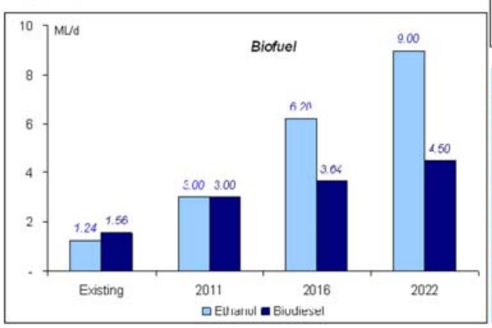
Biofuel (ML/d)	Potential	Existing
Ethanol	3.00	1.24
Biodiesel	4.20	1.56

With Government policy and regulation to promote the use of gasohol and biodiesel as alternatives for conventional gasoline, together with volatile and high oil price situation, gasohol and biodiesel consumptions increased rapidly in the past few years. Within 4 years, monthly gasohol selling ran from nearly zero at the beginning of 2004 to nearly 400 million liters at the end of 2008. Especially in the last 2 years, the monthly sale growth was close to 300%.

Currently, the prices of gasohol are lower than regular ULG around 3.80 to 17.30 B/liter, while the price of high speed diesel B5 is around 1.20 B/liter lower than regular HSD.



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



Gov plan to further promote the use gasohol and biodiesel, such as E20, E85, B5, and B10.

Number of 19 ethanol plants in operation, current prod 1.24 ml/d, the plan would increase to 9 ML/d in line with the projection of gasohol use in the future. Four more plants are under construction with 1.62 ml/d combined capacity, expected to complete within 2010.

Number of biodiesel B-100 13 plants in operation with 4.2 capacity, capacity Current prod 1.56 ml/d, expect to 4.5 ml/d in2022.

Source: Ministry of Energy (MoE)

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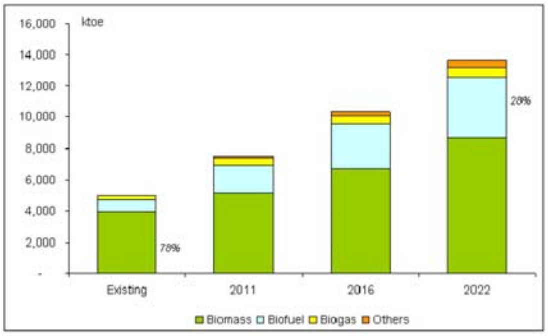
Sources of Renewable Energy



Among various sources of renewable energy in the plan, agricultural and agro-industrial wastes play the most important role.

In Thailand, Biomass is the largest source for renewable energy. It covers 3,930 ktoe at present, or more than three quarters of total renewable energy utilization, and it would continue to be the main source of renewable energy for the country until the end of the plan with its portion increase to 8,693 ktoe.

Biofuel is the other source of renewable energy that is being promoted. It is expected that the energy from biofuel would grow to more than 4 times of existing level and finally shares almost 1/3 of country's total renewable energy utilization in 2022.

According to the 15-Year Alternative Energy Plan, the country's renewable energy utilization is expected to grow as much as 173%, from existing 5,020 ktoe to 13,709 ktoe in 2022. The average growth rate is approximately 13.3% per year.

Renewable Energy (ktoe)	Existing	2011	2016	2022
Biomass	3,930	5,123	6,682	8,693
Biofuel	827	1,755	2,831	3,862
Biogas	237	497	580	654
Others	26	117	226	500
Total	5,020	7,492	10,319	13,709

Source: Ministry of Energy (MoE)

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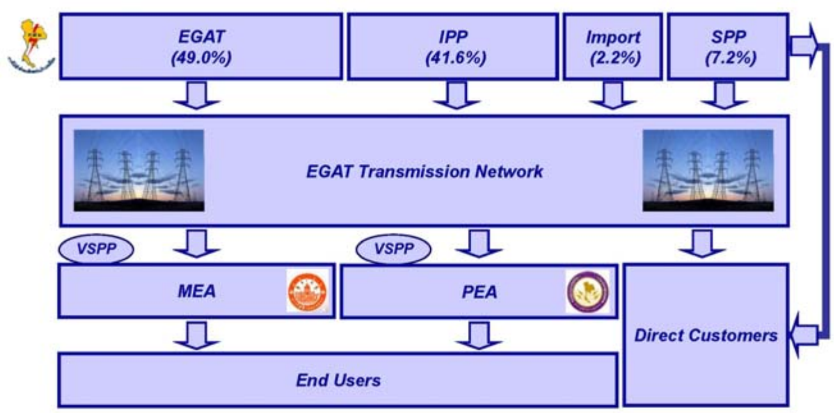
Thailand's Electricity Generation Industry



The structure of Thailand's electric power system is a type of a Single Buyer, where the Electricity Generating Authority of Thailand (EGAT) is a single buyer and owns around 49% of the generating capacity and the nation-wide transmission system. EGAT also buys the power from the Independent Power Producers (IPP) and the Small Power Producers (SPP) under the power purchase agreements. The IPP and SPP supply around 41.6% and 7.2% of total installed capacity of the system. Power is also imported from the neighboring countries to the grid for a small portion of approximately 2.2%. The bulk power is then sold to the Metropolitan Electricity Authority (MEA) and the Provincial Electricity Authority (PEA) to sell and distribute electricity to the end users in Bangkok and the vicinity areas, and in the remaining areas of the country, respectively. The Very Small Power Producers (VSPP) also generate and sell their excess power, mostly from renewable energy sources, to MEA and PEA.

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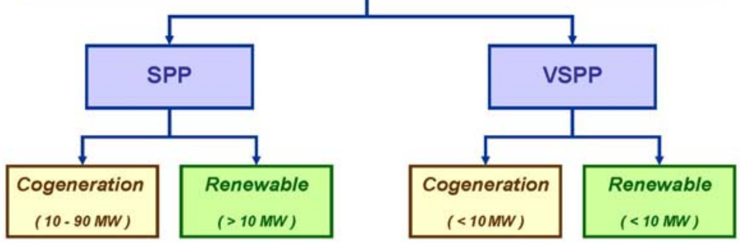
Promotion of SPP and VSPP Power Generation



Small Power Producer (SPP)

SPP Program allows private investment in electricity generation industry using the cogeneration system to produce both electricity and steam. The electricity generation using renewable energy is also allowed under SPP program. The SPP plant is allowed to sell excess power to EGAT up to 90 MW.

Very Small Power Producer (VSPP)

VSPP Program allows private investor to build and operate the plant and sell their excess electricity, produced from renewable energy or a cogeneration system, to the network of MEA or PEA at less than 10 MW. The renewable energy sources include wind, solar, mini/micro hydro, biogas, or various kinds of biomass, etc.

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Adder Tariff

As an incentive for electricity generation from renewable energy, the government offers the "Adder" tariff as a subsidy for the investor.

Adder is a higher tariff, granted to SPP and VSPP using renewable energy for power generation, provided on top of the normal tariff for 7-10 years from the COD. The amount of adder depends on the type of renewable energy used. In case of biomass SPP, the adder was determined through a competitive bidding system when the government issued a solicitation in May 2007.

The extra adders are also provided for the plant located in the area where PEA's diesel generator exist, and for the plant located in 3 Southern-most provinces (Yala, Pattani, and Narathivath).

	Adder (B/kwh)	Extra Adder (B/kwh) (a)	Extra Adder (B/kwh) (b)	Supported Period (Yr)
Biomass (<= 1 MW)	0.50			
Biomass (> 1 MW)	0.30			
Biogas (<=1 MW)	0.50			
Biogas (> 1 MW)	0.30	1.00	1.00	7
Waste	3.50			
Mini Hydro (<= 50 kW)	1.50			
Mini Hydro (50 - 200 kW)	0.80			
Wind (<= 50 kW)	4.50			
Wind (> 50 Kw)	3.50	1.50	1.50	10
Solar	8.00			

(a) For renewable plant located in the area which has PEA's diesel power generation
(b) For the plant located in the 3 Southern-border provinces

Apart from being a subsidy for economic feasibility of electricity generation from renewable energy, the adder also helps diversify the renewable energy sources, especially in the VSPP program. Variety type of biomass are utilized as fuel, such as bagasse, palm waste from palm oil factory, emptied palm bunches, woodchips from plantation, corn cob, rice straw, coconut fiber, etc.

Biogas is the other source of renewable energy that is gaining more interest as fuel for power generation. The investor can derive the biogas from either animal waste or industrial waste water. There are advantages over the existing treatment system both on environmental impact and on economic effectiveness since energy is obtained as a by-product.

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Source: Energy Policy and Planning Office (EPPO)

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SPP in Operation (March 2010)

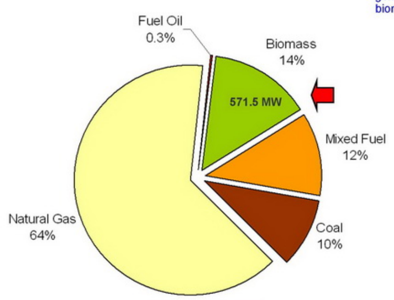
SPP in Operation (March 2010)

Type	#	MW
Coal	4	392.2
Natural Gas	21	2,615.8
Fuel Oil	1	10.4
Biomass	23	571.5
Mixed Fuel	4	476.0
Total	**53**	**4,065.9**

Currently, 53 SPP plants are in operation with total installed capacity of 4,065.9 MW, of which 2,305.8 MW or 57% is supplied to the grid. While the total installed generating capacity connected to the grid is 29,212 MW, the capacity from SPP supplied to the grid (both firm and non-firm contracts) accounts for 7.9%.

The largest portion of SPP capacity comes from 21 plants using natural gas fuel, while biomass supplies as second largest with 571.5 MW from 23 plants.

From 23 biomass SPP plants, 349.3 MW or 61% of their installed capacity is supplied to the grid. Bagasse, rice husk, and woodchips are the combined main fuels for the SPP biomass generating capacity. Together they represent 561.6 MW or 98% of the installed capacity from biomass.



SPP in Operation

Biomass	#	MW
Bagasse	8	180.4
Rice Husk	5	57.3
Rice Husk + Woodchips	2	57.8
Bagasse + Wooodchips + Rice Husk	2	104.9
Palm Waste + Emptied Palm Bunches + Cassava Rhizome	1	9.9
Woodchips	2	98.0
Bagasse + Rice Husk + Rice Straw	3	63.2
Total	**23**	**571.5**

Bagasse — Rice Husk — Woodchips: 561 MW (98%)

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Source: Ministry of Energy (MoE)

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VSPP in Operation (March 2010)

VSPP in Operation (March 2010)

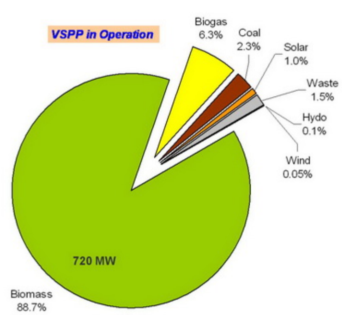
Type	#	MW
Biomass	53	720.0
Biogas	41	51.0
Coal	2	19.0
Solar	51	7.8
Waste	8	12.5
Hydro	3	0.6
Wind	3	0.4
Total	161	**811.3**

Currently, 161 VSPP plants are in operation with total installed capacity of 811.3 MW, of which 356.3 MW or 44% is supplied to the grid. While the total installed generating capacity connected to the grid is 29,212 MW, the capacity from VSPP supplied to the grid (both firm and non-firm contracts) accounts for 1.2%.

The largest portion of VSPP capacity at 720 MW comes from 53 plants using biomass fuel, while biogas fuel supplies as second largest with 51 MW from 41 plants. Total 771.0 MW or 95% of VSPP generating capacity comes from bio-material sources.

From 53 biomass VSPP plants, 287.8.8 MW or 40% of their installed capacity is supplied to the grid. Bagasse, rice husk, and woodchips are the combined main fuels for the SPP biomass generating capacity. Together they represent 680.8 MW or 95% of the installed capacity from biomass.

VSPP in Operation



Biomass	#	MW
Palm Waste	1	12.0
Bagasse	29	530.8
Bagasse + Rice Husk	1	39.4
Rice Husk	13	71.5
Rice Husk + Woodchips	2	27.1
Sawdust	1	0.6
Corn Cob	1	0.2
Emptied Palm Bunches	4	26.5
Woodchips	1	12.0
Total	**53**	**720.0**

Bagasse — Rice Husk — Woodchips: 680 MW (95%)

Biogas	#	MW
Animal Waste	8	1.6
Industrial Wastewater	29	47.6
Rice Straw	4	1.8
Total	**41**	**51.0**

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Source: Ministry of Energy (MoE)

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Bio-Material Projects under Development with Signed PPA (March 2010)

SPP under development with signed PPA

Energy / Fuel	#	MW
Biomass		
Bagasse	1	65.0
Woodchips	1	4.8
Total	2	69.8

There are 244 projects using biomass and biogas under SPP and VSPP programs which have already signed the Power Purchase Agreement (PPA) with the utilities to supply electricity to the grid. Total installed capacity is 2,202.7 MW. Again, bagasse, rice husk, and woodchips are the main fuels for these projects . All together they represent 1,953 MW or 92% of the total capacity.

Concerns would be the amount of biomass fuel to supply to the plants. With a large installed capacity of biomass power plants, large amount of fuel supply would need to be procured for the operation. The biomass fuel price in the future would also be a very important factor for the feasibility of these SPP and VSPP projects.

VSPP under development with signed PPA

Energy / Fuel	#	MW
Biomass		
Palm Waste	1	9.5
กากสบู่ดำ	2	19.0
Bagasse	12	258.0
Rice Husk	35	314.9
Rice Husk + Woodchips	98	965.9
Rice Husk + Corn Cob	1	9.0
Coconut Fiber	1	6.0
Corn Cob	1	9.9
Corn Cob + Rice Husk	1	6.0
Emptied Palm Bunches	6	48.5
เปลือกไม้	1	6.0
Casava Rhizome	4	21.9
Fast-Growing Woods	5	24.3
Woodchips	40	344.7
Others	1	5.1
Total	209	2,048.7
Biogas		
Animal Waste	4	1.4
Industrial Waste Water	26	79.6
Others	3	3.2
Total	33	84.2
	242	2,133

Bagasse — Rice Husk — Woodchips: 1,953 MW (92%)

Source: Energy Policy and Planning Office (EPPO)

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Electricity Generation from SPP and VSPP : Now and Future

	Biomass #	Biomass MW	Biogas #	Biogas MW
In Operation				
SPP	23	571.5	-	-
VSPP	53	720.0	41	51.0
Total	76	1,291.5	41	51.0
Under Development with Signed PPA				
SPP	2	69.8	-	-
VSPP	209	2,048.7	33	84.2
Total	211	2,118.5	33	84.2
Total In Operation + Under Development with Signed PPA	287	3,410.0	74	135.3

1,342.5 MW In Opreation

2,202.7 MW Developing

3,545.2 MW Total

3,980 MW 2022 Target

According to the 15-Year Alternative Energy Plan, the total capacity of electricity generation from biomass, biogas, and waste should finally reach 3,980 MW by the year 2022.

Currently, the total capacity in operation of SPP and VSPP from biomass and biogas is 1,342.5 MW.

At the same time, there are 244 SPP and VSPP plants which have already signed PPA and are under development, with the total capacity of 2,202.7 MW. These plants should start their operation within the next several years. Therefore, it is expected that the total capacity of electricity generation from agricultural and agro-industrial wastes should be more than 3,500 MW before the end of the plan.

Source: Energy Policy and Planning Office (EPPO)

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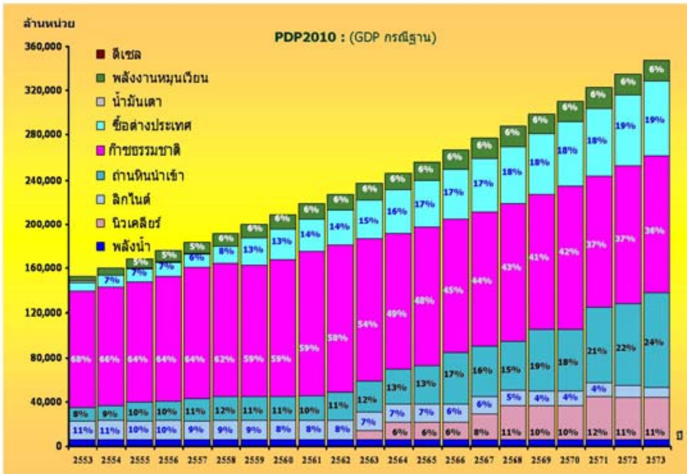
Draft Power Development Plan (March 2010)

Thailand Power Development Plan (PDP) is an optimum plan to indicate new power plants with appropriate size and types at appropriate time to serve the increasing demand in the next 10-15 years adequately. The PDP is formulated by EGAT under the policy framework of the Ministry of Energy in terms of reliability of power supply, fuel diversification, power purchase from neighboring countries, and power demand forest etc.



Recently, EPPO has set up the committee to prepare the new PDP. This new PDP requires the public hearing on the guideline to revise the current PDP to meet the changing circumstances and will be a long term plan (20 years) from 2010 onwards. This new version of PDP will emphasize on the stability of the country's power system, the distribution of the type of fuel sources which will promote renewable energy to promote Green PDP, as well as to support the efficient power generation system using the cogeneration system.

Base on the draft PDP, the system's total electricity generation from renewable energy sources is expected to increase from existing level and maintain at least 6% in the next decade. Note that this figure is only the portion that the energy is supplied into the country's power system, not including the own use by the plant owners.

