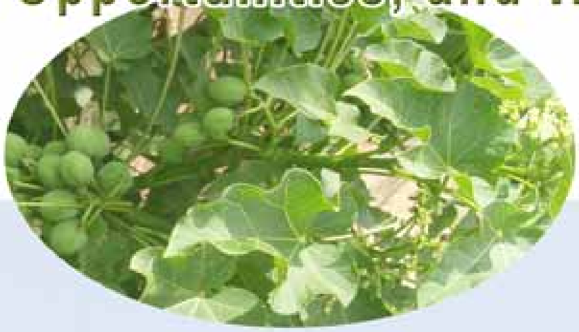
Regional Forum on Bioenergy Sector Development: Challenges, Opportunities, and Way Forward



UNITED NATIONS ESCAP
Economic and Social Commission for Asia and the Pacific

APCAEM
Asian and Pacific Centre for Agricultural Engineering and Machinery

TABLE OF CONTENTS

Forward 1
Acknowledgment 2
Biodiesel From Algae 4
India's Biodiesel Programme: Some Critical Issues 13
An Overview of Biodiesel Transesterification Technology in India 26
Current Status of Bioenergy Development in Indonesia 48
The Current Status of Biofuel in Korea 66
Biogas Support Programme of Nepal: Current Situation and Experiences/Lessons Learnt 80
A Year After: Status of Philippines Biofuel Act 101
Municipal Organic Waste as an Alternative Urban Bioenergy Source 114
Sector Development for Domestic Biodigesters: Experiences of SNV, Dutch Development Organisation 124
Regional Forum on Bioenergy: Conclusions and Recommendations 133

FOREWARD

Bioenergy is renewable energy made available from materials derived from biological sources. Due to volatile and rising energy prices as well as increasing world wide energy demand, bioenergy is seen by many nations as an attractive alternative or addition to meet their current and future energy needs. Many countries acknowledge bioenergy as a way to diversify their current energy mix, reduce dependency on fossil fuels such as oil and reduce transport greenhouse gas emissions. Currently, bioenergy resources such as forestry and agriculture crops, biomass residues and wastes already provide about 14 per cent of the world's primary energy supplies, with the potential to meet up to half of world energy demands during the next century.

However, bioenergy does not come without its own pitfalls. Without proper research, production, management and over-site, bioenergy can increase pressure on already strained natural resources leading to economic loss, and reduced quality of life. Bioenergy is also pointed out as a contributor to rising food prices and a threat to food security. There are good biofuels and bad biofuels, and, with good land and water management, there are good opportunities for many developing countries to produce their own transport fuels as well as food and fibre.

In the Asia-Pacific region there is a lag in providing access to energy services. Some 1.7 billion people in the region are using traditional biomass fuels and 1 billion people still lack access to electricity. United Nations Secretary-General Ban Ki-moon in his message to the sixty-fourth session of the United Nations Economic and Social Commission for Asia and the Pacific stated that "the Asia-Pacific region must promote sustainable and efficient energy use" as per capita energy consumption in the region more than doubled in the past 15 years. A balanced approach to biofuels is necessary, and its thoughtful incorporation and sustainable production paramount.

In response to the above, this past January of 2008, ESCAP-APCAEM as a subregional arm for promoting sustainable and inclusive development in North-East Asia, organized a regional forum on bioenergy sector development, concentrating on challenges, opportunities and the way forward, in collaboration with the Ministry of Agriculture and Cooperatives and the Department of Agriculture of Thailand. The Forum held in Bangkok was was attended by some 100 experts and policy-makers on bioenergy development from 15 selected member countries including Australia, Cambodia, China, Fiji, India, Indonesia, Lao PDR, Malaysia, Mongolia, Nepal, Philippines, Republic of Korea, Singapore, Thailand, and Viet Nam; UNESCAP, United Nations agencies (FAO, UNDP, UNIDO, UNEP), bilateral development organization (SNV), national institutions and private enterprises. In addition to the Forum, field visits to a small-scale biomass gasification power plant, biomass feedstock production system, bioethanol plant and biogas plant in Nakhorn Rachasima were arranged by the Ministry of Agriculture and Cooperatives of the Royal Government of Thailand.

The outcome of the ESCAP-APCAEM forum serves to guide the formulation of capacity-building programmes for policymakers, development practitioners and CDM projects on bioenergy. The forum also provided a platform for exchange of best practices and innovative solutions on how to foster public/private partnerships that would promote bioenergy development and bioenergy trade and investment in the region. In addition, the forum recommended the establishment of an Asia-Pacific bioenergy network to facilitate and promote bioenergy information sharing with experienced countries and through regional South-South cooperation.

The Regional Forum, focused on four relevant topics on bioenergy development, namely: 1) Biofuels Development in Asia and the Pacific, 2) Biogas and Biomass Development in Asia and the Pacific, 3) Next Generation Technology of Bioenergy, and 4) Climate Change and Green Business Opportunities. In the above regard, the following country contributions share diverse experiences, illuminating intricacies, gaps and barriers on bioenergy that can serve policymakers and other stakeholders in developing a more sustainable path that can be a factor for more inclusive economic and social development in our diverse region.

ACKNOWLEDGMENT

ESCAP-APCAEM offers its sincere gratitude to Bastiaan Teune, SNV Advisor Biogas/Renewable Energy, Viet Nam; Dr. Wang, Jing-Yuan of the Environmental Engineering Research Centre Nanyang Technological University, Singapore; Ms. Maya Lyn C. Manocsoc of Carbon Finance Solutions, Inc. (CaFiS), Philippines; Raju Laudari, Alternative Energy Promotion Centre (AEPC), Nepal; Dr. Hee-Chan Kang, Senior Researcher, Samsung Economic Research Institute, Republic of Korea; Dr. Teguh Wikan Widodo and Dr. Elita Rahmarestia of the Indonesian Center for Agricultural Engineering Research and Development (ICAERD), Indonesia; Dr. Anandajit Goswami, Associate Fellow, Centre for Global Agreements, Legislation and Trade, Resources and Global Security Division, The Energy and Resources Institute, India; Dr. Lin Gan, Senior Research Fellow, Center for International Climate and Environmental Research-Oslo; Mr. Varghese Paul and Mr. Abhishek Kar Action Programmes Division, The Energy and Resources Institute, India Habitat Centre; and Tom Beer, David Batten, John Volkman, Graeme Dunstan, Susan Blackburn of CSIRO Energy Transformed Flagship, CSIRO Aspendale Laboratories, Australia for sharing and taking time from their hectic work schedules to draft and provide bioenergy experiences from their respective countries.