Source: EGAT

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Roi Et Green Power Plant (Rice Husk)

Plant Location	Roi Et Province (510 km NE of Bangkok)
Area	40 Rai (64,000 sq.m.)
Fuel	~300 Ton/day of rice husk
LHV of Fuel	12.6 MJ/kg (3,000 kcal/kg)
Water Supply	Chi River, ~13.6 km pipeline
Connection	22 kV line PEA
Installed Capacity	9.95 MW
Contracted Capacity with EGAT	8.80 MW
Contract period	21 years SPP program

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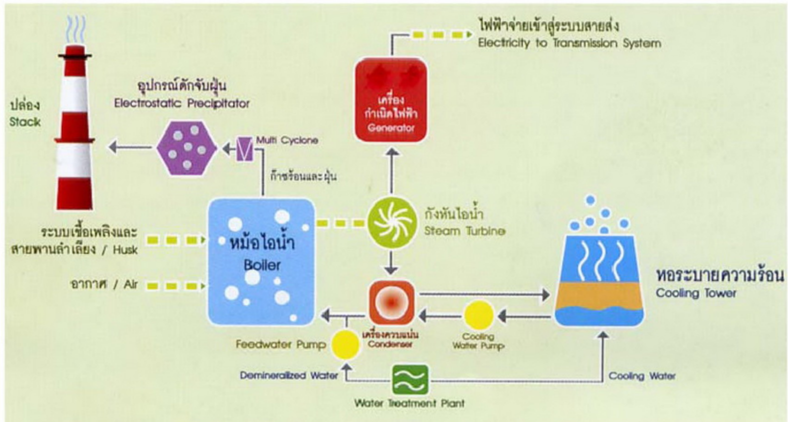
Generation Process



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Rice Husk Fuel

Consumption 300 Ton/day

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Rice Husk Transportation by Truck to Storage Area

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May 24th – 27th, 2010, Chiang Mai, Thailand

THAILAND'S ECONOMY REPORT
THAILAND'S BIOMASS POTENTIALS AND USES FOR BIOFUELS PRODUCTIONS

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ABSTRACT

Although Thailand has been turning itself into a more industrialized economy, agriculture is still its basic structure. Being one of the main producers of rice, sugarcane and cassava, the crops in their raw and processed forms have been the economy's main agricultural products. Along with the harvesting and processing, large amount of biomass has resulted as the unused portions of the cultivation and as the waste from the process. Utilization of these biomasses in productions of heat and energy has caught interests from both industries and researchers as it is not only the way to reduce the amount and increase the value of the biomass waste but also an alternative feedstock to ethanol industry which could face with the risk in under supply of the raw materials.

Keywords: Thailand, biomass, energy, biofuels, agriculture

1 INTRODUCTION

Thailand is one of the economies with much availability and diversity in natural resources. Being an agricultural-based economy, agro-industries including food and developing bio-based industries have become the major industries in Thailand. From the information provided by Department of Industrial Works, Ministry of Industry (n.d.), 10,571 factories could be categorized as agro-industrial factories, as in April 2010.

Many of the agricultural sectors and the factories could generate vast amount of unused biomass or other form of wastes from the production processes. However, utilization of those wastes is still limited. The most obvious use of the sugar waste such as molasses from sugar industry is for ethanol production and as an ingredient in animal feed. For other biomass such as sugarcane bagasse and rice husk, the current use is in electricity generation.

This article aims to report the current situations regarding Thailand's biomass potentials and their uses in term of providing energy. Focuses will be made on the main biofuels in current attention, which are ethanol and biodiesel. Brief introduction to bio-hydrogen work in Thailand would also be included.

2 THAILAND'S BIOMASS POTENTIALS

For the purpose of common understanding, biomass referred to in this article would mean the biomass that could be converted into a form of energy. Biomass is the by-products or waste from agriculture, wood chip waste from wood industry, animal manures, waste from agricultural products processing plants and community wastes.

In 2005, Department of Alternative Energy Development and Efficiency (DEDE) had considered 9 crops and plants as the potentials for production of alternative energy. These included sugarcane, rice, cassava, corn for animal feed, palm, pineapple, soy bean, coconut and eucalyptus and rubber tree woods (Chuanrakthum, 2005). At the time, the top 5 biomasses that have been utilized in industries were wood and wood chips, palm fiber, rice husk, bagasse and corncob.

Availability of biomasses depends largely on the annual production of their respective types of crops or plants. Sugarcane, rice and cassava have been the 3 major crops produced. Rising production of palm was observed with almost 30% increase in its production from production year 2006/07 to 2007/08 (Table 1).

Table 1 Plantaion areas and annual production (2006-2008) for each of the major crops and rubber tree (DEDE, n.d.)

Type	Plantation Area (km^2)		Production (10^3 ton)	
	2006/07	2007/08	2006/07	2007/08
Sugarcane	10,102.4	10,540.8	64,365	73,501
Rice	108,176	107,120	29,640	29,900
Sorghum	332.8	328.0	57	55
Corn	9,550.4	10,427.2	3,602	4,249
Palm	4,260.8	4,596.8	6,613	9,264
Cassava	11,740.8	11,835.2	26,915	25,155
Pineapple	955.2	929.6	2,305	2,278
Rubber tree	17,502.4	18,193.6	5,700	3,166

In the production year 2007/08, DEDE has estimated the amount of biomass generated from each of the major and potential crops and plants to be nearly 100 million tons. The energy (in ktoe) generated by those biomasses was approximately equal to the energy that could be generated by the amount of crude oil imported in that year (EPPO, 2010).

The amount of biomass from the 3 major crops: sugarcane, rice and cassava, contributed 89.4% of the total biomass in 2007/08 production year. Sugarcane bagasse and rice husk have already been utilized in industries to provide heat and power. In 2008, the energy use through the form of bagasse and rice husk accounted for 32.7% of the utilized biomass energy and only 10.7% of the potential energy that could be provided by the biomasses generated in that production year (DEDE, n.d.; 2008c).

Regarding the amount of biomass generated, oil palm was another potential. Although its annual production was far lesser than the 3 major crops, total biomass generated from the palm was in the amount similar to rice husk and cassava biomass (Table 2). Therefore, it could be regarded also as the potential sources of biomass for energy and fuel productions.

3 ETHANOL PRODUCTION IN THAILAND

Ethanol has become a large and fast-growing bio-based industry in Thailand. Starting in 2006 when the government opened the freedom on licensing the ethanol production and distribution, as in March 2010, there have been 47 ethanol plants that the licenses have been issued to, with the full licensing production capacity of 12.295 million liters per day (DEDE, 2010b). However, only 19 plants are now in operation with the total daily production of 2.925 million liters with 4 more plants which hold total

Table 2 Biomasses from various sources and their energy potentials, production year 2007/08 (DEDE, n.d.)

Sources of biomass	Biomass type	Biomass (10^3 ton)	Energy (GJ)	Crude oil equivalent (ktoe)
Sugarcane	bagasse	22,050.3	357,435,363	8,537
	shoot & leaves	17,640.24	289,652,741	6,918
Rice	husk	6,877	107,006,120	2,556
	straw	35,581	551,861,310	13,181
Corn	corncob	807.31	13,425,565	321
Oil palm	palm cluster	2,130.72	41,357,275	988
	fiber	1,389.6	27,708,624	662
	palm shell	555.84	11,744,899	281
	palm trunk	2,501.28	44,697,874	1,068
Cassava	cassava trunk	3,018.6	40,388,868	965
	rootstock	2,515.5	26,689,455	637
Rubber tree	sawdust	94.98	1,581,417	38
	wood bits	316.6	5,334,710	127
Eucalyptus	firewood	1,360	22,916,000	547
	bark	680	11,764,000	281
Wood from plantation	wood bits	600	10,110,000	241
	TOTAL	**98,118.97**	**1,563,674,221**	**37,348**

daily capacity of 1.62 million liters are to be operated within 2010-2011 (DEDE, 2008a; 2010d).

Currently, molasses is used as the raw materials by 12 ethanol plants, cassava by 5 plants and cane sugar by 1 plant. DEDE had estimated the amount of molasses and cassava that would be potentially used for ethanol production in the year 2009 to 2011. For molasses, the estimated supply for ethanol production rises from 1.11 million tons in 2009 to the estimated 2.57 million tons in 2011. The amounts are respectively accounted for 0.76 and 1.76 million liters per day. For cassava, the surplus of 2.42 and 2.56 million tons, of which 1.12 and 1.19 million liters per day of ethanol could be produced from, has been estimated for 2009 and 2011. Shortage of cassava for ethanol production is expected in 2010 due to the drop in cassava production (DEDE, 2010c).

According to the 15-year alternative energy development plan (2008-2022), a policy was made to push ethanol production capacity to 9 million liters per day in 2022. This would result in insufficient supply of raw material (Ministry of Energy, 2008). The prediction is not far from reality as from 2009 to 2011, the projection of the raw materials for ethanol production has been estimated to be under supplied especially in the case of cassava where the plant capacity of 4.05 million liters per day would be nearly 3.5 times higher than the estimated cassava supplied for ethanol production (DEDE, 2010c).

Above reasons causing under supply of ethanol raw materials have invoked the plan for improvement in sugarcane and cassava productivities to served the already well established production processes. Another plan is to support the use of alternative plants for ethanol production (Ministry of Energy, 2008). Currently, sweet sorghum has been focused by many researchers in Thailand as an alternative raw material for ethanol production.

Strategy and Business Development Department of the Export-Import Bank of Thailand (EXIM) had made an article indicating cellulosic ethanol as new alternative in ethanol production. They based their opinion on the rising oil price that would lead to the risk of total dependency on fossil fuel. However, they pointed out high production cost as the main obstacle in cellulosic ethanol business as compared with the production from sugar- and starch-based ethanol (EXIM, 2007).

Although not clearly expressed as a material in focus, amount of biomass in Thailand has clearly demonstrated its potential to be used as an alternative raw material for ethanol production. One company, Thai Roong Ruang Ethanol, has found its collaboration with Japan in establishing the first and the only cellulosic ethanol plant in Thailand. The plant utilizes both molasses and bagasse as raw materials in its process.

Researches on various aspects of ethanol have attracted researchers in various academic and research institutes from across the economy. At least 141 research reports and graduate theses (year 1980 – 2010) have resulted from the search for ethanol related publications in the Research Library of National Research Council of Thailand (http://www.riclib.nrct.go.th). Most of the research involved the production by fermentation process.

Based on the search on BIODATA (http://biodata.trf.or.th), over 180 names have come up as the active researchers involving in ethanol-related research. Approximately half of the researchers focused their works on lignocellulosic materials or pentose sugars. Treatments of the biomass as raw materials for ethanol production were also in focus with main attentions given towards treatment of sugarcane bagasse, cassava waste and rice straw. It should be noted also that the data search did not include those who conduct their researches on enzymes that hydrolyzed the hemicellulosic and cellulosic parts of the biomass.

Researches involving the fermentation to produce ethanol from biomass have mostly utilized yeast, both xylose-utilizing strains and the common *Saccharomyces cerevisiae* in ethanol conversion process. Fewer have focused on the use of the bacteria, *Zymomonas mobilis*. In term of the raw materials, the biomass mostly in attention has been cassava waste, peels and pulps. Owing to the starch residues in the biomass, ethanol production from these cassava's fractions was usually relatively high as compared to the use of actual hemicellulosic or cellulosic fractions (Table 3).

Most of the researches on lignocellulosic or cellulosic ethanol in Thailand have involved, at some stage, the hydrolysis of the raw materials. For those that focused on ethanol production, interests were made into the cellulosic fraction as could be noticed from the examples of research works (Table 3) that the organisms employed were mostly *Saccharomyces cerevisiae* or *Zymomonas mobilis*. A few researches have focused on the hemicellulosic part, which contained mainly xylose, and the organisms of choice have included those in *Candida* spp., *Pichia stipitis* and *Kluyveromyces* sp., which could assimilate xylose and are known ethanol producers. Genetic improvements of microorganisms for improved ethanol production, both in terms of productivity and range of substrates utilized, have been of interest to many of Thai researchers. However, available research information and results are still limited.

4 BIODIESEL PRODUCTION IN THAILAND

Currently, total of 14 companies (15 plants) in Thailand obtain the permit to produce biodiesel. However, the total capacity of 5.908 million liters per day has not yet been reached. The current figure in January 2010 is only 1.89 liters per day (DOEB, 2010; DEDE 2010e).

The information in Table 4 indicated the increasing demand for biodiesel (B100) with the large increase in 2008. The demand for B100 in 2009 exceeded the production capacity of 560.42 million liters in that year and also exceeded the predicted demand. The trend continues in 2010 when the B100 used in the blending for B2 and B5 has already exceeded the production by 41% in February.

This increasing demand in biodiesel forced the demand in raw materials for its production. The main raw material for biodiesel production in Thailand[1] is palm stearin, which accounted for 49% of the raw materials used. Other raw materials include refined bleached deodorized palm oil (RBDPO) at 27%, crude palm oil (CPO) at 22% and the remaining 2% is used cooking oil.

[1] Based on the main raw material used by the registered plants and their daily production capacity.

Table 3 Summary of ethanol production results from researches involving ethanol from biomass[#]

Raw materials /substrate	Microorganism	Ethanol (g/l)	Reference
Cassava risome	*Z. mobilis* TISTR 405	10.6	Kingsuwannarut, 2002
Cassava peels	*S. cerevisiae*	5.54	Yoonan et al., 2005
Cassava peels	*S. cerevisiae*	4.53	Yoonan et al., 2007
Cassava waste	*S. cerevisiae* TISTR 5596	36.2	Srinorakutara et al., 2006
Cassava waste	*S. cerevisiae*	7.12	Kongkiattikajorn, 2004
Cassava solid waste	*S. cerevisiae* TISTR 5596	36.2	Suesat et al., 2004
Cassava peels & waste	*S. cerevisiae* & *C. tropicalis*	0.7	Yowapouy, 2007
Cassava peels & waste	*S. cerevisiae* TISTR 5343	18.64	Eksomthramate, 2008
Cassava pulp	*S. cerevisiae* TISTR 5049	2.28	Kongkiattikajorn & Yoonan, 2004
Cassava pulp	*Candida tropicalis* BCC7755	14.3	Rattanachomsri et al., 2009
Rice straw	*S. cerevisiae* TISTR 5013	10.26	Klaewkla, 1994
Paper mulberry	*C. krusei* NBRC 1664	10.86	Pumira, 2005
Weeds	*Kluyveromyces marxianus* NRRL Y-1109	0.26	Yimyong, 2004
Sunflower stalk	*S. cerevisiae*	0.016	Vaithanomsat et al., 2009
Sweet sorghum bagasse	*S. cerevisiae* TISTR 5048	1.42	Thanonkeo et al., 2005
Corncob	*Z. mobilis*	3.95	Junkaew et al., 2008
Saw dusts	*Z. mobilis*	1.74	Junkaew et al., 2008
Sugars: xylose/glucose	*S. cerevisiae* 5019 & *C. tropicalis* 5045	7.32	Rodmui, 2003
Xylose	*Pichia stipitis* CBS 5773	15.1	Limtong et.al., 2000
Xylose	*C. shehatae*	14	Limtong et.al., 2000
Xylose	*C. shehatae* TISTR5843	8.17	Boonmee et al., 2007

[#] Only those with the online searchable contents. Ethanol reported resulted from different hydrolysis methods, different amount used and different fermentation techniques.

Table 4 Comparison of biodiesel demands and production (million liters)

Year	Production[*]	B100 used for B2 and B5[**]	Predicted demand[***]
2005	-	0.27	-
2006	-	2.15	-
2007	67.77	62.12	-
2008	447.52	445.18	492
2009	560.42	609.34	492
2010	58.65[#]	99.95[#]	492
2011	-	-	1,121
2012	-	-	1,167

[#] Data at February 2010
[*] Biodiesel production reported by DEDE (2010e)
[**] B100 Demand for B2 and B5 Biodiesel Blends reported by DEDE (2010a)
[***] Demand, Supply and Raw Material for Biodiesel Production from Crude Palm Oil (DEDE, 2008b)

As palm is the major provider of the raw materials for biodiesel industry, its production is expected to also rise to avoid excessive import. However over the past 3 years from 2007-2009, the production of oil palm did not show the correlated trend. The palm production increased 31% from approximately 6.39 million tons in 2007 to 9.26 million tons in 2008. The production then dropped slightly to 8.32 million tons in 2009 (OAE, 2009). Attention has therefore been turned into security in availability of raw material for biodiesel production. The alternative raw materials to palm oil, which are in interest, include Jatropha oil and microalgae oil.

Researches involving biodiesel production in Thailand are widely conducted. In term of research in production context, the information based from BIODATA and Thailand Digital Collection (TDC) indicated that palm oil, used cooking oil and Jatropha oil are the most widely investigated raw materials. However, increasing interest into the use of oils from microalgae and oleaginous yeast are evident.

Although biomass does not seem to fit with the production of biodiesel, its use could be found in the production of microalgae and yeast, which are the alternative sources for oil as the biodiesel raw materials. Microalgae are generally perceived as a photoautotrophic but some strains could be cultivated in heterotrophic environment with no light and using organic carbon for growth. Claim was made that microalgae grown in heterotrophic environment could accumulate the oil as high as 4 times as compared to cultivation in photo-autotrophic environment (Leesing, 2007). Similarly, cultivation of oleaginous yeast could also be achieved using the organic carbons obtained from hydrolysis of biomass from agricultural and agro-industrial sections.

5 RESEARCHES IN BIO-HYDROGEN PRODUCTION

Although the use of hydrogen as an energy source is not yet active in Thailand, the researches on production of hydrogen especially via biological systems have caught attention of some research groups. Utilizing wastewater from various agro-industrial sources as the carbon source for microorganisms used in bio-hydrogen production has been a common practice for many Thai researchers as it also double acted as a mean in wastewater treatment. Increasing interest in utilizing agricultural wastes (biomass) in bio-hydrogen production has also evident. The biomasses of interest have been bagasse and oil palm fiber.

6 CONCLUSION

Although biomasses such as rice husk and sugarcane bagasse have already been utilized in industries to provide direct heat or in electricity generation, there is still large amount of biomass that is not being used. These also include the biomass from other crops or trees. Biomasses have caught attention of many researchers as alternative raw materials for production of biofuels, especially ethanol. In the future, the use of biomass for production of biofuel would be a mean to relieve the lack or under supply of the raw materials to Thai ethanol industry, which now relies heavily on cassava and molasses. Production of other biofuels such as biodiesel and bio-hydrogen could also use biomass as the source for carbon in the production process by microorganisms. Even though it has not yet been in practice, such researches have been actively carried out in Thailand.

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[2] All references are in Thai unless otherwise stated.