Also, ESCAP-APCAEM is grateful to all who provided substantive participation including FAO, UNDP, UNEP, UNIDO and bilateral development organizations and the private sector at the Regional Forum on Bioenergy Sector Development, Concentrating on Challenges, Opportunities and the way forward this past January 2008 in Bangkok.

This publication has been prepared by ESCAP-APCAEM under the direction of Joong-Wan Cho, former Head, and Amitava Mukherjee, Head, ESCAP-APCAEM.

The publication received editorial support, additional drafting, and formatting by Eric Roeder with input from Kyu-Hong Choi. Additional support was provided by Ms. Zhaorui Meng and the cover design by Wei Zhen.

BIODIESEL FROM ALGAE

Tom Beer[1,2], David Batten[1], John Volkman[2], Graeme Dunstan[2], Susan Blackburn[2]

1. CSIRO Energy Transformed Flagship

CSIRO Aspendale Laboratories

PN1, Aspendale, Vic. 3195

Tel: +61 3 9239 4400 Fax: +61 3 9239 4444

Tom.beer@csiro.au

2. CSIRO Marine and Atmospheric Research

Executive Summary

Worldwide interest in producing biofuels from biomass is growing rapidly. There are several reasons for this, including:

- Global warming associated with higher levels of GHG emissions
- The onset of peak oil in a global economy
- National energy security concerns, and
- Perceived opportunities for more sustainable regional development.

Interestingly, algae produced most fossil fuels in the first place. Given that microalgae are so diverse, pervasive, productive and less competitive with other plants as a source of food for human consumption, it is hardly surprising that their popularity is growing. Whilst microalgae are aquacultured to produce various high-value foods, nutraceuticals and chemicals, the methods adopted have not yet been shown to be economically and ecologically viable for the production of biodiesel in quantities large enough to replace fossil fuels. Several challenges remain to rectify this, including the following:

- Lack of sufficient suitable land having near optimal climatic conditions, as well as
    - necessary nutrient media sources nearby and
    - supporting industry, infrastructure and transport facilities
- Sub-optimal level of control of variables in open systems
- Diurnal, seasonal and climatic variation
- Biological contamination of algal media
- Sub-optimal algal strain selection, mix and modification
- Lack of any high-level life cycle analysis of GHG emissions
- Difficulties in scaling-up from small-scale photobioreactors to commercially-viable production facilities

Without further research and a high degree of product innovation, most dedicated algae-to-biodiesel projects also face uneconomically high costs for:

- Site acquisition and preparation
- Bioreactor construction materials
- Construction, deployment and reconstruction
- Chemical and energy inputs
- Algal harvesting, dewatering and concentration
- Lipid extraction
- Biodiesel and by-product processing
- Surveillance, process control and maintenance
- Transport

Introduction

Though it is possible to produce biofuels, primarily ethanol, from macroalgae (seaweed) this paper will primarily discuss the possibility of obtaining a diesel-like fuel from microalgae. Certain species of microalgae offer the possibility of a sustainable, low GHG emissions feedstock for the production of biofuels that

- grows rapidly
- yields significantly more biofuel per hectare than oil plants
- can sequester excess carbon dioxide as hydrocarbons
- contains no sulfur and has low toxicity
- is highly biodegradable
- does not compete significantly with food, fibre or other uses
- does not involve destruction of natural habitats

Microalgae contain lipids and fatty acids as membrane components, storage products, metabolites and sources of energy. When grown under standard, nutrient-replete conditions, microalgae show large differences in percentages of the key macronutrients: by dry weight, typically 25 per cent to 40 per cent of protein, 5 per cent to 30 per cent of carbohydrate and 10 per cent to 30 per cent of lipids/oils. Species containing considerably higher oil content have been found and more than a dozen algal species have been mentioned as possible candidates for producing biodiesel. A summary of some of the leading biodiesel candidate species found to date can be found in Appendix 1.

Microalgae, which produced most fossil fuels originally, need light, nutrients and warmth to grow. On a large-scale, this occurs naturally in bogs, marshes and swamps, salt marshes or salt lakes. Smaller-scale sources include wastewater treatment ponds, animal waste and other liquid wastes. When algal growth conditions exist, the steps involved in producing biodiesel from the algae are shown in Figure 1.

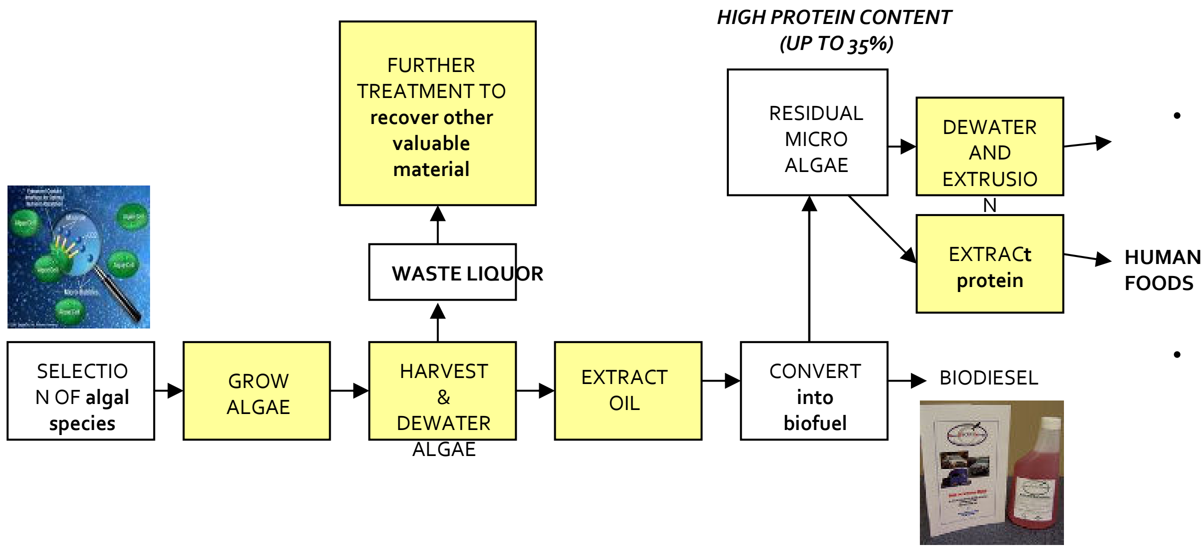


Figure 1: Algae to Biodiesel Pathway

Microalgae are diverse, pervasive, productive and less competitive with other plants as a source of food for human consumption. Though microalgae are aquacultured widely to produce various high-value foods, nutraceuticals and chemicals, the methods adopted have not yet been shown to be economically and ecologically viable for the production of biodiesel in quantities large enough to replace fossil fuels.

Review of Past Activities

Over the past four decades, a significant amount of research has examined the potential of microalgae for the production of usable biomass and to sequester CO_2-rich flue gases from power plants (for a review, see Stepan et al., 2001). Microalgae as a source of energy were first explored following the oil crisis of the 1970s by the US Department of Energy, starting with R&D at the University of California, Berkeley on microalgae wastewater treatment, with the harvested algal biomass to be converted to methane gas through anaerobic digestion (Benemann et al., 1977). Via the National Renewable Energy Laboratory (NREL), the Aquatic Species Programme (ASP) ran from1978 until 1996 to study the feasibility of using algae grown in ponds and using CO_2 from coal-fired power plants to produce biodiesel. In 1998 NREL published *A Look Back at the US Dept of Energy's Aquatic Species Programme: Biodiesel from Algae* (Sheehan et al., 1998). While microalgae can offer good oil profiles for biodiesel, the cost of production was (and still is) a major impediment. However, NREL considered that algae have the potential to provide substantially more biodiesel than oilseed crops and in addition, land and water resources are not impediments. As part of the ASP, microalgal strains were isolated, characterized and tested. Some of these strains are still available from the University of Hawaii but, since none of them are Australian, they may be inappropriate for Australian conditions under current quarantine regulations.

In Japan, the Marine Biotechnology Institute (MBI) patented two microalgae suitable for this use (JP3509902-B2, JP3459275-B2, 1993) as they are capable of enhanced growth in the harsh environment typical of water enriched with waste gases from power plants and other factories (high CO_2, SO_2 and extreme pH). Also, they are considered a viable method for reducing CO_2 emissions to the atmosphere. Further work by the MBI has resulted in the development and optimization of highly efficient photobioreactors capable of high levels of CO_2 conversion to biomass.

Economical assessments of photobioreactors have indicated that CO_2 mitigation from power plants using microalgae would be more economical when combined with co-products like biofuels (Ono and Cuello, 2006). Research comparing different sources for fuel derivations found that one microalgal species but not another would produce net renewable energy for a 100MW coal-powered thermal plant (Sawayama et al., 1999), showing that microalgal species selection, based on chemical composition and growth characteristics is very important with respect to potential economic gains. A commercial scale experiment (2ha) combining photobioreactors and open pond culture for CO_2 mitigation and bioduel production by a selected species of microalgae has shown that significant reductions in fossil fuel use and CO_2 emissions can be achieved, while using less land space than terrestrial land plants to produce equivalent yields (Huntley and Redalje, 2006). Similarly, it was suggested that microalgae would be the only viable source of renewable biodiesel capable of replacing existing supplies of transport fuels (Cristi, 2007).

The current intense interest in microalgae as a source of biofuels and GHG mitigation led the International Network on Biofixation of CO_2 and Greenhouse Gas Abatement http://www.co2captureandstorage.info/networks/networks.htm to publish a report *Microalgae Biofixation processes: applications and potential contributions to Greenhouse Gas Mitigation Options* (Van Harmelen and Oonk, 2006). This report recommended that in the short term (5 to 20 years) the use of microalgae for GHG mitigation and biodiesel production should be in conjunction with co-applications such as wastewater treatment processes for removal and recovery of nitrogen and phosphorous, thus providing an economic nutrient source for algal growth. In the mid term (10 to 20 years), it was recommended that GHG mitigation and biodiesel be combined with production of high value co-products, with the potential for stand alone dedicated biofuel production being a long term (20+ years) prospect.

Recently, NREL announced that it would collaborate with US major oil company Chevron on research into producing road fuel from algae. Although no one has yet proven microalgae to be an economic proposition at a commercial scale, a number of companies including private equity-backed, US-based GreenFuel Technologies are conducting research. Also, Royal Dutch Shell announced that it would fund a project that aims to produce transport fuel from algae, as biofuel production from palm oil and crops are increasingly criticised for causing deforestation and higher food prices. Shell said it will build a pilot facility in Hawaii to grow marine algae from which it will extract vegetable oil that will be converted into a form of diesel for use in trucks and cars. This plant would only use non-genetically modified algae.

On the genetic front, genome analysis of Chlamydomonas, a green alga, by Merchant et al. (2007) has uncovered hundreds of genes that are uniquely associated with carbon dioxide capture and generation of biomass. Among the 15,000-plus genes revealed in the study are those that encode the structure and function of the chloroplast, the specialized organelle that houses the photosynthetic apparatus that is responsible for converting light to chemical energy.