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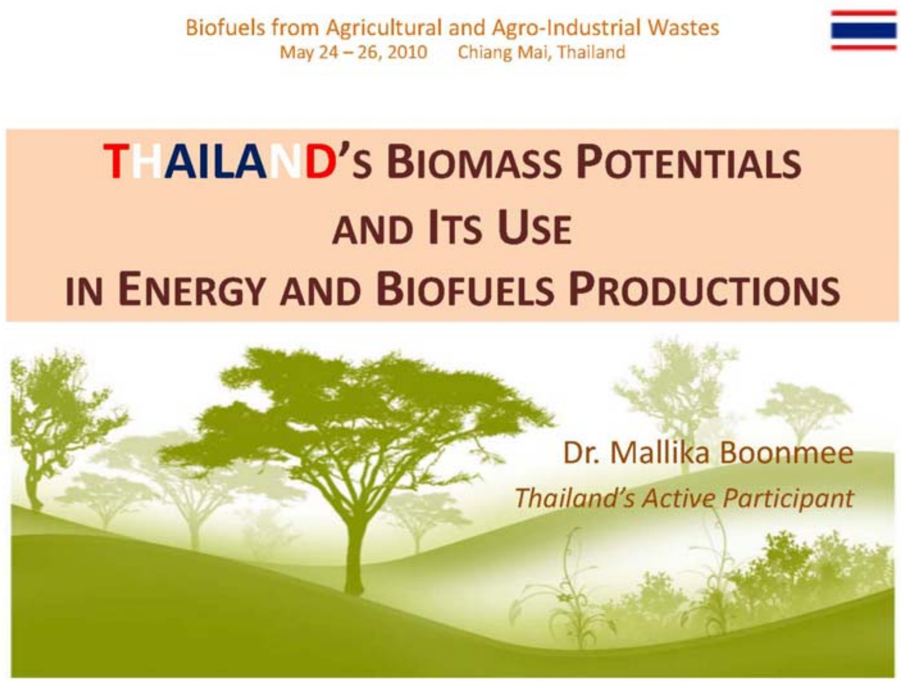
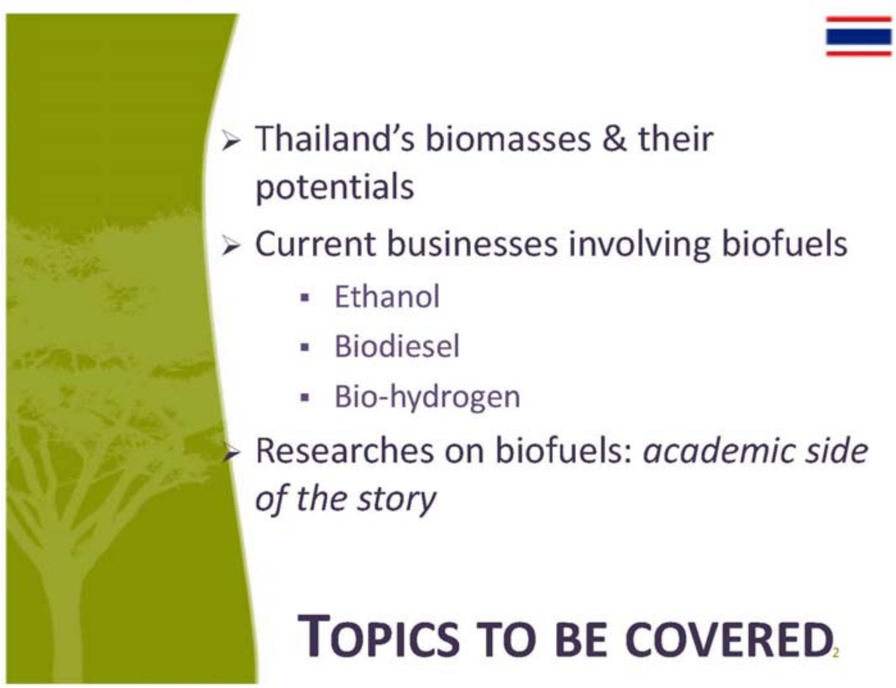
Session IV: Active participant (Thailand); Assistant Professor Dr. Mallika Boonmee





BIOMASS

- Could be converted into a form of energy
  - By-products or waste from agriculture
  - Wood chip waste from wood industry
  - Animal manures
  - Waste from agricultural products processing plants
  - Community wastes

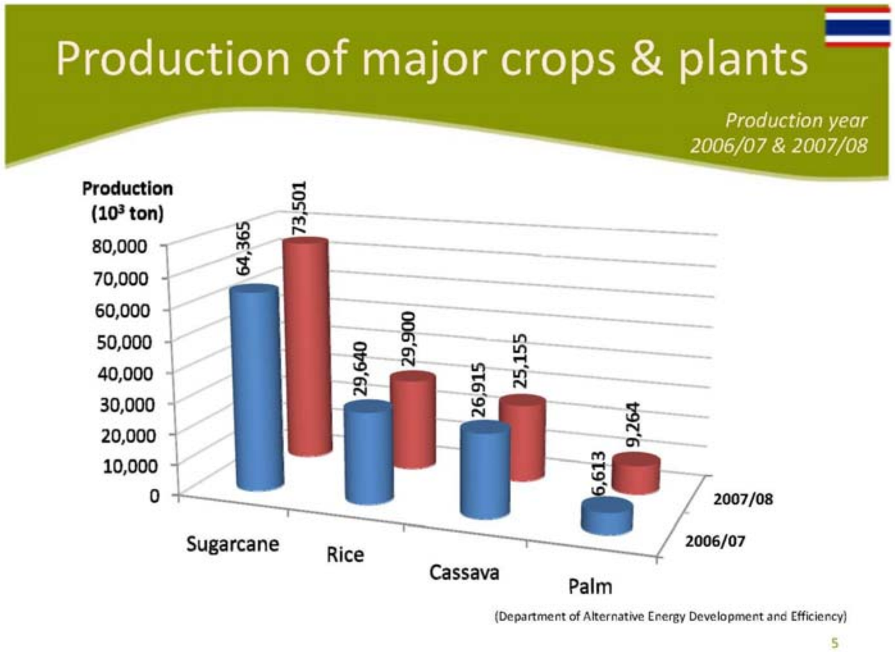
3

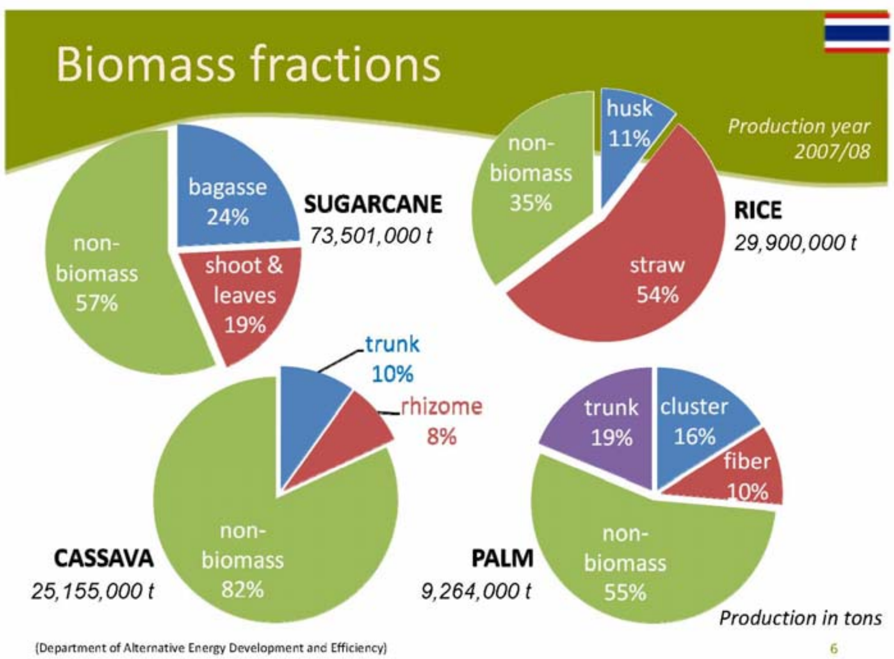
THAILAND'S BIOMASSES

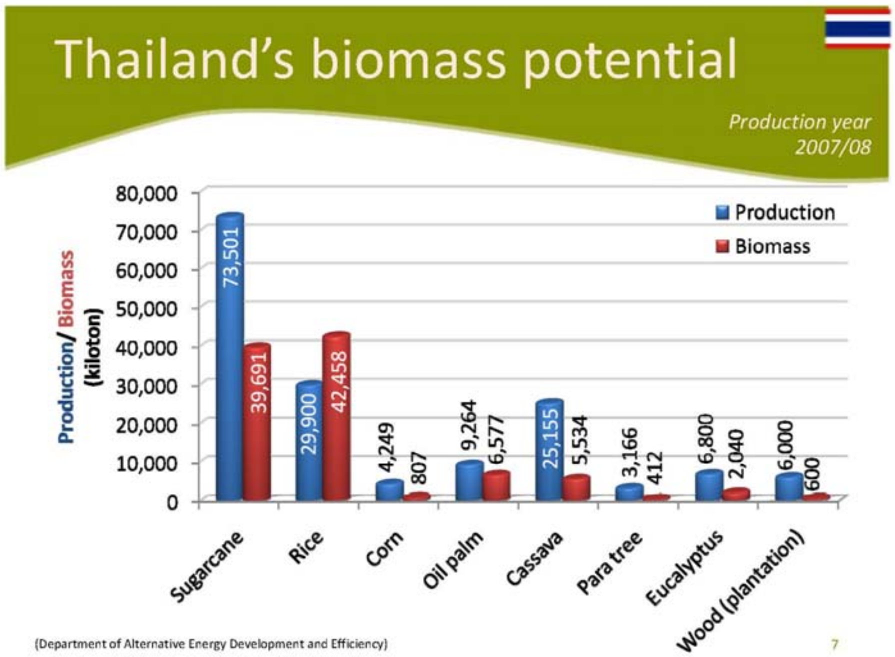
9 potentials

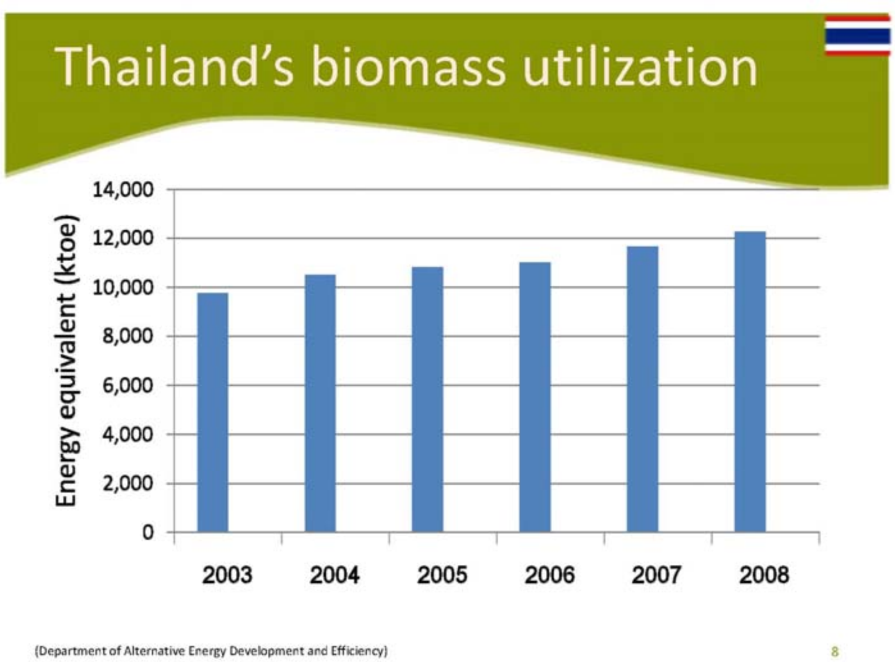
already in use

4

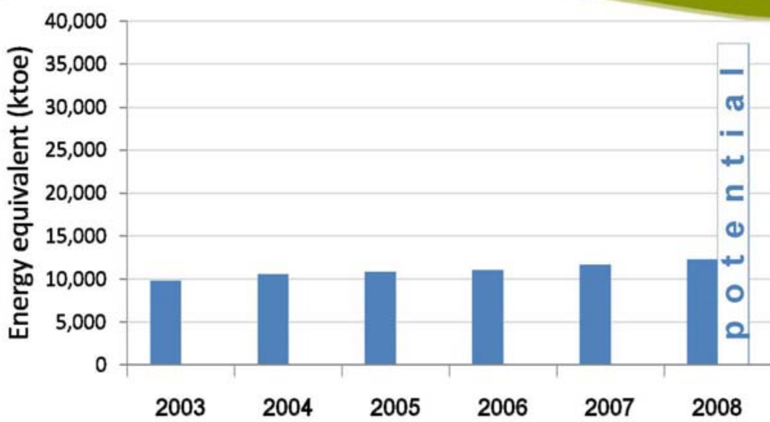

Production of major crops & plants
Production year
2006/07 & 2007/08
Production
(10³ ton)
80,000
70,000
60,000
50,000
40,000
30,000
20,000
10,000
0
64,365
73,501
29,640
29,900
26,915
25,155
6,613
9,264
2007/08
2006/07
Sugarcane
Rice
Cassava
Palm
(Department of Alternative Energy Development and Efficiency)
5


Biomass fractions
Production year
2007/08
bagasse
24%
shoot &
leaves
19%
non-
biomass
57%
SUGARCANE
73,501,000 t
husk
11%
straw
54%
non-
biomass
35%
RICE
29,900,000 t
trunk
10%
rhizome
8%
non-
biomass
82%
CASSAVA
25,155,000 t
trunk
19%
cluster
16%
fiber
10%
non-
biomass
55%
PALM
9,264,000 t
Production in tons
(Department of Alternative Energy Development and Efficiency)
6


Thailand's biomass potential
Production year
2007/08
80,000
70,000
60,000
50,000
40,000
30,000
20,000
10,000
0
Production/ Biomass
(kiloton)
Production
Biomass
73,501
39,691
29,900
42,458
4,249
807
9,264
6,577
25,155
5,534
3,166
412
6,800
2,040
6,000
600
Sugarcane
Rice
Corn
Oil palm
Cassava
Para tree
Eucalyptus
Wood (plantation)
(Department of Alternative Energy Development and Efficiency)
7


Thailand's biomass utilization
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
Energy equivalent (ktoe)
2003
2004
2005
2006
2007
2008
(Department of Alternative Energy Development and Efficiency)
8

Thailand's biomass utilization



(Department of Alternative Energy Development and Efficiency)

9

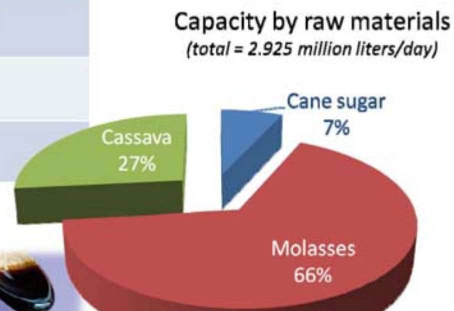
ETHANOL PRODUCTION: THAILAND

- Permission to produce and distribute ethanol as fuel in 2006
- 47 plants with permission (Mar 2010)
  - Total capacity = 12.295 million liters / day
- 19 plants currently in operation
  - Total daily capacity = 2.925 million liters
  - 4 more plants to be operated within 2010-2011
  - Extra daily capacity = 1.62 million liters

10

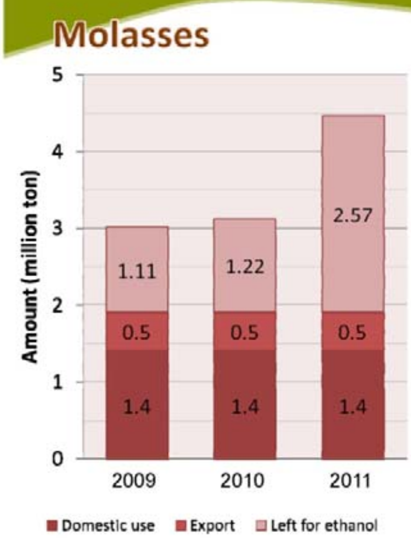
Raw materials

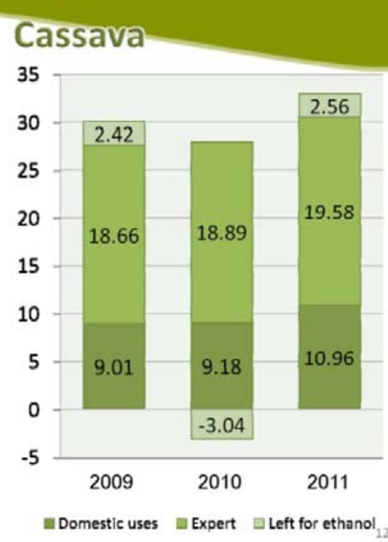
Raw materials	No. of plants
Molasses	12
Cassava	5
Cane sugar	1



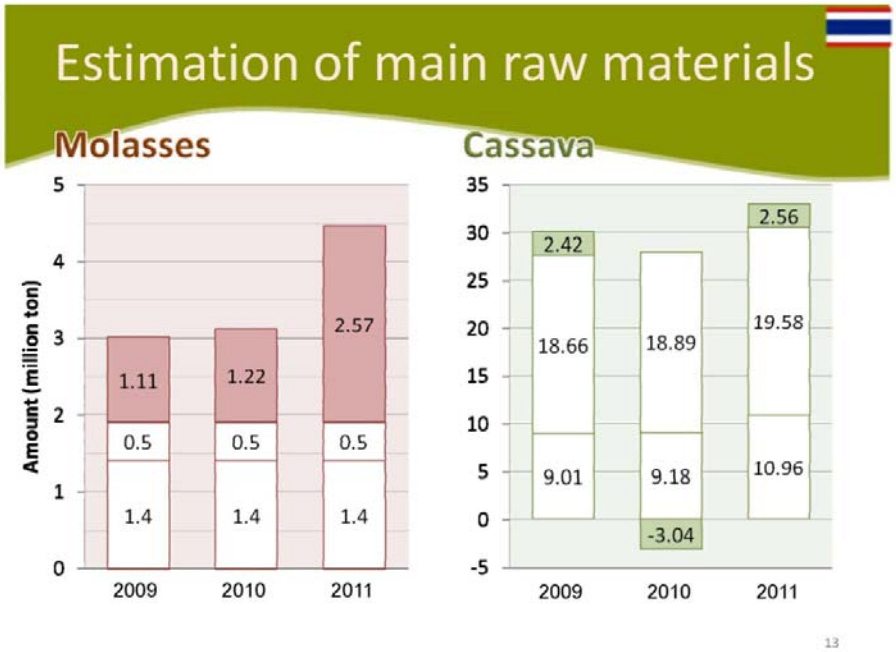
11

Estimation of main raw materials

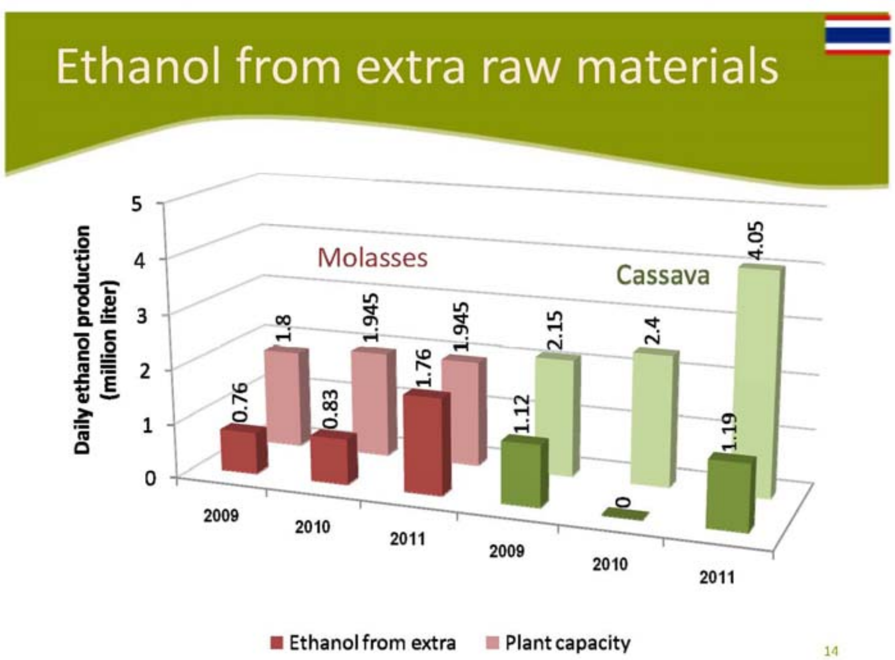




12



Estimation of main raw materials
Molasses
Cassava
Amount (million ton)
1.4
0.5
1.11
1.22
2.57
2009
2010
2011
9.01
18.66
2.42
9.18
18.89
-3.04
10.96
19.58
2.56
13



Ethanol from extra raw materials
Daily ethanol production (million liter)
Molasses
Cassava
0.76
1.8
0.83
1.945
1.76
1.945
1.12
2.15
0
2.4
1.19
4.05
2009
2010
2011
2009
2010
2011
Ethanol from extra
Plant capacity
14

- In 2022: increase daily ethanol production capacity to **9 million liters**
  - 15-year alternative energy development plan (2008-2022)
- Plan to accommodate short supply of raw materials (technical)
  - Improvement of ***sugarcane and cassava productivities***
  - ***Alternative plants*** for ethanol production

15

LIGNOCELLULOSIC MATERIALS

Availability

VS

current utilization

- **High production cost**
- **Production efficiency**

16

RESEARCH ON ETHANOL IN THAILAND

- Substrates of interest
  - Cassava and its residues
  - Sugarcane juice
  - Sweet sorghum juice
  - LIGNOCELLULOSE from various biomasses

17

Popular biomasses used in research on ethanol production

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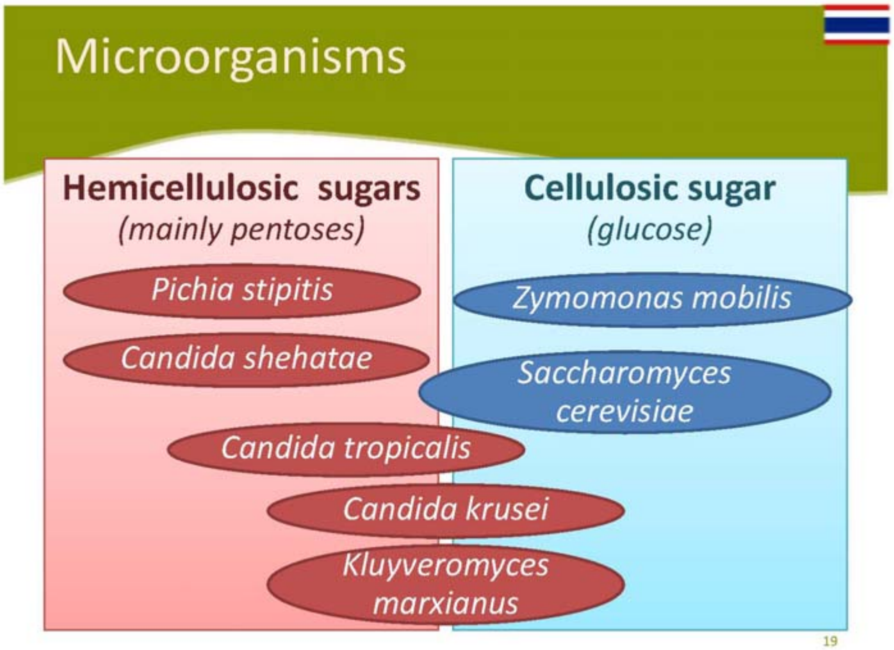

Research: *biomass substrates*

Substrate	Microorganism	Ethanol (g/l)	Reference
Cassava waste	*S. cerevisiae* TISTR 5596	36.2	Srinorakutara et al., 2006
Cassava peels & waste	*S. cerevisiae* TISTR 5343	18.64	Eksomthramate, 2008
Cassava pulp	*C. tropicalis* BCC7755	14.3	Rattanachomsri et al., 2009
Cassava rhizome	*Z. mobilis* TISTR 405	10.6	Kingsuwannarut, 2002
Rice straw	*S. cerevisiae* TISTR 5013	10.26	Klaewkla, 1994
Paper mulberry	*C. krusei* NBRC 1664	10.86	Pumira, 2005
Corncob	*Z. mobilis*	3.95	Junkaew et al., 2008

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Research: *pure sugars*

Substrate	Microorganism	Ethanol (g/l)	Reference
Xylose	*Pichia stipitis* CBS 5773	15.1	Limtong et.al., 2000
Xylose	*C. shehatae*	14	Limtong et.al., 2000
Xylose	*C. shehatae* TISTR5843	8.17	Boonmee et al., 2007
Xylose/glucose	*S. cerevisiae* 5019 & *C. tropicalis* 5045	7.32	Rodmui, 2003

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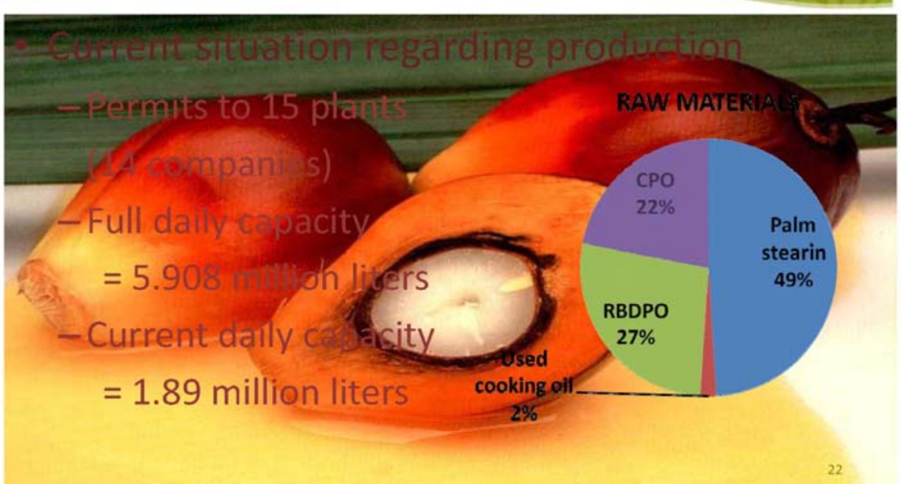
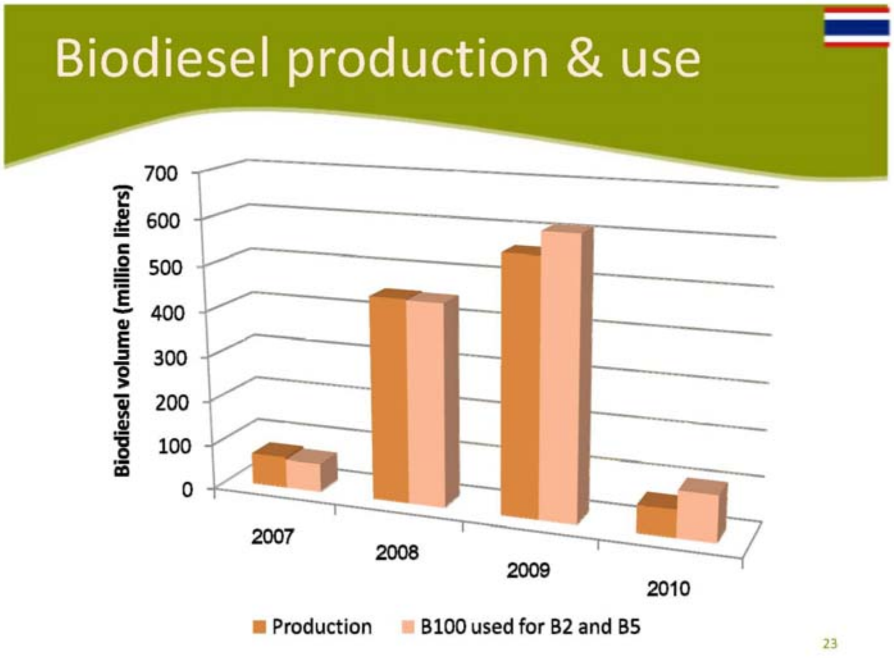
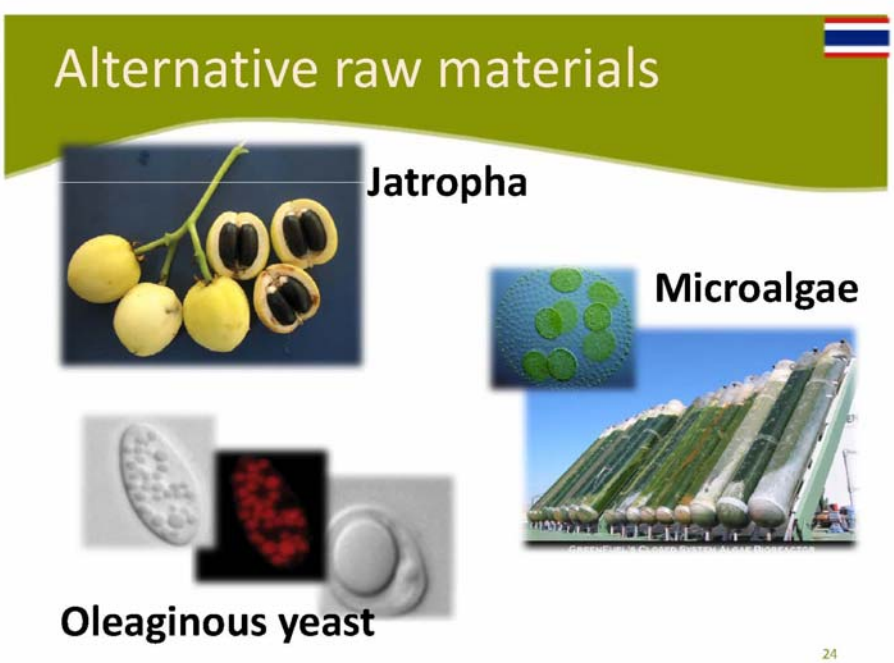
BIODIESEL PRODUCTION: THAILAND




Biodiesel production & use
700
600
500
400
300
200
100
0
Biodiesel volume (million liters)
2007
2008
2009
2010
Production
B100 used for B2 and B5
23


Alternative raw materials
Jatropha
Microalgae
Oleaginous yeast
24

BIO-HYDROGEN PRODUCTION

- Early experimental stage
- Substrates
  - Agro-industrial wastewater e.g. cassava wastewater
  - Pure sugars
  - Sugar-/starch- based substrates
- More interest in using lignocellulosic materials as sources for sugars.

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Session V

Asia-Pacific
Economic Cooperation

International APEC Symposium on
"Biofuels from Agricultural and Agro-Industrial Wastes"
May 24th – 27th, 2010, Chiang Mai, Thailand

STUDY ON ALGAE AS ENERGY SOURCE AT DEPARTMENT OF MECHANICAL ENGINEERING, CHIANG MAI UNIVERSITY

Tanongkiat Kiatsiriroat

Department of Mechanical Engineering, Faculty of Engineering,
Chiang Mai University, Chiang Mai 50200, Thailand

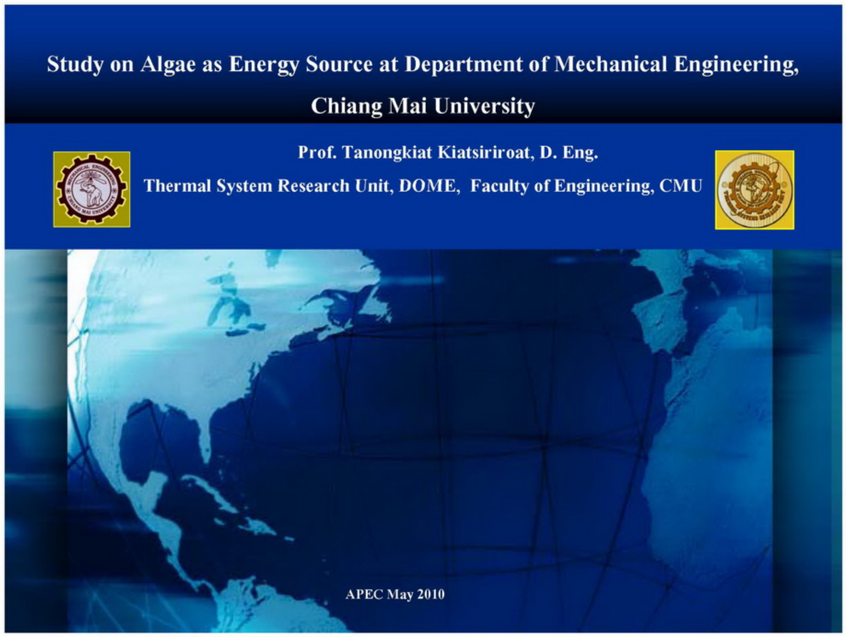
ABSTRACT

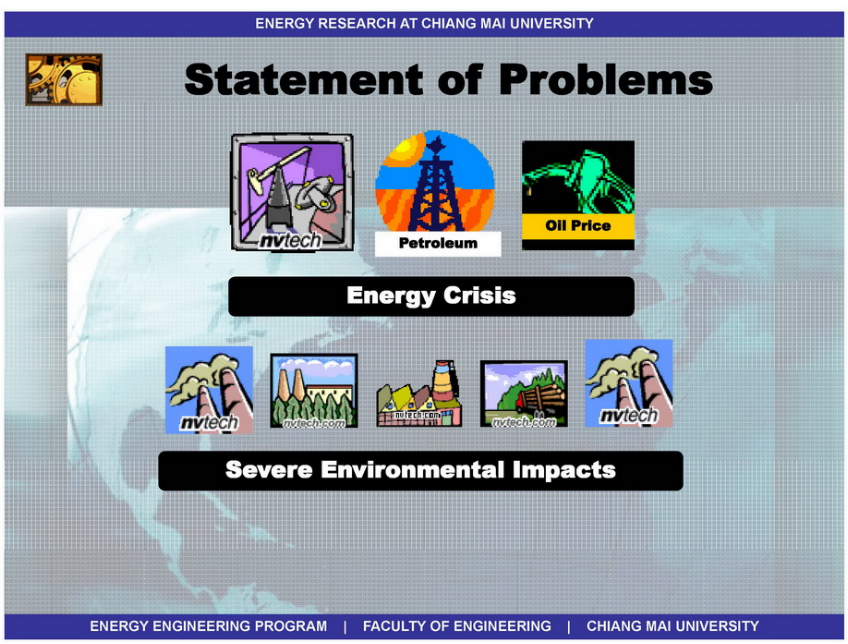
Algae could be taken as an alternative energy source because it could capture CO_2 for its growth and some types have high content of fatty acid. Moreover, algae has high growth rate and it could be harvested in a shorter period compared with other energy plants such as fast rotation tree or palm tree, etc.

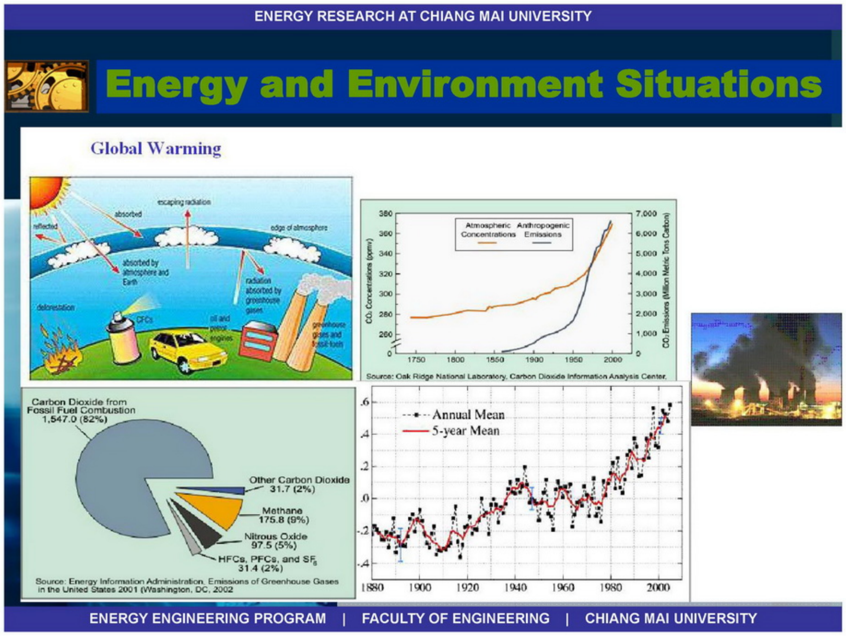
The research on algae as bio-energy source has been carried out into two parts. The first one is to study the growth rate of Chlorella when it is open-type feeding on vertical wall. This technique will use small area of horizontal plane and algae could capture CO_2 directly from the environment. If algae farming is installed, it could generate cooling to the environment. The second part is to find out bio-oil and bio-char yielded from some types of algae in Thailand under pyrolysis process. The bio-oil qualities are close to heavy oil and diesel oil and the bio-chars from algae have similar fuel characteristics with solid fossil fuels and those from other biomass under pyrolysis process at the same range of operating temperature.