In Australia, a company called BioMax, a subsidiary of The Victor Smorgon Group, is trying to use algae from Cherry Lake in Altona to produce biodiesel. BioMax has licensed an algae based emissions-to-biofuels technology from Greenfuels in the United States and is trialing the Greenfuels technology at the Hazelwood power station. Their Hazelwood trials will use power plant flue gas to convert CO_2 and NOx into lipids, protein and carbohydrates, with the latter two becoming animal feed. At the research level, the South Australian Research and Development Institute (SARDI) received funding to establish a National Photobioreactor Facility in South Australia.

Current Technical Challenges

Several major challenges lie ahead, including the following:

- Lack of sufficient suitable land having near optimal climatic conditions, as well as
    - necessary nutrient media sources nearby and
    - supporting industry, infrastructure and transport facilities
- Sub-optimal level of control of variables in open systems
- Diurnal, seasonal and climatic variation
- Biological contamination of algal media
- Sub-optimal algal strain selection, mix and modification
- Lack of any high-level life cycle analysis of GHG emissions
- Difficulties in scaling-up from small-scale photobioreactors to commercially-viable production facilities

Without further research and a high degree of product innovation, most dedicated algae-to-biodiesel projects also face uneconomically high costs for:

- Site acquisition and preparation
- Bioreactor construction materials
- Construction, deployment and reconstruction
- Chemical and energy inputs
- Algal harvesting, dewatering and concentration
- Lipid extraction
- Biodiesel and by-product processing
- Surveillance, process control and maintenance
- Transport

Regional Advantages

A major variable limiting algal production processes is climate, as defined by temperature, sunlight and moderate seasonality. Locations with suitable climatic conditions are those areas with annual average temperatures of 15ºC or higher (van Harmelen and Oonk, 2006). These include Mexico, the southern parts of the United States and Asia and most of South America, Africa and Australia. The suitable areas are the tropical or dry zones in Figure 2. As minimum winter and night-time temperatures are the real limiting factors, Australia, South-east Asia and the Pacific may possess a competitive advantage over several other candidates for microalgal growth on a large scale.

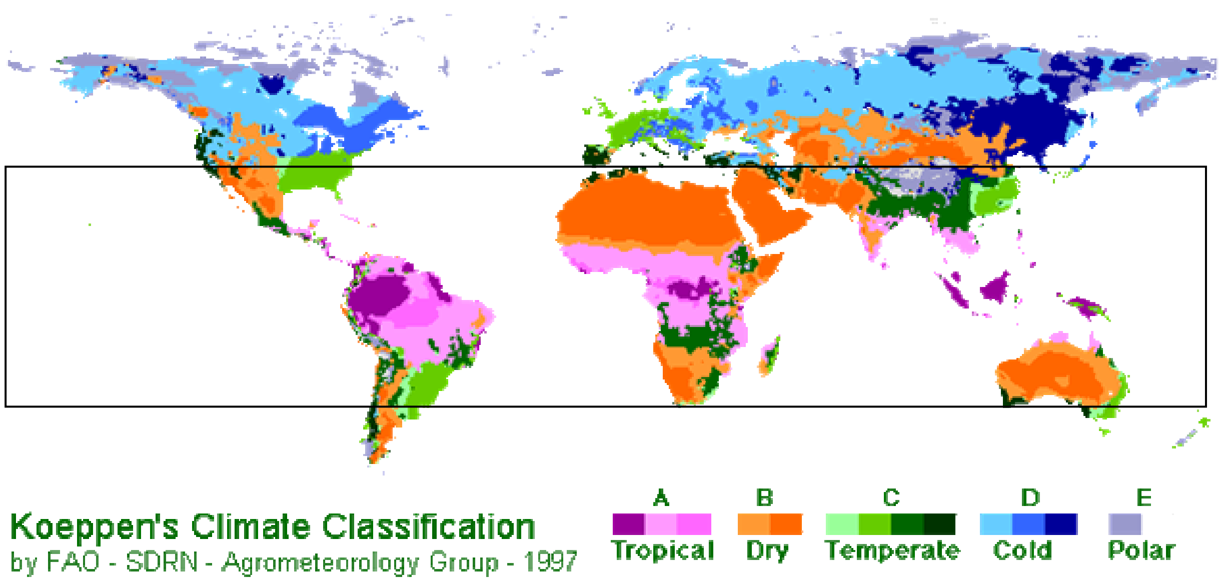


Figure 2: Suitable Climatic Conditions for Microalgae Processes

Additional resource requirements are suitable (currently uneconomic) land, saline or waste water and CO_2. van Harmelen and Oonk, 2006, (page 30) consider that the most suitable sites for the initial application of microalgae mass cultures for biofuels production and GHG abatement are locations such as sewage farms or animal feed lots where human, animal and some industrial wastes contain sufficient nutrients (mainly nitrogen & phosphorus) for algal growth. They propose a set of criteria for such operations and find South-East Asia – from China to Indonesia - to be suitable for practical production of microalgae from human wastes and from pig wastes.

In addition, within Australia, CSIRO, which is the Australian Government's scientific and industrial research agency has expertise in: Algal Selection and Optimisation, Algal Dewatering, Algal Biorefinery and Potential Co-product Utilization, Microbial Biomass for Stationary Energy Production, and in Thermal and Fluids Engineering – all of which can be applied to the production of biodiesel from algae.

References

Benemann, J.R., Weissman, J.C., Koopman, B.L. & Oswald, W.I. (1977): Energy production with microalgae, *Nature* 268: 19-23.

Benemann, J.R. (2003): Biofixation of CO_2 and greenhouse gas abatement with microalgae: technology roadmap. Report submitted to the U.S. Department of Energy, National Energy Technology Laboratory under subcontract agreement 7010000926.

Carlsson, A., van Beilen, J.B., Möller, R. and Clayton, D., (2007): Micro- and macro-algae: utility for industrial applications, Report from the EPOBIO project, CPL Press, UK.