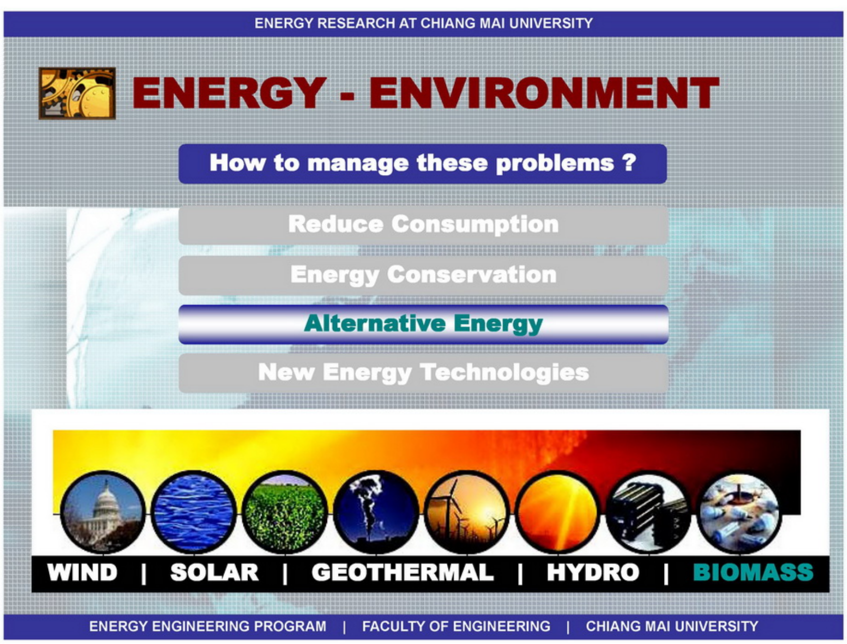
Bio-chars from algae after pyrolysis have high percentage of carbon content, therefore, this technique has a high potential to capture CO_2 from atmosphere in a form of carbon and this could be kept into the ground.

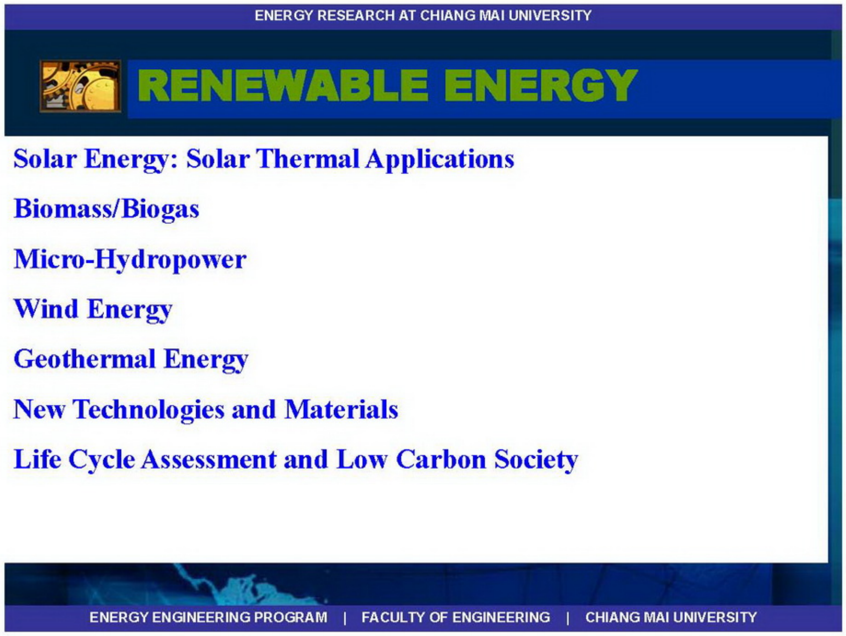
Session V: Keynote speaker (Thailand); Professor Dr. Tanongkiat Kiatsiriroat

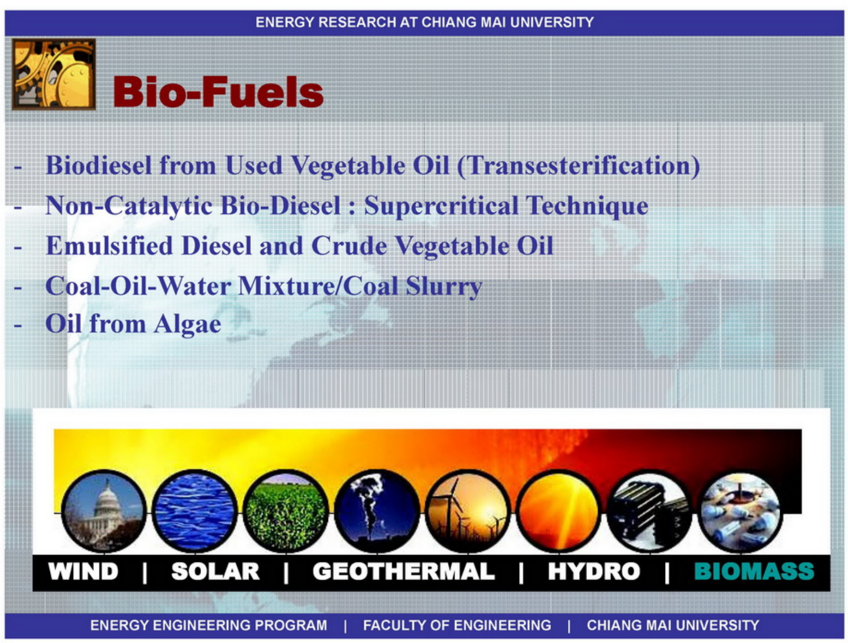


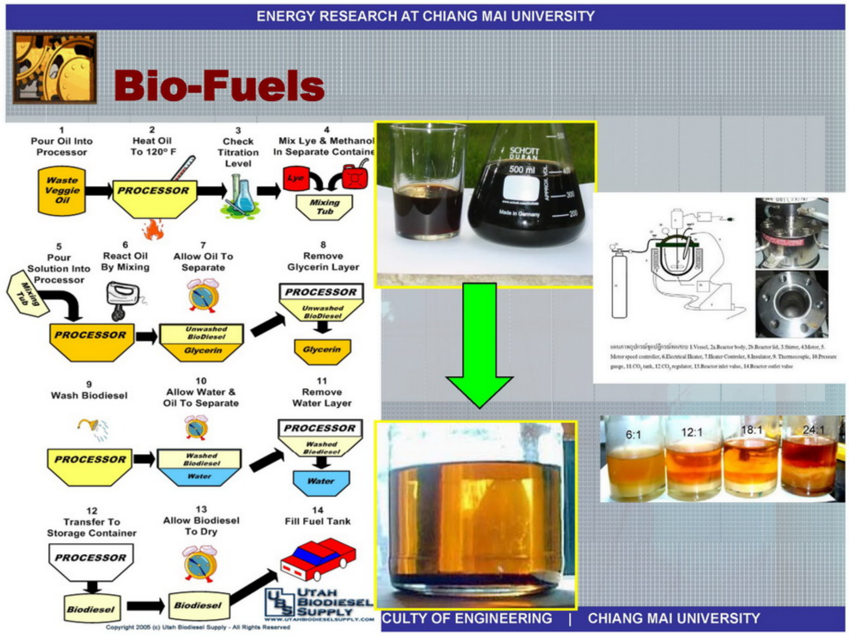


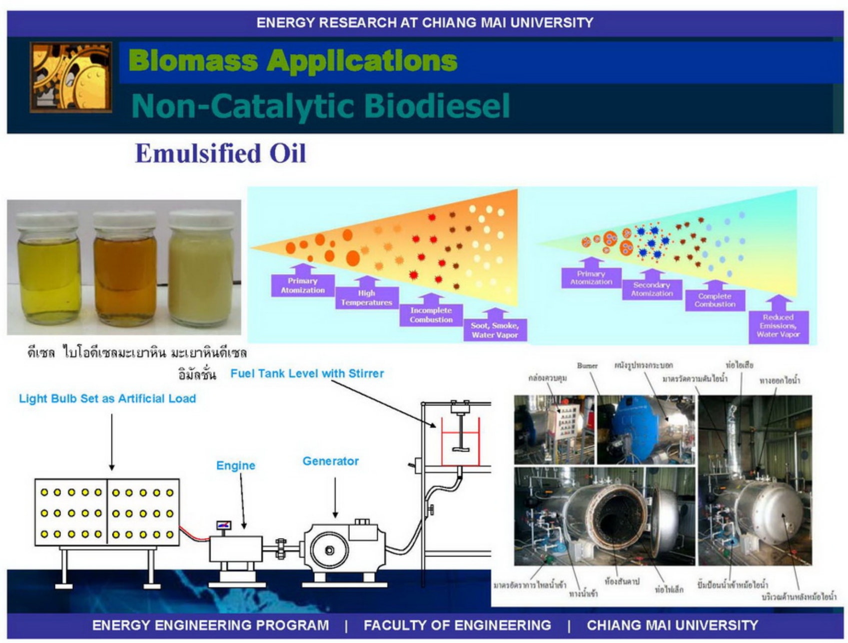

ENERGY RESEARCH AT CHIANG MAI UNIVERSITY
Energy and Environment Situations
Global Warming
Carbon Dioxide from Fossil Fuel Combustion 1,547.0 (82%)
Other Carbon Dioxide 31.7 (2%)
Methane 175.8 (9%)
Nitrous Oxide 97.5 (5%)
HFCs, PFCs, and SF6 31.4 (2%)
Annual Mean
5-year Mean
ENERGY ENGINEERING PROGRAM | FACULTY OF ENGINEERING | CHIANG MAI UNIVERSITY


ENERGY RESEARCH AT CHIANG MAI UNIVERSITY
ENERGY - ENVIRONMENT
How to manage these problems ?
Reduce Consumption
Energy Conservation
Alternative Energy
New Energy Technologies
WIND | SOLAR | GEOTHERMAL | HYDRO | BIOMASS
ENERGY ENGINEERING PROGRAM | FACULTY OF ENGINEERING | CHIANG MAI UNIVERSITY


ENERGY RESEARCH AT CHIANG MAI UNIVERSITY
RENEWABLE ENERGY
Solar Energy: Solar Thermal Applications
Biomass/Biogas
Micro-Hydropower
Wind Energy
Geothermal Energy
New Technologies and Materials
Life Cycle Assessment and Low Carbon Society
ENERGY ENGINEERING PROGRAM | FACULTY OF ENGINEERING | CHIANG MAI UNIVERSITY


ENERGY RESEARCH AT CHIANG MAI UNIVERSITY
Bio-Fuels
- Biodiesel from Used Vegetable Oil (Transesterification)
- Non-Catalytic Bio-Diesel : Supercritical Technique
- Emulsified Diesel and Crude Vegetable Oil
- Coal-Oil-Water Mixture/Coal Slurry
- Oil from Algae
WIND | SOLAR | GEOTHERMAL | HYDRO | BIOMASS
ENERGY ENGINEERING PROGRAM | FACULTY OF ENGINEERING | CHIANG MAI UNIVERSITY


ENERGY RESEARCH AT CHIANG MAI UNIVERSITY
Bio-Fuels
1 Pour Oil Into Processor
2 Heat Oil To 120° F
3 Check Titration Level
4 Mix Lye & Methanol In Separate Container
Waste Veggie Oil
PROCESSOR
Lye
Mixing Tub
5 Pour Solution Into Processor
6 React Oil By Mixing
7 Allow Oil To Separate
8 Remove Glycerin Layer
Mixing Tub
PROCESSOR
Unwashed BioDiesel
Glycerin
9 Wash Biodiesel
10 Allow Water & Oil To Separate
11 Remove Water Layer
Washed Biodiesel
Water
12 Transfer To Storage Container
13 Allow Biodiesel To Dry
14 Fill Fuel Tank
Biodiesel
UTAH BIODIESEL SUPPLY
Copyright 2005 (c) Utah Biodiesel Supply - All Rights Reserved
6:1
12:1
18:1
24:1
CULTY OF ENGINEERING | CHIANG MAI UNIVERSITY


ENERGY RESEARCH AT CHIANG MAI UNIVERSITY
Biomass Applications
Non-Catalytic Biodiesel
Emulsified Oil
Primary Atomization
High Temperatures
Incomplete Combustion
Soot, Smoke, Water Vapor
Primary Atomization
Secondary Atomization
Complete Combustion
Reduced Emissions, Water Vapor
ดีเซล ไบโอดีเซลมะเยาหิน มะเยาหินดีเซลอิมัลชั่น
Fuel Tank Level with Stirrer
Light Bulb Set as Artificial Load
Engine
Generator
Burner
กล่องควบคุม
ท่อไอเสีย
ทางออกไอน้ำ
ห้องสันดาป
ท่อไฟเล็ก
ทางน้ำเข้า
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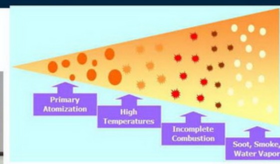
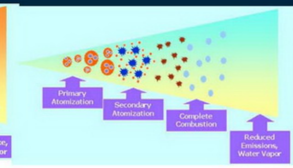
ENERGY RESEARCH AT CHIANG MAI UNIVERSITY

Biomass Applications

Non-Catalytic Biodiesel : Emulsified Oil

ดีเซล ไบโอดีเซลมะเยาหิน มะเยาหินดีเซล
อิมัลชั่น





Oil	HHV (kJ/kg)	Density (kg/m^3)	Viscosity (Cst.)
Diesel	46,420	826	3.433
BioDiesel(Tung Oil)	38,733	900	8.121
Diesel/TungOil Emulsion	41,171	830	4.840

ค่าการทดลอง	Diesel	Biodiesel	Emulsified Oil
Fuel Rate (m_f), cm^3/s	2.39	3.316	2.61
Steam Rate, kg/s	0.023	0.0221	0.0227
Gas Temperature T_g °C	217	220	208
Percentage of O_2, %	4.12	4.07	4.01
Percentage of CO_2, %	12.46	12.50	12.54
Amount of CO, ppm	2	129	1
Amount of NO_x, ppm	77	73	65
Amount of SO_2, ppm	5	1	1

Boiler

Fuel	Boiler Efficiency
Diesel	69.00 %
Biodiesel	62.28 %
Emulsified Oil	66.94 %

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Algae as Alternative Energy Source

Why Algae could be taken as an Alternative Energy Source

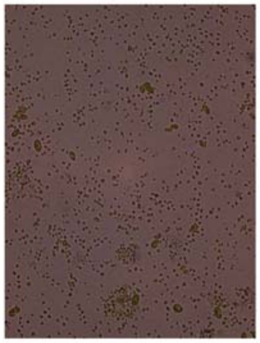
1. Algae could capture CO2 for its growth and some types have high content of fatty acid.
2. Algae has high growth rate and it could be harvested in a shorter period compared with other energy plants such as fast rotation tree or palm tree, etc.

- 1 acre could get algae 80 kg/d which yields oil 28 lit/d which is 4 times of oil from palm tree and 12 times of that from jatropha.
- CO2 could be captured 44 kg/d.
[http://www.eng.chula.ac.th/newsletter/index.php?q=node/118]

Algae Feeding

Algae Feeding on Vertical wall

1. Use small area of horizontal plane.
2. Algae could capture CO2 from the environment.
3. Algae farm could generate cooling to the environment.



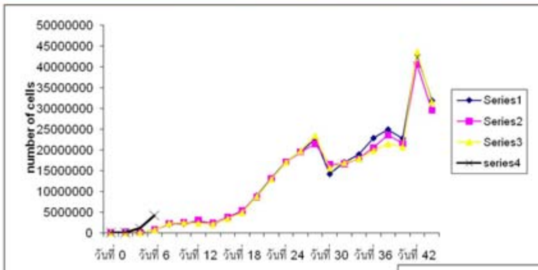
Chlorella Spp

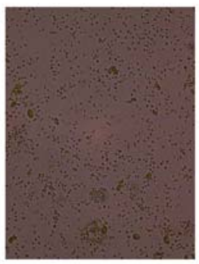
Algae to Fuel Oil

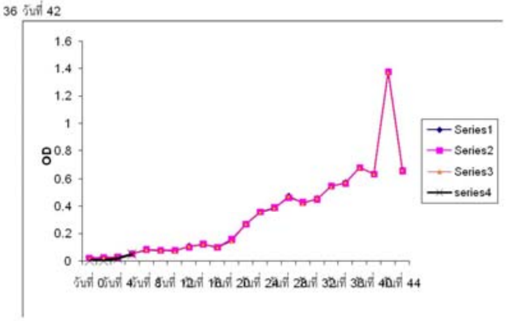
6 Days Operation

30 Days Operation

Algae to Fuel Oil



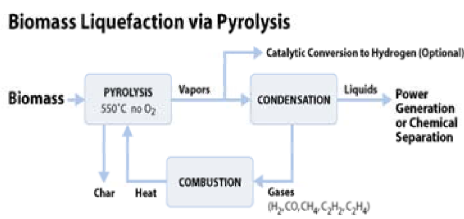


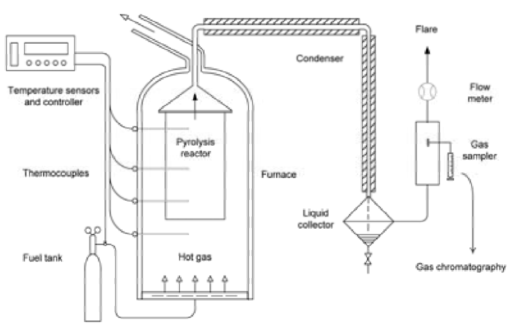


Algae to Fuel Oil

Pyrolysis of Algae

1. Slow Pyrolysis
2. Fast Pyrolysis



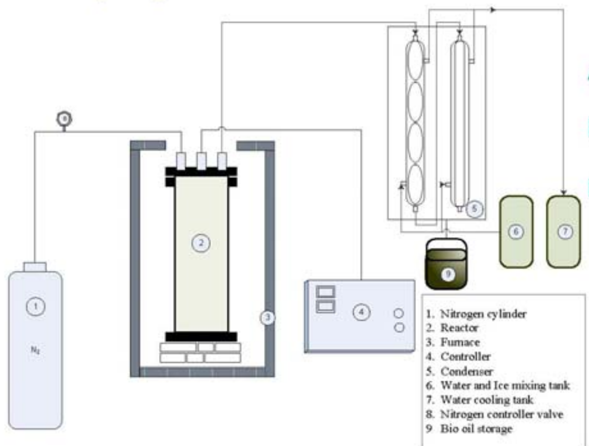


Yields:
fuel gas/liquid
and solid char

Algae to Fuel Oil

Pyrolysis of Algae

Slow Pyrolysis



Amount of algae:
125 g/batch
Rate of Carrier Gas:
(N_2) 30 ml/min
Heating Rate: 8 °C/min

Algae to Fuel Oil

Pyrolysis of Algae

Slow Pyrolysis

Spirulina spp

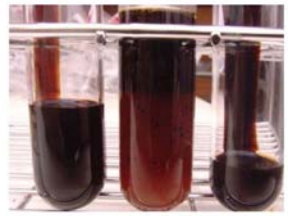
Sprogyra spp (ไก)

Cladophora spp (เทา)

Algae to Fuel Oil

Pyrolysis of Algae

Slow Pyrolysis



Spirulina spp

Sprogyra spp (ไก)

Cladophora spp (เทา)

Algae to Fuel Oil

Reaction products, wt%	Temperature (°C)			
	450	500	550	600
Gas (G)a	26	25	23	27
Liquid (L)	43	43	46	41
Bio-oil	19	20	21	16
Solid residue(R)	32	32	31	31

[a] G = 100 - (L + R).

Reaction products	Product distributions (wt%)		
	Spirulina spp	*Sprogyra Spp*	*Cladophora spp*
Gas (G)a	23	29	44
Liquid (L)	46	43	29
Solid residue(R)	31	28	27

[a] G = 100 - (L + R).

Algae to Fuel Oil

Chemical class compositions of bio-oils from slow pyrolysis of *Spyrulina* at 550°C

Data	formular	% area	MW
Toluene	C_7H_8	52.99	92.06
Ethylbenzene	C_8H_{10}	6.08	106.17
Indole	C_8H_7N	8.67	117.06
Hepeadecane	$C_{17}H_{36}$	32.26	240.28

Proximate and Ultimate Analyses of Algae Bio-Char compared with other solid fuels

Name	Fixed Carbon %	Volatiles %	Ash %	S %	HHV (kJ/g)	C %	H %	O %	N %
Coal - Pittsburgh Seam	55.80	33.90	10.30	3.10	31.75	75.50	5.00	4.90	1.20
Peat (S-H3)	26.87	70.13	3.00	0.11	22.00	54.81	5.38	35.81	0.89
Charcoal	89.31	93.88	1.02	1.00	34.39	92.04	2.45	2.96	0.53
Oak char (565°C)	55.60	27.10	17.30	0.10	23.05	64.60	2.10	15.50	0.40
Casuarina Char (950°C)	71.53	15.23	13.24	0.00	27.12	77.54	0.93	5.62	2.67
Coconut Shell Char (750°C)	87.17	9393.00	2.90	0.00	31.12	88.95	0.73	6.04	1.38
Eucalyptus char (950°C)	70.32	19.22	10.45	0.00	27.60	76.10	1.33	11.10	1.02
* Spirulina char(550°C)	44.50	7.03	47.82	0.07	15.78	45.26	1.24	0.28	2.57
* Sprogyra char(550°C)	26.68	35.50	37.81	1.68	16.68	51.14	0.56	0.69	1.98
* Cladophora char(550°C)	59.66	16.81	23.53	0.53	22.96	62.37	0.37	4.07	2.11

Bio-chars from algae have similar fuel characteristics with solid fossil fuels and those from other biomass under pyrolysis process at the same range of operating temperature.

Bio-char from algae has a percentage of carbon content over 50 %, therefore, this technique has a high potential to capture carbon in CO2 from atmosphere and the carbon could be kept in the ground.

Algae to Fuel Oil

Conclusion

- Outdoor feeding of algae is possible.
- Harvesting of algae could be performed in a short period of time ~ 30 days.
- Bio-oil from algae under pyrolysis has a quality between heavy oil and diesel oil.
- Bio-char from algae has a percentage of carbon content over 50 %, therefore, this technique has a high potential to capture carbon in CO2 from atmosphere and the carbon could be kept in the ground.

THE END
จบการนำเสนอ
Thank You for Your Kind Attention
For more information, please contact
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Thermal System Research Unit
Department of Mechanical Engineering
Faculty of Engineering, Chiang Mai University,
Chiang Mai 50200, THAILAND
Tel.053-944144, 944146 Fax 053-944145
E-MAIL
tanong@dome.eng.cmu.ac.th
หน่วยวิจัยระบบทางอุณหภาพ | ภาควิชาวิศวกรรมเครื่องกล | คณะวิศวกรรมศาสตร์ | มหาวิทยาลัยเชียงใหม่

Appendix
Curriculum Vitae

Asia-Pacific
Economic Cooperation

International APEC Symposium on
"Biofuels from Agricultural and Agro-Industrial Wastes"
May 24th – 27th, 2010, Chiang Mai, Thailand

KEYNOTE SPEAKER CURRICULUM VITAE

Presenter	
APEC Economy	Australia
Full Name	Peter L. Rogers
Academic Title or Position at the Place of Employment	Emeritus Professor, Biotechnology
Affiliated Organization	University of New South Wales, Sydney, Australia
Fields of Interest	Biotechnology, Biochemical Engineering
Full biography such as experiences,	• Degrees :BChem Eng (Adelaide,1963);DPhil (Oxford 1966); MBA (UNSW 1976),DSc (Oxford 1988) • International Appointments : Research Scientist (NRC, Canada,1970-1),Visiting Professor(MIT,Boston 1974-5), Visiting Professor (ETH, Zurich 1984) • International Experience : Consultancies with World Bank • UNESCO, UNDP, UNIDO, US Dept of Energy and Australian • Aid Programs ; also with Dupont, Grain Processing Corporation (US), BASF (Germany), and ICI/Orica, CSR and Manildra Starch P/L (Australia)
Research Skills	• Extensive University experience in teaching and research/ research supervision (more than 50 PhD students). • Research skills in biochemical engineering,biotechnology,

	molecular biology, economic analysis of bioengineering /fermentation processes.
Presentations:(2005 – 2010)	Numerous Conference Presentations both in Australia and internationally on biofuels and higher value fermentation products including pharmaceuticals by enzymatic processes
Publications:(2005 – 2010)	Total publications more than 200 in international journals, 6 international patents. Key recent publication/review on biofuels in Advances in Biochem Eng/Biotechnol. 'Zymomonas mobilis for Fuel Ethanol and Higher Value Products 108,263-288 (2007). More than 20 peer-reviewed publications (2005-2010) on biofuels and higher value products.
Awards and Honors:	• Rhodes Scholarship (Oxford 1963), Canadian National • Research Council Fellowship (NRC, Ottawa,1970-1) • US Fogarty International Fellowship (MIT,1974-5) • Australian Representative of UNESCO Network for Microbiology in SE Asia (1987-1995) • UNESCO Visiting Fellowship (NIBGE, Pakistan) 1990. • DSc (Oxford) (1988); Exxon-Mobil Award for Excellence in Chemical Engineering (2004); Hanson Medal from IChemE (UK) for publication Second Generation Biofuels (2009). • Fellow of Institute of Engineers Australia (IEAust).

Contact information:	
Address:	School of Biotechnology and Biomolecular Science, UNSW
Phone number:	02 9385 3896
E - mail:	p.rogers@unsw.edu.au

Asia-Pacific
Economic Cooperation

International APEC Symposium on
"Biofuels from Agricultural and Agro-Industrial Wastes"
May 24th – 27th, 2010, Chiang Mai, Thailand

KEYNOTE SPEAKER CURRICULUM VITAE

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Asia-Pacific
Economic Cooperation

International APEC Symposium on
"Biofuels from Agricultural and Agro-Industrial Wastes"
May 24th – 27th, 2010, Chiang Mai, Thailand

ACTIVE PARTICIPANT CURRICULUM VITAE

Presenter	
APEC Economy	**Indonesia**
Full Name	**Dadan Kusdiana**
Academic Title or Position at the Place of Employment	**DR**
Affiliated Organization	**Ministry of Energy and Mineral Resources**
Fields of Interest	**Small scale biofuel production, sustainable biofuel development, practical technology, rural empowerment**
Full biography such as experiences, etc.	Dr. Dadan Kusdiana was born in Sumedang, Indonesia on 29 December 1968. He was graduated from Bogor Agricultural University in 1992 majoring in agricultural engineering. In 1993, he then joined Ministry of Energy and Mineral Resources with first assignment on energy efficiency. From 1998 to 2004, he got a scholarship from Government of Indonesia to continue his master and doctoral degree in Kyoto University, Japan with research topic on biodiesel production process. Currently, he is now Head for Rural Energy Division, Directorate General of Electricity and Energy Utilization. He is a member of Indonesian Renewable Energy Society and Indonesian Biofuel Forum.
Research Skills	Biodiesel production process
Presentations:(2005 – 2010)	Various presentations on biofuel and renewable energy have been

	made for mostly bilateral and multilateral cooperation.
Awards and Honors:	Best young research on Energy from Japan Energy Society in 2004

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Phone number:	+62 21 522 5180
E - mail:	dadan.kusdiana@djlpe.esdm.go.id

International APEC Symposium on
"Biofuels from Agricultural and Agro-Industrial Wastes"
May 24th – 27th, 2010, Chiang Mai, Thailand

ACTIVE PARTICIPANT CURRICULUM VITAE

Presenter	
APEC Economy	Indonesia
Full Name	Dr. Oberlin Sidjabat
Academic Title or Position at the Place of Employment	Researcher, Head of Technology Research Group for Conversion Process & Catalyst
Affiliated Organization	R&D Centre for Oil and Gas Technology "LEMIGAS"
Fields of Interest	Biofuel, Catalytic Processing for Energy
Full biography such as experiences, etc.	**Education:** • Academy of Analytical Chemistry, Bogor, Indonesia, B.Sc (1975) • Chemical Engineering, The University of New South Wales, Sydney, Australia, Ph.D (1995) **Work Experiences:** • LEMIGAS employee as researcher • Head of Process Technology and Catalyst Group • Coordinator for Research on Biodiesel • Coordinator for ARHDM Catalyst Selection in PERTAMINA Balongan • Coordinator for Pilot Plant of Biodiesel • Development and Installation of Biodiesel Plant in Rokan

	Hulu, Province of Riau, with capacity 30 Ton per day (As Coordinator of Project)
Research Skills	Biofuel, Catalytic Processing for Fuel and Environment
Presentations:(2005 – 2010)	• The Effect of Biodiesel Blending by Splash Technique in Engine Performance, The 7th Asian Petroleum Technology Symposium, Ho Chi Minh, Viet Nam,18-19 February 2009 • Carbon Capture And Storage – Enhancement Oil Recovery Potential in Indonesia, Indonesia-UK Working Group on Environmental and Climate Change, London, UK, 15-16 June 2009
Publications:(2005 – 2010)	• Feasibility Study of Crude oil Refining from Sharing Contractor of Oil Company for reducing Fuel Deficit, Mineral & Energi, (2009), Vol. 7 (Indonesian language) • The Effect of Water and Ethanol in reactivity of iso-amyl alcohol hydrogenolysis with Ni/Zeolite catalyst, Lembaran Publikasi Lemigas, (2008), Vol. 42, (Indonesian language) • The Effect of Ca and Cr in Production of Bio-gasoline from Metyl-Esther as feedstock, Lembaran Publikasi Lemigas, (2009), Vol. 43, (Indonesian Languange)
Awards and Honors:	

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Asia-Pacific
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International APEC Symposium on
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ACTIVE PARTICIPANT CURRICULUM VITAE

Presenter	
APEC Economy	Malaysia
Full Name	Dr. Lee Keat Teong
Academic Title or Position at the Place of Employment	Associate Professor (Deputy Dean)
Affiliated Organization	University Sains Malaysia
Fields of Interest	• Energy Sustainability • Biofuel from Biomass • Air Pollution Control
Full biography such as experiences, etc.	Dr. Lee Keat Teong obtained his Ph.D in Chemical Engineering from University Sains Malaysia (USM) in 2004. His research interest is mainly in renewable energy, energy sustainability and environmental pollution control. He is currently an associate professor and deputy dean at the School of Chemical Engineering, University Sains Malaysia. Dr. Lee has completed numerous funded research projects from national and international awarding bodies. Up to date, he has published more than 70 research articles in various international peer-reviewed

	journals. Currently he is working on the production of biofuels (biodiesel and bioethanol) from biomass (mainly oil palm biomass) using various technologies. Apart from that, he also has special interest on the social and sustainability aspects of biofuels.
Research Skills	Design of Experiments

Presentations:(2005 – 2010)	**ONLY list 2009 onwards** • A Comparative Study on the Energy Policies in Japan and Malaysia in Fulfilling Their Nations' Obligation Towards Kyoto Protocol for CO_2 Reduction", 1st Regional Conference on Geo-Disaster Mitigation and Waste Management in ASEAN, Kuala Lumpur, Malaysia, 3–4th March 2009, pp 90-101. • Estimation of Kinetic Parameters for the Reaction between RHA/CaO/CeO_2 Sorbent and SO_2/NO form Flue Gas at Low Temperature", 1st Regional Conference on Geo-Disaster Mitigation and Waste Management in ASEAN, Kuala Lumpur, Malaysia, 3–4th March 2009, pp 142-147. • Supercritical Alcohol Technology in Biodiesel Production – A Comparative Study between Methanol and Ethanol", 9th International Symposium on Supercritical Fluids, Bordeaux, France, 18-20 May 2009. • Effect of Free Fatty Acids, Water Content and Co-solvent on Biodiesel Production by Supercritical Methanol Reaction", e 9th International Symposium on Supercritical Fluids, Bordeaux, France, 18-20 May 2009. • Mitigation of Environmental Issues via Kyoto Protocol: A Realistic or Foolish Approach", 5th Dubrovnik Conference in Sustainable Development of Energy, Water and Environment Systems", Dubrovnik, Croatia, 29 September – 3rd October 2009. • Potential of Waste Palm Cooking Oil in Catalyst-free Biodiesel Production", 5th Dubrovnik Conference in Sustainable Development of Energy, Water and Environment Systems", Dubrovnik, Croatia, 29 September – 3rd October 2009. • Reactive Extraction and In Situ Esterification of Jatropha curcas L. Seeds for the Production of Biodiesel", 1st International Conference on Advances in Renewable and Sustainable Energies (BIOGREEN 2010), Cancun, Mexico, 7 – 13 March 2010.
Publications:(2005 – 2010)	**ONLY list 2009 onwards** Irvan Dahlan, Keat Teong Lee, Azlina Harun Kamaruddin, Abdul Rahman Mohamed, "Evaluation of Various Additives on the Preparation of Rice Husk Ash (RHA)/CaO-Based Sorbent For Flue Gas Desulfurization (FGD) at Low Temperature", Journal of Hazardous Materials, Elsevier, Vol. 161 (1) 2009, pp 570-574. S. Sumathi, S. Bhatia, K.T. Lee, A.R. Mohamed, "Optimization of Microporous Palm Shell Activated Carbon Production for Flue Gas Desulfurization: Experimental and Statistical Studies", Bioresource Technology, Elsevier, Vol. 100 (4) 2009, pp 1614-1621. Keat Teong Lee and Ooi Wan Koon, "Modified Shrinking Unreacted-Core Model for the Reaction between Sulfur Dioxide and Coal Fly Ash/CaO/$CaSO_4$ Sorbent", Chemical Engineering Journal, Elsevier, Vol. 146 (1) 2009, pp 57-62. K.T. Tan, K.T. Lee, A.R. Mohamed and S. Bhatia, "Palm Oil:

	Addressing Issues and Towards Sustainable Development", Renewable and Sustainable Energy Reviews, Elsevier, Vol. 13 (2) 2009, pp 420-427. Jibrail Kansedo, Keat Teong Lee and Subhash Bhatia, "Biodiesel Production from Palm Oil via Heterogeneous Transesterification", Biomass and Bioenergy, Elsevier, Vol. 33 (2) 2009, pp 271-276. Jibrail Kansedo, Keat Teong Lee and Subhash Bhatia, "Cerbera odollam (Sea Mango) Oil as A Promising Non-edible Feedstock for Biodiesel Production", Fuel, Elsevier, Vol. 88 (6) 2009, pp 1148-1150. S. Sumathi, S. Bhatia, K.T. Lee and A.R. Mohamed, "Performance of An Activated Carbon Made from Waste Palm Shell in Simultaneous Adsorption of SO_X and NO_X of Flue Gas at Low Temperature", Science in China Series E: Technological Sciences, Springer, Vol. 52 (1) 2009, pp 198-203. Man Kee Lam, Kok Tat Tan, Keat Teong Lee, Abdul Rahman Mohamed, "Malaysian Palm Oil: Surviving the Food vs. Fuel Dispute for a Sustainable Future", Renewable and Sustainable Energy Reviews, Elsevier, Vol. 13 (6-7) 2009, pp 1456-1464. Gui Meei Mei, Keat Teong Lee and Subhash Bhatia, "Supercritical Ethanol Technology for the Production of Biodiesel: Process Optimization", The Journal of Supercritical Fluids, Elsevier, Vol. 49 (2) 2009, pp 286-292. Irvan Dahlan, Keat Teong Lee, Azlina Harun Kamaruddin, Abdul Rahman Mohamed, "Selection of Metal Oxides in the Preparation of Rice Husk Ash (RHA)/CaO Sorbent for Simultaneous SO_2 and NO Removal", Journal of Hazardous Materials, Elsevier, Vol. 166 (2-3) 2009, pp 1556-1559. Ahmad Zuhairi Abdullah, Noraini Razali, Keat Teong Lee, "Optimization of Mesoporous K/SBA-15 Catalyzed Transesterification of Palm Oil using Response Surface Methodology, Fuel Processing Technology, Elsevier, Vol. 90 (7-8) 2009, pp 958-964. Kok Tat Tan. Keat Teong Lee and Abdul Rahman Mohamed, "Production Of FAME by Palm Oil Transesterification via Supercritical Methanol Technology", Biomass and Bioenergy, Elsevier, Vol. 33 (8) 2009, pp 1096-1099. Wei-Ming Yeoh, Kim-Yang Lee, Siang-Piao Chai, Keat-Teong Lee, Abdul Rahman Mohamed, "Synthesis of High Purity Multi-walled Carbon Nanotubes over Co-Mo/MgO Catalyst by the Catalytic Chemical Vapor Deposition of Methane", New Carbon Materials, Vol. 24 (2) 2009, pp 119-123. Kian Fei Yee, Kok Tat Tan, Ahmad Zuhairi Abdullah, Keat Teong Lee, "Life Cycle Assessment of Palm Biodiesel: Revealing Facts and Benefits for Sustainability", Applied Energy, Elsevier, Vol. 86 (Supplement 1) 2009, pp S189-S196. Siew Hoong Shuit, Kok Tat Tan, Keat Teong Lee, Azlina Harun Kamaruddin, "Oil Palm Biomass as A Sustainable Energy Source: A Malaysian Case Study", Energy, Elsevier, Vol. 34 (9) 2009, pp 1225-1235. D.O. Ogenga, K.T. Lee, M. Mbarawa, "Sulphur Dioxide Abetment Using Synthesized South African Limestone/Siliceous Sorbents", Engineering Letters, Vol. 17 (3) 2009. Lee Chung Lau, Kok Tat Tan, Keat Teong Lee, Abdul Rahman

Mohamed, "A Comparative Study on the Energy Policies in Japan and Malaysia in Fulfilling Their Nations' Obligations towards the Kyoto Protocol", Energy Policy, Elsevier, Vol. 37 (11) 2009, pp 4771-4778.