Cristi, Y. (2007): Biodiesel from microalgae. *Biotechnology Advances* 25; 294-306.

Dimitrov, K. (2007): Greenfuel technologies: a case study for industrial photosynthetic energy capture, mimeo.

Huntley, M.E. and Redalje, D.G. (2006): CO_2 mitigation & renewable oil from photosynthetic microbes: a new appraisal, in *Mitigation and Adaptation Strategies for Global Change*, Springer-Verlag.

Merchant, S.S., Prochnik, S.E.,Vallon, O. et al. (2007) The chlamydomonas genome reveals the evolution of key animal and plant functions, Science 12 October 2007: Vol. 318. no. 5848, pp. 245 – 250 DOI: 10.1126/science.1143609

Miao, X. and Wu, Q. (2004): High yield bio-oil production from fast pyrolysis by metabolic controlling of *Chlorella protothecoides*. *J. Biotechnol*. 110; 85-93.

Ono, E. and Cuello, J. (2006): Feasibility of microalgal carbon dioxide sequestration technology with photobioreactor and solar collector. *Biosystems Engineering* 95: 597-606.

Qin, J. (2005): Bio-hydrocarbons from algae, Report for the Rural Industries Research and Development Corporation, RIRDC Publication No. 05/025.

Scragg, A.H., Morrison, J. and Shales, S.W. (2003): The use of a fuel containing Chlorella vulgaris in a diesel engine, *Enz. Microbiol. Technol*. 33; 884-889.

Sawayama, S., Minowa, T. and Yokoyama, S-Y, (1999): Possibility of renewable energy production and CO_2 mitigation by thermochemical liquefaction of microalgae. *Biomass and Bioenergy* 17: 33-39.

Sheehan, J., Dunahay, T., Benemann, J., Roessler, P. (1998): A look back at the U.S Department of Energy's aquatic species program: biodiesel from algae, National Renewable Energy Laboratory, Report NREL/TP-580-24190.

Stepan, D.J., Shockey, R.E., Moe, T.A., Dorn, R. (2001): Subtask 2.3 – Carbon dioxide sequestering using microalgal systems. Final Report prepared for US Department of Energy, Pittsburgh, PA.

Tredici, M.R. (1999): Bioreactors. In Flickinger, M C and Drew, S W (eds) *Encyclopedia of Bioprocess Technology: Fermentation, Biocatalysis, and Bioseparation*. John Wiley & Sons, pp. 395-419.

van Harmelen, T. and Oonk, H. (2006): Microalgae biofixation processes: applications and potential contributions to greenhouse gas mitigation options. In: International Network on Biofixation of CO_2 and greenhouse gas abatement with microalgae operated under the International Energy Agency Greenhouse Gas R & D Program, TNO.

Appendix 1: MICROALGAL YIELDS and other properties

Commercialisation of microalgae at an industrial scale for a variety of fine chemicals already occurs in Australia. For example, *Dunaliella salina* is grown in large ponds in WA and SA for production of astaxanthin, oil and algal meal (Cognis). Similarly, in the United States, a number of strains (including dinoflagellates, diatoms and a thraustochytrid) are grown in large-scale fermenters to produce oils tailored for high levels of key essential polyunsaturated fatty acids for human and animal nutritional supplements (e.g. Martek). These commercially viable microalgal based industries were made possible through targeted investment in research on algal species selection and optimising culture conditions. The use of microalgae for the commercial production of biodiesel in Australia will require similar investment in the research required to identify the most useful strains and to develop optimum culture conditions to maximise oil production.

Table 1 gives some of the strains that CSIRO (Hobart) has identified as having favourable characteristics for biodiesel production. They are all good oil producers, have favourable fatty acid compositions, are likely to be amenable to large-scale culture and harvest techniques and have had no reports of toxicity but reflect only a small sample of the potential range of possible algal species. There is the potential for higher lipid and fatty acid yields than the data presented in the table, by culture condition manipulation.

Table 1: Some candidate strains of microalgae for biodiesel production.

Species	Growth rates[1]	Lipid content: per cent dry weight	18:1 Fatty acids
Ankistrodesmus braunii		Up to 73 per cent	Up to 54 per cent
Chlorella protothecoides		Up to 58 per cent	Up to 61 per cent
Neochloris oleoabundans		Up to 54 per cent	Up to 36 per cent
Pleurochrysis carterae	Up to	Up to 50 per cent	Typically

[1] Growth rates in g l^{-1} d^{-1} are based on bioreactors. Growth rates in g m^{-2} d^{-1} are based on ponds.

	0.1 g $l^{-1}d^{-1}$		<10 per cent
Nannochloropsis spp.		Up to 41 per cent	Typically <12 per cent
Arthrospira (Spirulina) platensis		Up to 29 per cent	Typically <5 per cent
Tetraselmis suecica	Up to 19 g m^{-2} d^{-1}	Up to 25 per cent	Up to 16 per cent
Dunaliella tertiolecta		Up to 23 per cent	Typically <10 per cent
Nannochloris atomus		Up to 21 per cent	Up to 5 per cent
Euglena gracilis		Typically 14-20 per cent	Up to 13 per cent
Scenedesmus dimorphus	Up to 0.039 g l^{-1} d^{-1}	Up to 9 per cent	Up to 12 per cent

INDIA'S BIODIESEL PROGRAMME: SOME CRITICAL ISSUES

Mr.Varghese Paul
and
Mr Abhishek Kar

Action Programmes Division
The Energy and Resources Institute
India Habitat Centre
Lodhi Road
New Delhi-110003
Tel: +91-11-24682100/24682111
Fax: : +91-11-24682144/24682145
Email: 1)vpaul@teri.res.in
2)akar@teri.res.in

Executive Summary

Recognizing the need for energy security the Government of India has, in recent times, provided major emphasis on biofuels, particularly biodiesel. With the launch of the National Mission on Biodiesel, a large number of initiatives have happened across the country. However, there are some inherent deficiencies in the way the programmed has been conceptualized and implemented. This paper examines some of the deficiencies of the programme including the potential impact on forest conservation. The paper also examines the reasons behind much expected carbon trade not happening in the sector in India. Finally, the paper identifies actions which are critical in taking forward the biodiesel progarmme.