Srimala Sreekantana, Zainovia Lockman, Roshasnorlyza Hazan, Minoo Tasbihi, Lee Keat Teong, Abdul Rahman Mohamed, "Influence of Electrolyte pH on TiO_2 Nanotube Formation by Ti Anodization", Journal of Alloys and Compounds, Elsevier, Vol. 485 (1-2) 2009, pp 478-483.

Man Kee Lam, Keat Teong Lee, Abdul Rahman Mohamed, "Sulfated Tin Oxide as Solid Superacid Catalyst for Transesterification of Waste Cooking Oil: An Optimization Study", Applied Catalysis B: Environmental, Elsevier, Vol. 93 (1-2) 2009, pp 134-139.

Man Kee Lam, Keat Teong Lee, Abdul Rahman Mohamed, "Life Cycle Assessment for the Production of Biodiesel: A Case Study in Malaysia for Palm Oil versus Jatropha Oil", Biofuels, Bioproducts & Biorefinery, Wiley InterScience, Vol. 3, 2009, pp 601-612.

Wei-Ming Yeoh, Kim-Yang Lee, Siang-Piao Chai, Keat-Teong Lee, Abdul Rahman Mohamed, "Synthesis of High Purity Multi-walled Carbon Nanotubes over Co-Mo/MgO Catalyst by the Catalytic Chemical Vapor Deposition of Methane", Carbon, Vol. 47 (12) 2009, pp 2941.

Irvan Dahlan, Keat Teong Lee, Azlina Harun Kamaruddin and Abdul Rahman Mohamed, "Rice husk ash/ calcium oxide/ceria sorbent for simultaneous removal of sulfur dioxide and nitric oxide from flue gas at low temperature", Environmental Engineering Science, Mary Ann Liebert, Inc. Vol. 26 (7) 2009, pp 1257-1265.

Hossein Mazaheri, Keat Teong Lee, Subhash Bhatia and Abdul Rahman Mohamed, "Subcritical Water Liquefaction of Oil Palm Fruit Press Fiber for the Production of Bio-oil: Effect of Catalysts", Bioresourse Technology, Elsevier, Vol. 101 (2) 2010, pp 745-751.

Siew Hoong Shuit, Keat Teong Lee, Azlina Harun Kamaruddin, Suzana Yusup, "Reactive Extraction and In Situ Esterification of Jatropha curcas L. Seeds for the Production of Biodiesel", Fuel, Elsevier, Vol. 89 (2) 2010, pp 527-530.

Kok Tat Tan, Keat Teong Lee, Abdul Rahman Mohamed, "A Glycerol-free Process to Produce Biodiesel by Supercritical Methyl Acetate Technology: An Optimization Study via Response Surface Methodology, Bioresource Technology, Elsevier, Vol. 101 (3) 2010, pp 965-969.

Goh Chun Sheng, Lee Keat Teong, "A Visionary and Conceptual Macroalgae-based Third Generation Bioethanol (TGB) Biorefinery in Sabah, Malaysia as an Underlay for Renewable and Sustainable Development", Renewable and Sustainable Energy Reviews, Elsevier, Vol. 14 (2) 2010, pp 842-848.

Steven Lin, Lee Keat Teong, "Recent Trends, Opportunities and Challenges of Biodiesel in Malaysia: An Overview", Renewable and Sustainable Energy Reviews, Elsevier, Vol. 14 (3) 2010, pp 938-954.

Jing Yan Tock, Chin Lin Lai, Lee Keat Teong, Kok Tat Tan, Subhash Bhatia, "Banana Biomass as Potential Renewable Energy Resource: A Malaysian Case Study", Renewable

	and Sustainable Energy Reviews, Elsevier, Vol. 14 (2) 2010, pp 798-805. S. Sumathi, S. Bhatia, K.T. Lee and A.R. Mohamed, "SO_2 and NO simultaneous removal from simulated flue gas over cerium-supported palm shell activated at lower temperatures-role of cerium on NO removal", Energy & Fuels, Elsevier, Vol. 24 (1) 2010, pp 427-431. S. Sumathi, S. Bhatia, K.T. Lee and A.R. Mohamed, "Selection of best impregnated palm shell activated carbon (PSAC) for simultaneous removal of SO_2 and NOx", Journal of Hazardous Materials, Elsevier, Vol. 176 (1-3) 2010, pp 1093-1096. Chun Sheng Goh, Kok Tat Tan, Keat Teong Lee, Subhash Bhatia, "Bioethanol from lignocellulose: Status, Perspectives and Challenges in Malaysia", Bioresource Technology, Elsevier, Vol. 101 (13) 2010, pp 4834-4841. Tan Hui Teng, Keat Teong Lee, Abdul Rahman Mohamed, Second Generation Bioethanol (SGB) from Malaysian Palm Empty Fruit Bunch: Energy and Exergy Analyses, Bioresource Technology, Elsevier, Vol. 101 (14) 2010, pp 5719-5727. Irvan Dahlan, Zainal Ahmad, Muhammad Fadly, Keat Teong Lee, Azlina Harun Kamaruddin, Abdul Rahman Mohamed, "Parameters Optimization of Rice Husk Ash (RHA)/CaO/CeO_2 Sorbent for Predicting SO_2/NO Sorption Capacity Using Response Surface and Neural Network Models", Journal of Hazardous Materials, Elsevier, Vol. 178 (1-3) 2010, pp 249-257. Kok Tat Tan, Meei Mei Gui, Keat Teong Lee, Abdul Rahman Mohamed, "An Optimized Study of Methanol and Ethanol in Supercritical Alcohol Technology for Biodiesel Production", Journal of Supercritical Fluid, Elsevier, Vol. 53 (1-3) 2010, pp 82-87. Kok Tat Tan, Keat Teong Lee, Abdul Rahman Mohamed, "Effects of Free Fatty Acids, Water Content and Co-solvent on Biodiesel Production by Supercritical Methanol Reaction", Journal of Supercritical Fluid, Elsevier, Vol. 53 (1-3) 2010, pp 88-91.
Awards and Honors:	• National Science Fellowship (PhD program) from July 2000 to Jun 2003 • Ministry of Science, Technology and Environment, Malaysia • Best Thesis Award 2004 Universiti Sains Malaysia • Excellence Service Award 2006 – Universiti Sains Malaysia

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ACTIVE PARTICIPANT CURRICULUM VITAE

Presenter	
APEC Economy	Mexico
Full Name	Roberto de la Maza Hernández
Academic Title or Position at the Place of Employment	Director General for Biofuels
Affiliated Organization	Mexican Ministry of Energy
Fields of Interest	Environmental policy, renewable sources of energy, environmental services and climate change mitigation.
Full biography such as experiences, etc.	• 2008 up to date: Director General for Biofuels, Mexican Ministry of Energy. • 2003-2008: Technical Secretary of the Commission for the Environment, Natural Resources and Fisheries, Mexican Senate. • 2001-2002: Master in Environmental Policy, Carlos III University of Madrid. • 1997-1999: Adviser of the legal department of the Ministry of Environment, Natural Resources and Fisheries.
Research Skills	• Latin America Forest Policy Research and Influence Project. International Student Initiative for Action on Climate Change (ISIACC). ETHsustainability. 2008. • World YES Forum. The environmental impact assessment process as a mean of implementation of public participation and its limitations in Latin American economies. ETHsustainability. 2005.
Presentations:(2005 – 2010)	• October, 2009: The introduction of ethanol in the gasoline of the main cities of Mexico. V Congreso Internacional de Transporte Sustentable, organized by CTS Mexico and EMBARQ in Mexico City, Mexico. • June, 2009: Environmental considerations for the introduction of Biofuels. Biofuels Seminar organized by the Mexican Institute of Ecology, Mexico City, Mexico. • April, 2009: Biofuels Program in Mexico. IV Latin-American and the Caribbean Biofuels Seminar, organized by OLADE in Cali, Colombia.
Publications:(2005 – 2010)	• Coauthor. Strategy for hydro environmental services in

	Quintana Roo, Mexico. Serie Acciones. Número 1. Corredor Biológico Mesoamericano. 2009. • Protected areas and tourism. An option for sustainable development. Ecoturismo y turismo de aventura en México: Normatividad y legislación. Comisión de Turismo de la Cámara de Diputados. 2006.
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ACTIVE PARTICIPANT CURRICULUM VITAE

Presenter	
APEC Economy	Mexico
Full Name	Ms. Irasema Infante Barbosa
Academic Title or Position at the Place of Employment	• Director of Economic Affairs, of the Mesoamerican Integration and Development Project Direction General • B.A. in International Relations (2005) and B.A. in Political Science (2006), Instituto Tecnológico Autónomo de México (ITAM).
Affiliated Organization	Ministry of Foreign Affairs, Mexico
Fields of Interest	Regional Integration, Renewable Energies, Public Policy Formulation
Full biography such as experiences, etc.	• Director of Economic Affairs, Mesoamerican Integration and Development Project Direction General, Undersecretary for Latin America and the Caribbean, Ministry of Foreign Affairs (January 2009-to date) • Deputy Director of Economic Affairs of the Plan Puebla-Panama General Coordination, Undersecretary for Latin America and the Caribbean, Ministry of Foreign Affairs (May 2007- Dec 2008). • Head of Department for US Foreign Policy, North America Direction General, Undersecretary for North America, Ministry of Foreign Affairs (July 2006- May 2007).
Research Skills	• Member of the special team in charge of the elaboration of press notes and briefs for the *Mexico Business Summit* (Monterrey 2007, Veracruz 2006 and Veracruz 2005 edition). • Research assistant of Prof. Carlos Marichal, Historical Studies Center, El Colegio de México, (May 2005-2006). Relevant projects: Collaboration in the translation and support materials of the text: *Bankruptcy of Empire: Mexican Silver and the Wars between Spain, Britain and France, 1760-1810,* Cambridge University Press, 2007. - Collaboration in the Research Program: "Fuentes para la historia del Petróleo en México" (Sources for the oil history in Mexico) and support in the creation of the website: http://www.colmex.mx/ceh/petroleo/present.php.

	• Research assistant of Prof. Geronimo Gutierrez, Department of Political Science, ITAM (August 2005-May 2006). Collaboration in public policy formulation. • Research assistant of Prof. Alonso Lujambio, Department of Political Science, ITAM (2004-2005). Monitoring of the war in Iraq and UN's electoral assistance. • Interdisciplinary Research Center for Sciences and Humanities, National Autonomous University of Mexico (UNAM) translation to Spanish of Michael Monteon's essay titled "Debt Crisis and changes in Latin American policies" (2003) in Guajardo, Guillermo *Nor success, nor failure, ideas, resources and actors in Latin American policies of the XX Century*, Mexico, Plaza & Valdes, 2005. • Research Assistant of Prof. Guillermo Guajardo Soto, Department of International Studies, ITAM (2002-2003). • Assistance for international observers invited by the National Action Party (PAN) during Mexico's presidential elections (2000).
Presentations:(2005 – 2010)	• December 4, 2009. Lecture about Project Mesoamerica for the Foreign Policy Formulation class of International Relations B.A. Program, ITAM, Mexico City • October 28, 2009. Presentation about the Mesoamerican Biofuels Program at the "VI National Meeting of the Mexican Network on Bioenergy and International Symposium on Bioenergy Projects", Querétaro, Qro. • October 13, 2009. Presentation of the Mesoamerican Biofuels Program at the "Third State and Second Regional Forestry Congress", Ciudad Victoria, Tamaulipas. • September 4, 2009. Presentation of the Mesoamerican Biofuels Program at the Inauguration of the production plant of biofuel based crude oil viscosity reducer created by Geo Estratos Company, Altamira, Tamaulipas. • August 24, 2009. Presentation about the Mesoamerican Biofuels Program at the "First Meeting of the Mesoamerican Biofuels Research and Development Network", Tuxtla Gutierrez, Chiapas • June 10, 2009. Presentation of the Mesoamerican Biofuels Program at the "Regional Congress of Agricultural Industries: The importance of agribusiness in the XXI century", Universidad Autónoma de Chiapas, Arriaga, Chiapas.
Publications:(2005 – 2010)	*A note about Mexican voting abroad*, ITAM Law Journal. Num 1. 2006.

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ACTIVE PARTICIPANT CURRICULUM VITAE

Presenter	
APEC Economy	Viet Nam
Full Name	Doan Thai Hoa
Academic Title or Position at the Place of Employment	Assoc. Prof. Dr., Head of Department of Pulp and Paper Technology
Affiliated Organization	Ha Noi University of Technology
Fields of Interest	Bioefinery
Full biography such as experiences, etc.	Teaching and doing research on Pulp and Paper Technology and Biorefinery
Research Skills	Pulp and Paper Technology Bio-ethanol production from biomass Waste water treatment
Presentations:(2005 – 2010)	Presentations in 4 International and National Workshops on Biomass
Publications:(2005 – 2010)	10 papers in International and National Journals

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ACTIVE PARTICIPANT CURRICULUM VITAE

Presenter	
APEC Economy	Viet Nam
Full Name	Nguyen Van Thong
Academic Title or Position at the Place of Employment	Senior Expert on International Cooperation
Affiliated Organization	Insitute of Energy
Fields of Interest	Energy and Electricity with International Companies & Organizations
Full biography such as experiences, etc.	Studied at Wroslaw Polytechnic University, Poland Field of study: Energy Mechanics. Final degree: Mechanical Engineer.
Employment Records	From 1976 to 1994 (Institute of Energy and Electrification) - Working as an engineer, researcher of thermal power plants. Involved in power plant site selection, pre-feasibility and feasibility studies, studies on renewable energy planning and development. 1995 up to now (Institute of Energy) - Participated in "The Study on National Energy Master Plan", "National Power Development Master Plan" and Renewable energy Master Plan for Economy", as Energy expert; - Working as senior Expert on international cooperation responsible for communication, organizing meetings, seminars, workshops, and as assistant coordinator in performance of international cooperation projects in the field of energy and electricity with international companies, organizations etc.

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KEYNOTE SPEAKER CURRICULUM VITAE

Presenter	
APEC Economy	**U.S.A**
Full Name	**Dr. Kulinda Davis, PhD**
Academic Title or Position at the Place of Employment	**Director – Product Development**
Affiliated Organization	**Verenium Corporation**
Fields of Interest	**Cellulosic ethanol, algae-based biofuel production**
Full biography such as experiences,	• Dr. Kulinda Davis has a track record in the initiation of biofuel projects. She secured competitive multi –million U.S. government grants and developing strategic partnerships to execute biofuel project development. She is currently a Product Director at Verenium Corporation with direct oversight for a multimillion dollar enzyme product targeted at the biofuels industry. • During her tenure at Sapphire Energy an algae –based biofuels start-up, Kulinda made significant strides playing a key role as project director in securing $50M in DOE grant money for a $135M 1.5 million gallon a year Integrated Algal Biorefinery (IABR). She also identified valuable opportunities

	for intermediate and final product streams of the IABR project, evaluating the economics, putting together research joint ventures, negotiating Letters of Intent and generating proformas. She directly oversaw the disposition of solid products derived from the IABR extraction and their delivery to the biomass degrading recycling systems. • With her base understanding or all aspects of cellulosic ethanol production processes and business acumen, Kulinda was a perfect fit for the position of Technical Director Emerging Technologies at Pacific Ethanol. When she joined Pacific Ethanol there was no clear strategy for alternatives to corn for ethanol production. In 18 months Kulinda developed a cellulosic ethanol strategy and as Principal Investigator landed $25M is DOE grant money for a 2.7 MGY Integrated Ethanol Biorefinery in the state of Oregon. She masterfully put together a partnership deal with a renowned international cellulosic ethanol technology developer. • The two projects she initiated at Sapphire Energy and Pacific Ethanol are on-going and are proudly profiled in the DOE funded portfolio of projects aimed at achieving the U.S. national goals for biofuel development. She is in the U.S under the prestigious National Interest Waiver status recognized for he contributions to securing America's energy future.
Research Skills	• Management and technical experience working in cellulose- and algae –based fuel development processes spanning feasibility studies, planning and design of advanced biofuel projects; development and implementation of corporate strategy and R&D and operational strategies • Project management skills applied in the renewable fuel space including managing cross-disciplinary projects involving microbiology, engineering, construction , operations and business development to ensure effective integration of work teams • Identification of unit operation performance indicators and managing optimization efforts that facilitate proactive technical and business analysis • Comprehensive experience of a wide variety of microbiological and analytical techniques as applied to fermentation systems including , bioreactor operations, HPLC and GC operations
Presentations:(2005 – 2010)	Kulinda Davis, PhD. "Demonstration scale cellulosic ethanol production technology" Harvesting Clean Energy Conference VIII – Portland, OR. January 2008. Kulinda Davis, Panelist Optimizing Ethanol Plants "Next Generation Technologies: What are the Opportunities for Plant Optimization Projects". May 2008, Minneapolis, MN.
Publications:(2005 – 2010)	Davis, L., Svenson, C., Pearce, J., Rogers, P. "Evaluation of *Zymomonas*-based ethanol production from a hydrolysed waste starch stream." Biomass and Bioenergy, 30 Issues 8/9 (2006) pp. 809-814. Davis, L., Y-J, Jeon, Svenson, C., Pearce, J., Rogers, P. "Evaluation of wheat stillage for ethanol production by

	recombinant *Zymomonas mobilis*." Biomass and Bioenergy, 29 (2005) pp. 49-59.
Awards and Honors:	$ 75 million secured funding from the U.S. Department of Energy for biofuel projects

Presentation:	
Title	Biofuel Development in the U.S.: A Race to the Starting Line
Abstract (up to 200 characters)	The U.S. is widely regarded as a leader in the development of advanced biofuels from agricultural and agro-industrial wastes and purpose grown feedstock e.g., algae. Through aggressive policy, the U.S. has set an ambitious goal of producing 36 billion gallons of biofuels per year by 2022 and a short term goal of producing 100 million gallons of advanced biofuels per year by 2014. A number of companies are currently demonstrating technologies producing cellulosic ethanol, biobutanol and drop-in fuels and have stated target production capacities that will exceed the short-term goal. However, significant challenges are yet to be overcome to achieve commercialisation.

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ACTIVE PARTICIPANT CURRICULUM VITAE

Presenter	
APEC Economy	Philippines
Full Name	Teresita Ramos-Perez
Academic Title or Position at the Place of Employment	Associate Professor
Affiliated Organization	Department of Environmental Science, Ateneo de Manila University
Fields of Interest	Ecology, Limnology, Algal taxonomy, Use of phytoplankton for pollution monitoring, algal culture and algal immobilization
Full biography such as experiences,	• Associate Professor. Present Position. (2209). Department of Environmental Science, Ateneo de Manila University. • Director 2006 to 2009 (March 2009) . Department of Environmental Science, Ateneo de Manila University. • Review Committee for Environment Management Bureau (Department of Environment and Natural Resources). 2008 to present. • Associate Director 2004- 2005, Department of Environmental Science, Ateneo de Manila University. • Officer-In-Charge 2003-2004, Department of Environmental Science, Ateneo de Manila University. • Assistant Professor 2001-present, Department of Environmental Science, Ateneo de Manila University. • Deputy Director for Research and Extension 1998 - 2000, Institute of Biology, College of Science, U.P. Diliman.

	• Assistant Professor 1996 - 2001. Institute of Biology, College of Science, U.P. Diliman.
Publications:(2005 – 2010)	Jacinto, ML.; David, CP.; Perez, T. and De Jesus, B. 2009. Comparative Efficiency of Algal Biofilters in the Removal of Chromium and Copper from waste water. Ecological Engineering. (In Press). Perez T., et al. 2008. Catchment characteristics, hydrology, limnology and socio-economic features of Lake Taal, Philipines. Aquatic Ecosystems and Development : Comparative Asian Perspectives. Schiemer et al. (eds). Margraf Publishers. Germany. Diangan, M., T. Perez and R. Claveria. 2008. Analysis of land application as a method of disposal for distillery effluent. Int. J. Environment and Health. 2 (2): 258 – 271. Claveria, R., G. Senerino and T. Perez. 2008. Bathymetry and sedimentation in Palacpaquen Lake, San Pablo City. Laguna, Philippines. Loyola Schools Review. 7: 73-85. Claveria, R., T. Perez, J. Tesorero, B. Pasaporte and G. Bayugo. 2007. Petrographic analysis of rocks and sediments around the Seven Lakes of San Pablo, Laguna : Implications regarding sulfate distribution and provenance. Loyola Schools Review.64-77. Enriquez, E. and T. Perez. 2005. Response of Phytoplankton to Temporal Changes in Nutrinets in Taal Lake, Batangas, Philippines. Proceedings of the First National Congress on Philippine Lakes (LakeCon 2003). (Cuvin-Aralar et al. eds.) SEAMEO SEARCA, Laguna, Philippines. Perez, T. as author to the two chapters of the book Introduction to Environmental Science : Managing Resources for Sustainable Development. Edited by Espiritu, EQ. Claveria, R., T. Perez et al. 2005. Nutrient Trends in Water, Soil, and Sediments in a Riparian Ecosystem in Indang, Cavite: Implications to Community Resource Management. Loyola Schools Review. IV: 31-50. Perez, T. 2003. Alginate Immobilization of Phil. Microalgal Isolates. Loyola Schools Review. II: 25-30. Perez, T. and A. Sumugat. 2001. Microalgal heavy metal indicators in the fresh systems of Nonoc and Dinagat Islands, Rott, E., S. Silva and T. Perez (in press). Biodiversity of phytoplankton from 5 SE-Asian lakes sampled within FISHSTRAT. Algological studies. Rott, E.; Kling, H. and Perez, T. 2001. Planktonic centric diatoms from the volcanic lake Taal, Philippines. In: Jahn, R., J. Kociolek, A. Witkowski & P. Compere (eds): Lange-Bertalot-Festschrift:39-52. Ganter, Ruggell. Perez, T. 1998. Development of a Cost Effective Toxicity testing Using Marine Micro Algae. Proceedings of The Second Asia-Pacific Marine Biotechnology Conference and The Third Asia-Pacific Conference on Algal Biotechnology Perez, T.1997. Annotated Bibliography on the Fresh Algae of the Philippines. CIDS University of the Philippines (in press). Botanikang Panlaboratoryo (Several authors). 1997. Sentrong Wikang Filipino, University of the Philippines.
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Asia-Pacific
Economic Cooperation

International APEC Symposium on
"Biofuels from Agricultural and Agro-Industrial Wastes"
May 24th – 27th, 2010, Chiang Mai, Thailand

ACTIVE PARTICIPANT CURRICULUM VITAE

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APEC Economy	Thailand
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Academic Title or Position at the Place of Employment	Senior Vice President – Corporate Planning
Affiliated Organization	Electricity Generating Public Co.Ltd. (EGCO)
Fields of Interest	Power Generation and Energy
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International APEC Symposium on
"Biofuels from Agricultural and Agro-Industrial Wastes"
May 24th – 27th, 2010, Chiang Mai, Thailand

ACTIVE PARTICIPANT CURRICULUM VITAE

Presenter	
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Academic Title or Position at the Place of Employment	Assistant Professor
Affiliated Organization	Khon Kaen University
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Full biography such as experiences, etc.	2003-2009 Lecturer Khon Kaen University 2009 Assistant Professor Khon Kaen University
Research Skills	Analysis of bacterial kinetics
Presentations:(2005 – 2010)	Prawphan Yuvadetkun, Kunjana Plengsiri, Sutthawan Intarapanich and Mallika Boonmee* (2009) Effects of inoculum concentration and yeast extract for ethanol production from Sweet Sorghum Grain by *Saccharomyces cerevisiae* and *Zymomonas mobilis*. In: *The 19th Annual Conference of Thailand's Chemical Engineering and Applied Chemistry Society*, October 26-27, 2009, Kanchanaburi, Thailand. (Poster presentation)

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Publications:(2005 – 2010)	Mallika Boonmee*, Paweena Pakping and Montree Promkudtum (2007) Cultivation in Series for Sequential Conversion of Mixed Glucose/Xylose to Ethanol by *Zymomonas mobilis* and *Candida shehatae*. *Chiang Mai University Journal of Agro-Industry*. 1,29-36. (Thai content) Mallika Boonmee*, Sootharwan Intarapanich and Onanong Cotano (2008) Effect of Temperature Control on Acetic Acid

	Production by *Acetobacter* spp. *Naresuan Agriculture Journal*, 11(2), 99-106. (Thai content) Mallika Boonmee, Noppol Leksawasdi, Wallace Bridge and Peter L. Rogers* (2006) Electrodialysis for Lactate Removal in the Production of the Dairy Starter Culture *Lactococcus lactis* NZ133. International Journal of Food Science and Technology, 42(5), 567–572.
Awards and Honors:	*Outstanding Poster Presentation*: The 9th Thailand Research Fund Annual Meeting, October 15-17, 2009, Petchaburi, Thailand.

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Asia-Pacific
Economic Cooperation

International APEC Symposium on
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May 24th – 27th, 2010, Chiang Mai, Thailand

KEYNOTE SPEAKER CURRICULUM VITAE

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APEC Economy	Thailand
Full Name	Prof T Kiatsiriroat
Academic Title or Position at the Place of Employment	Professor
Affiliated Organization	Department of Mechanical Engineering, Chiang Mai University
Fields of Interest	BioFuels, Thermal Processes
Full biography such as experiences,	• Teaching and doing R&D work on thermal processes and energy technology at King Mongkut's University of Technology Thonburi(KMUTT) since 1978. • Professor and Dean, School of Energy and Materials, KMUTT, 1994-1995. • Professor, Department of Mechanical Engineering, Chiang Mai University, 1995-present. • Associate Regional Editor, Applied Thermal Engineering. • Editor, Engineering Journal, Faculty of Engineering, Chiang Mai University.
Publications:(2005 – 2010)	Vorayos, N., Kiatsiriroat, T. and Vorayos, N., Performance analysis and economic consideration of solar ethanol distillation with different types of solar collectors, The International of Ambient Energy, 27(1), 2006, pp. 3-14.

	Vorayos, N. and Kiatsiriroat, T., Performance analysis of solar ethanol distillation, Renewable Energy, 2006, vol. 31, pp.2543-2554. Sampattagul, S., Rewlayngan, J. and Kiatsiriroat, T., Eco-evaluation of bio-diesel from used vegetable oils in small scale production in Thailand, The International Life Cycle Assessment and Life Cycle Management Conference, October, 2007, Portland, Oregon, USA. Vorayos, N., Vorayos, N. and Kiatsiriroat, T., Life cycle assessment of dendrothermal power generation in Thailand including economic feasibility analysis: A case study, The International Life Cycle Assessment and Life Cycle Management Conference, October, 2007, Portland, Oregon, USA. Permsuwan, A., Tararux, C. and Kiatsirioat, T., Experimental study on non-catalytic biodiesel production from palm oil and ethanol under pressurized carbon dioxide, Commemorative Int. Conf. of the 4th Cycle Anniversary of KMUTT Sustainable Development to Save the Earth: Technologies and Strategies Vision 2050: SDSE2008, December, 2008, Bangkok. Piamdee, J., Vorayos, N., Kiatsiriroat, T., Arjharn, W. and Vorayos, N., Comparison Study on Life Cycle Assessment of Small Scale Dendrothermal Power Generation in Thailand including Economic Feasibility Analysis: a Case Study, World Renewable Energy Congress 2009-Asia, 19-22 May, 2009, Bangkok, Thailand. Vorayos, N., Malawanno, N. and Kiatsiriroat, T., Experimental Test of Ethanol Distillation by Direct Boiling in Solar Collector,World Renewable Energy Congress 2009-Asia, 19-22 May, 2009, Bangkok, Thailand. Chaiwong, K., Kiatsiriroat, T. and Thararax, C., Effect of temperature on bio-oil generation in slow pyrolysis of Spirulina platensis, Int. Conf. on Green and Sustainable Innovation 2009, December 2-4, 2009, Chiang rai, Thailand.
Awards and Honors:	• Outstanding Researcher, Faculty of Engineering, Chiang Mai University Academic year 1998-2000. • Senior Reseach Scholar in Mechanical Engineering, Thailand Research Fund,2002. • Science and Technology Award, Thailand Toray Science Foundation, 2007. • PTIT Fellow, Petroleum Institute of Thailand, 2009-2010. • Outstanding Alternative Energy Scientist Leadership Award on Solar Thermal Energy Technology, World Alternative Energy Sciences Expo 2009. • Outstanding Alumnus(Education), Faculty of Engineering, Kasetsart University, 2009.

Presentation:	
Title	Study on Algae as Energy Source at Department of Mechanical Engineering, Chiang Mai University
Abstract (up to 200 characters)	• Algae could be taken as an alternative energy source because it could capture CO_2 for its growth and some types have high content of fatty acid. Moreover, algae has high growth rate and it could be harvested in a shorter period compared with other energy plants such as fast rotation tree

	or palm tree, etc. • The research on algae as bio-energy source has been carried out into two parts. The first one is to study the growth rate of Chlorella when it is open-type feeding on vertical wall. This technique will use small area of horizontal plane and algae could capture CO_2 directly from the environment. If algae farm is installed, it could generate cooling to the environment. The second part is to find out bio-oil and bio-char yielded from some types of algae in Thailand under pyrolysis process. The bio-oil qualities are close to heavy oil and diesel oil and the bio-chars from algae have similar fuel characteristics with solid fossil fuels and those from other biomass under pyrolysis process at the same range of operating temperature. • Bio-chars from algae after pyrolysis have high percentage of carbon content, therefore, this technique has a high potential to capture CO_2 from atmosphere in a form of carbon and this could be kept into the ground.

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Questionnaires

Questionnaire

International APEC Symposium on

"Biofuels from Agricultural and Agro-Industrial Wastes"

May 24th – 27th, 2010, Chiang Mai, Thailand

Instructions The questionnaire is divided into three parts as following;

Part 1 Personal Information

Part 2 Questions

Part 3 Suggestions

Part 1 Personal Information

Instructions Please write ✓ sign in the box (☐) which is the most accurate

1. Gender ☐ 1. Male 56.60% ☐ 2. Female 43.40%
2. Age.............................years

20 - 30 years old	30.19%
31 - 40 years old	32.08%
41 - 50 years old	18.87%
51 - 60 years old	13.21%
61 - 70 years old	5.66%

3. Economy....................................

Thai	76.92%
Australia	1.92%
Indonesia	5.77%
Japan	1.92%
Korea	1.92%
Malaysia	1.92%
Mexico	3.85%
Philippines	1.92%
Viet Nam	3.85%

4. Occupation

   ☐ Researcher 34.62% ☐ Scientist 7.69%

   ☐ Entrepreneur 3.85% ☐ Trader/ Other 32.69%

   ☐ Student 21.15%

5. Educational Level

   ☐ Below Bachelor Degree 1.92% ☐ Bachelor Degree 17.31%

   ☐ Master Degree 30.77% ☐ Doctorate Degree 50.00%

Part 2 Questions

Instructions Please write ✓ sign in the box (☐) which is the most accurate

List of Questions	Evaluation Level				
	5 Most likely	4 Likely	3 Moderate	2 Low	1 Lowest
1. If situation permit, you will select the biofuels even though the price is higher than normal fuels	15.38 %	46.16 %	21.15 %	13.46 %	3.85 %
2. The biofuels development in your economy is not sufficient	7.69 %	34.62 %	40.38 %	13.46 %	3.85 %
3. Education plays important roles in the decision of selecting biofuels	34.62 %	48.07 %	11.54 %	5.77 %	0.00 %
4. Please rate the level of negative impact from fossil fuels to the environment	50.94 %	26.42 %	16.98 %	3.77 %	1.89 %
5. This symposium make you realize the Importance of biofuels in the future	58.49 %	35.85 %	3.77 %	1.89 %	0.00 %
6. This symposium helps you establish biofuels network	35.85 %	39.62 %	20.75 %	1.89 %	1.89 %
7. After the symposium you will transfer the gained knowledge to community, friends and/or student	43.40 %	41.51 %	15.09 %	0.00 %	0.00 %
8. How useful of this symposium to your organization	28.30 %	56.60 %	13.21 %	1.89 %	0.00 %
9. In your economies, what is the level of opportunities/roles of women in biofuels related agency/organization of biofuels	2.00 %	50.00 %	44.00 %	4.00 %	0.00 %

List of Questions	Evaluation Level				
	5 Most likely	4 Likely	3 Moderate	2 Low	1 Lowest
10. Your level of biofuels understanding <u>before</u> participating in the biofuels symposium	9.43 %	33.96 %	33.96 %	22.64 %	0.00 %
11. Your level of biofuels understanding <u>after</u> participating in the biofuels symposium	30.19 %	62.26 %	5.66 %	1.89 %	0.00 %

Part 3 Suggestions

Your recommendation of lecture/discussion topic(s) to be included in the future APEC funded symposium which is related to biofuels

1. Comparison of impact from fossil fuels and biofuels regarding to climate change crisis
2. Further information on policy and situation of biofuels in Thailand
3. Research grant from government to support biofuels
4. Implementation of low cost raw materials for production of biofuels from factories wastes
5. Biofuels development and trends
6. Issues regarding local framework on biofuels as well as environmental concerns regarding biofuels production. Biofuels can be an option for energy and supply but not the only solution.
7. Economic feasibility and sustainability aspects of biofuels
8. Investment for application the biofuels from agricultural and agro industrial wastes
9. Biofuels from algae
10. Examples of successful biofuels project in the APEC member economies
11. The second and third generation biofuels
12. Challenges for developing of biofuels in APEC member economies

13. Sustainability issue of biomass/biofuels and relevant energy system
14. Commercialization of second/third generation biofuels in ASEAN economies
15. Collaboration of private and educational sectors on biofuels development

Other suggestions

1. General participant should be funded to visit sites as well.
2. It would be interesting to have an assessment/diagnosis on biofuels in the APEC member economies in order to develop projects or identify common interests
3. All levels of students from Bachelor to Doctorate Degrees should participate in this event
4. This is an excellent Symposium
5. Technology transfer from developed to developing economy is essential
6. The results of this symposium should be submitted to relevant APEC fora such as APEC energy working group
7. This is a well organized symposium
8. Meeting should be set up on a yearly basis so that sustainable development can be achieved
9. The lecture/discussion topics in the symposium are good. The participants are active with multitude of experiences and opinions to share

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