Introduction

India's economy grew at an annual average growth of 7.6 per cent during the planning period of 2002-2007. To deliver a similar but sustained growth rate of 8 per cent–10 per cent (the required growth rate if India has to eradicate poverty and meet its human development goals) till 2031/32 and meet the lifeline energy needs of all citizens, India needs, by a conservative estimate, 1.35 BTOE (billion tonnes of oil equivalent) of commercial energy by 2031/32 compared to the 2003/04 consumption level of 0.33 BTOE (Planning Commission, 2006). As the country is short of energy resources, there is a need to tap all energy options, notably renewables and nuclear power, and diversify the energy basket.

With poor crude oil reserve of only 0.5 per cent of the world's oil reserves, over 70 per cent of the oil demand is met through imports. The World Energy Outlook has forecasted that by 2030, 94 per cent of India's crude oil demand would be met by imports. In this context, energy security assumes significance in view of uncertainty of supply and increasing price of petroleum fuels.

Recognizing these and the need for ensuring access to energy for the poor, the Government of India (GoI) has, in recent times, provided major emphasis to biofuels, particularly biodiesel. Currently, country's bio-diesel programme is based on tree bore oil (TBO) derived from non-edible oil seeds, primarily *Jatropha curcas*.

In order to streamline the activities, a National Biodiesel Mission (NMB) has been constituted with the Ministry of Rural Development as the nodal agency. The NMB will be implemented in two phases. The first phase, consisting of setting up demonstration projects in both forest and non-forest lands , was proposed to be launched in 2003 and to be completed by 2007covering an area of 0.4 million ha. This phase was expected to yield about 3.75 tons of oil seed per hectare annually (Planning Commission 2003). The expected annual biodisel production from this phase was 0.48 million tons at the rate of 1.2 tonnes/ha/year. A transesterification plant of biodiesel production capacity 80,000 tonnes/year was to be set up as part of this phase. Because of a delay in necessary approval from the government and lack of funding, the work under this phase started only in 2006. The second phase (2007-12), designed as a self-sustaining expansion programme, aims to produce sufficient quantity of biodiesel to achieve a 20 per cent blend by 2011-12. This phase expects to cultivate around 11-13 million ha of wastelands with Jatropha. In addition to reducing import dependence and providing energy security, the other spin off benefits intended from the programme are revegetaion of a vast tract of wasteland , employment generation for the poor, environmental benefits like reduced carbon dioxide emissions and carbon trading.

Though there has been a lull at the central government level after the initiation of the mission, some state governments have taken very pro-active measures to promote bio diesel programmes in their respective states. Table 1 summarises major biodiesel initiatives by state governments. As perusal, the initiatives are at the early stage and there exists wide variations in the provisions of the policy, the institutional mechanisms as well as the target land for raising Jatropha. Though while both Chhattisgarh are Uttarakhand are targeting public-private partnership, the emphasis in Chhattisgarh is on revenue wastelands against degraded forest lands in Uttarakhand. While some of the states like Andhra Pradesh and Chhattisgarh has announced minimum support price for Jatropha and Pongamia, others are yet to do so.

Table 1: Steps taken by sate governments to facilitate biodiesel activities.

Source: Compiled from various state government websites

State	Initiatives
Andhra Pradesh	• Formulated a draft biodiesel policy to facilitate establishment biodiesel crops in approximately 0 .75 million ha under biodiesel crops. • Propose to set up a biodiesel board • A separate department to coordinate activities to raise biodiesel crops in 0/73 million ha of culturable wastelands • Announced a minimum support price (MSP) of Rs 6 for Jatropha seeds
Chhattishgarh	• Established an exclusive authority-Chhattisgarh Biodiesel Development Agency (CBDA) • MSP of Rs6.5 for Jatropha seeds • Joint Venture Company (JVC) with Chhattisgarh Renewable Energy Agency (CREDA) is the institutional mechanism for private sector investment in biodiesel activities. Revenue wasteland would be leased to JVCs
Orissa	• Declared a policy in August, 2007 for cultivating Jatropha in 2 million hectare of wastelands • Orissa Renewable Energy Development Agency (OREDA) will act as the Nodal Agency for bio-diesel development in the state. • The government will encourage private entrepreneurs to set up biodiesel units by providing back end credit and subsidy.
Rajastahan	• In January 2007, Rajasthan Government announced a draft biofuel policy for the state. • The Government has appointed Rajasthan biofuel Development Authority as the nodal agency
Tamil Nadu	• 50 per cent subsidy on planting material for Jatropha and other bio fuel crops • The subsidy available to agro-processing industry will be extended to biofuel and biodiesel extraction plants
Uttarakhand	• Established Uttarakhand Biodiesel Authority , with Forest Department as the facilitator • Biodiesel Development Activities would be undertaken on a public private partnership basis.

Though lots of advances have happened, there are some inherent deficiencies in the way the programme has been conceptualised and implemented like improper targeting of land, inadequate R&D, etc. This paper analyses the critical issues plaguing the programme and then comes up with recommendations to tackle those issues. It should be noted that this paper limits itself to first half of the value chain (till production of seed) in production of biodiesel and does not deal with issues related oil expelling, transeterication and, marketing

Issues Plaguing the Bio diesel Programme

Lack of standardized cultivation package

Though Jatropha has been grown as a fence crop or as small-scale plantations for local level applications in India, large scale plantations for biodiesel production is a recent phenomenon. Large-scale plantations are being established with out adequate research and development programmes. The current packages are not backed by scientific research, but on the basis of observations and speculations. Some key parameters, other than the quality of germplasm, which determine the yield and hence the economic viability of plantation are:

- Spacing: Irrespective of the soil conditions and water availability for irrigations the blanket spacing of 2 x 2 m or 2.5 x 2.5 m are currently recommended. Results coming from the field now indicates that
- Irrigation: The theory that Jatropha doesn't require irrigation has now been disproved. Many studies now indicate that irrigation would have a positive impact on seed yield (PRAYAS 2006; Puri and Swamy 2003). Initial results from a trial in Andhra Pradesh by The Energy and Resources Institute (TERI) corroborate this fact.
- Fertilizer application: The optimum fertilizer dosage for Jatropha has not been finalised. The other issue is whether chemical fertilizers are desirable from an energy and CO_2 perspective. Biofertilzers could be an alternative. Trials conducted at TERI indicate that seed yield and biomass increases by 30 per cent by application of mycorrhizal fertilizers (Adholeya and Singh 2006)
- Pruning: Pruning is a standard practice followed in many horticultural species to increase the number of branches and to induce and invigorate flowering and fruiting. But the extent of pruning varies from species and site conditions. This is true in case of Jatropha also.

Wide variation in yield and oil content

One of the key determinants of the economic viability of biodiesel production is the yield of seeds, which shows wide variation in case of Jatropha (table 2). The variation in yield can be attributed to difference in the soil conditions and the cultivation practices. But the most important factor is the variation among germplasms existing within the country.

Table 2: Variation in yield of Jatropha

Reference	Type of data	Reported yield on maturity
Agro-forestry Federation, Nashik (Patil and Singh 2003)	Primary data from block plantations	1.0-1.2 tonne/ha.
Planning Commission, 2003	Estimates for poor soil (Kutch)	1.6-2.5 tonne/ha.
	Estimates for average soil	3.3-5.0 tonne/ha.
Becker and Francis	Estimates for poor soils with low nutrient content	1.5-2.0 tonne/ha.
TERI (2005 a)	Estimates for rain-fed and irrigated conditions	3.0-5.0 tonne/ha.

Similarly there are wide variations in oil content as well. An analysis of various Jatropha collections across the country by The Energy and Resources Institute (TERI) has shown a variation in oil content from 25-38 per cent (Kaushik, 2006). National Oilseed and Vegetable Oils Development Board (NOVODB) reports oil content varying from 21-42 per cent.

While this large variation in germplasm offers scope for future breeding programme, the immediate problem is that with a large number of Jatropha nurseries mushrooming across the country it's the poor quality material which is often reaching the farmer's field. Currently there are no regulations on setting–up of nurseries and there are no quality control measures in place. This would have future implications on yield, oil content and the economy of the joint venture.

Over emphasis on one feedstock –Jatropha

The Indian biodiesel programme has been primarily based on Jatropha. This is due to the perceived advantages of Jatropha like wide adaptability, low requirement of water and fertilizers, pest resistance, high seed yield, easy propagation, not browsed by cattle, etc. Since some of these perceptions have been disproved, its time to look at other alternatives. Otherwise, very large scale monoculture plantations of single species may not be desirable from a biodiversity and sustainability point of view. An outbreak of pests and diseases could wipe out entire plantations in one stroke. Some alternatives that could be tried are Pongamia (*Pongamia pinnata*), Paradise tree (*Simarouba glauca*) and *Salvadora oleoides.* The major criticism against these crops have is their long gestation period for initial seeding. However, effective breeding programmes can address this. If one compares Jatropha with Pongamia, except for the gestation period, the suitability of Pongamia is as good as Jatropha (Table 3).

Table 3 : Comparison of Jatropha and Pongamia

Characteristics	Jatropha	Pongamia
Ecosystem	Arid to semi-arid	Semi-arid to sub-humid
Rainfall	Low to medium (200-1000 mm)	Medium to high (500 – 2500 mm)
Soil	Well drained soils	Tolerant to water logging, saline and alkaline soils
Nitrogen fixation	Nitrogen fixer	Fixes Nitrogen
Plant suitability	Wastelands, degraded lands, live fence for arable lands, green capping of bunds, shallow soils	Field boundary, nala bank stabilization, wastelands, tank foreshore
Plant habit	Mostly bush, can be trained as small tree	Tree can be managed as bush by repeated pruning
Leaves	Not palatable by livestock	Not palatable by livestock, used as green leaf mulch
Gestation period	Short, starts yielding during 3^{rd} Year, attains maturity at 6^{th} Year	Long, starts yielding after 4^{th} to 7^{th} year. Yield increases with increase in canopy.
Harvest	Fruits to be plucked	Fruits to be collected
Oil content	27-38 per cent in seed	27-39 per cent in kernel
Protein	38 per cent	30-40 per cent
Oil cake	As manure (4.4 per cent N, 2.09 P, 1.68 per cent K)	As manure (4.0 per cent N, 1.0 per cent P, 1.0 per cent K)
Fire wood	Not useful	Good as firewood, high calorific value 4600 K cal/kg

Source: TERI , 2005b

Are wastelands the right choice?

One of the major premises behind India's biodiesel programme has been the fact that wastelands are available and could be planted with Jatropha to produce biodiesel. Two questions arise here 1) whether wasteland to the extent envisaged is actually available, and 2) even if available whether plantations on wastelands would be able to realise the type of yield envisaged.

The NMB's estimates of production of biodiesel are based on an average seed yield of 3.75 tons/ha. But achieving this would require inputs like fertilizers and irrigation. TERI's experience in working with Jatropha in various parts of the country has revealed that 2-3 summer months of irrigation is very critical. Such irrigation may not be possible under the type of wasteland being targeted under the mission, and yield could be as low as 1.25-1.5 tonnes/ha. The original estimated amount of wasteland required for 20 per cent blending by 2011-12 is around 11 million ha. If the yield falls to 1.5 tonnes/ha, the area required for producing 20 per cent blend would increase to around 28 million ha.

Getting this much amount of wasteland would be difficult. The country has around 64 million ha of wasteland , out of which around 40 million ha have been considered suitable for Jatropha (Mandal and Mithra , 2006). It is this same amount of land which many other government programmes are targeting. To cite an example, India's forest policy mandates maintaining 33 per cent the geographic area of the country (328 m ha) under forests. The current forest and tree cover of the country is about 78.82 m ha (FSI 2005). The additional area that needs to be afforested/reforested would work out to 31 m ha. Land encroachment would further limit the availability of land (see Sudha et al 2003).

One can argue that Jatropha plantation can also serve the purpose of revegetating the wastelands. However, for this there are other better options available like planting of multi-purpose trees which can meet the fuelwood, fodder and timber requirements of the rural populace, which Jatropha doesn't provide. Further, pruning or cut-back of branches is essential for inducing fruiting in Jatropha with the result that the plant would remain bushy and never reach a tree height.

Impact of Jatropha cultivation on forest conservation

One of the important concerns at the global level is whether promotion of biofuels would lead to deforestation. While in India diversion of existing forests for raising Jatropha may not be possible, because of the stringent laws governing forests, there could be indirect factors affecting forest conservation due to promotion of biofuels, especially Jatropha.

As mentioned earlier, the Jatropha programme could be competing for the same wastelands that could be potentially afforested through forestry programmes, which would translate to a lost opportunity for increasing forest cover.

Targeting degraded forestland for raising Jatropha would also have an impact on forest conservation. For instance, in states like Uttarakhand the strategy for bio diesel production involves planting Jatropha in degraded forest lands through *Van Pancahayats* [2]. The state has drawn up an ambitious plan of raising Jatropha plantations in 0.2 million ha (Lohia 2006). Such plans for planting degraded forestland exist in states like Andhra Pradesh and Rajasthan. But for biodiesel crops, these lands would have been re-vegetated though traditional forestry species.

[2] A village level committee for managing forests.

The other aspect could be the spin-off impact on forests due to planting of Jatropha in wastelands, most of which are Common Property Resources (CPR) meeting the traditional needs of the local people. Many studies have indicated that CPRs are critical to the livelihoods of the rural poor in India and act as safety nets during agricultural crises (see Gundimeda ,2004). They provide a wide varsity of goods to the users like fuelwood, fodder, food, fibre, timber, etc. Analysis of various micro studies in India by Gundimeda (2004) indicates that CPRs provide around 12- 25 per cent of the household income of the rural poor. Raising Jatropha plantations in these lands could potentially exert pressure on the forest for meeting the fuelwood, fodder and timber requirements. Past experience shows that unregulated grazing and collection of fuel wood are the major contributors of deforestation and land degradation in India.

Carbon benefits from Jatropha; an expectation not realized

There has been much interest in India regarding carbon benefits from Jatropha- both carbon sequestration at plantation level as well as the emission reduction due to fuel switching from petro-diesel to biodiesel. However, not much has happened on both fronts until now.

In case of sequestration projects, the potential for carbon benefits under the Clean Development Mechanism (CDM) is very limited on various counts:

- The wood density of Jatropha is very low. Tests conducted in United States indicate that it ranges from 0.22-0.37 (Benge 2006).
- As per the forest definition communicated by GOI to United Nations Framework Convention on Climate Change (UNFCCC), crops must attain a height of 5m at maturity to qualify as forests. Though in certain cases, Jatropha is reported to attain a height of about 5-6 m, it is not always the case.
- For seed production purposes, Jatropha is normally subjected to heavy pruning. From second year onwards almost the entire plant is subjected to 70 per cent pruning to invigorate more branching and fruiting, with the result that the plant remains in a bushy form. This has two implications: firstly, the plant is not allowed to reach tree height (5m), secondly 70 per cent of the biomass is removed ever the year which needs to be deducted from the potential sequestration. Even if one assumes a higher biomass accumulation rate of 5 tonnes/ha/year, the net carbon sequestration rate is only 1.05 tonne C/ha/year (5 x 0.3x.7)

This brings out two issues, the eligibility of Jatropha to qualify as tree/ forest, and its low sequestration rate.

On the other hand, there is huge potential for fuel switching projects. For instance a Project Design Document (PDD) prepared by Southern Online Biotechnologies , based in Andhra Pradesh, estimates an annual emission reduction to the tune of 26,792 tonnes of CO_2 equivalent to replacing 9000 tonnes of petro-diesel used for transport by biodiesel (pdd available at http://cdm.unfccc.int/UserManagement/FileStorage/FS_686206579). The company aims to set-up a trasestetrification unit of 30 t/day or 9000 tonnes/year. The feedstock is a mix of Pongamia/Jatropha oil and animal fat. Pongamia/Jatropha to be grown on 1000 ha of land is expected to provide 6000 tonnes of vegetable oil from the fifth year of plantations. Around 9500 tones of vegetable oil is required to produce 9000 tones of biodiesel. The balance would be met from animal fat. The project proponents claim to have submitted a new methodology for this (The status of this methodology could not be ascertained from the CDM site of UNFCCC). Lack of appropriate methodology is the major stumbling block in realising the potential. An earlier methodology (NM0224) submitted by Naturol Bio-Energy Limited, for manufacture of biodisel from was rejected by the Method Panel on the following grounds:

- No consideration of avoidance of double counting at the end user level;
- Treatment of upstream components due to cultivation: Though the methodology included upstream components as project emissions, it did not consider components such as emissions from land clearance and field burning;
- Shift of pre-project activities: The methodology did not eliminate clearly shifting of agricultural activities, which was replaced by biodiesel plantations, to forest areas. The methodology also didn't consider or eliminate emissions from fertilizer application due to shift in pre-project activities.

Recommendations

The recommendations given below emanate from the issues identified in the previous section:

Need for a comprehensive R& D programme on biodiesel crops

As discussed earlier, the country has entered into a biodiesel programme without conducting adequate research. It is high time coordinated research is undertaken on the following issues with respect to biodiesel crops.

- Breeding programme to produce high yielding varieties with high oil content and;
- Breeding programmes to reduce the gestation period, especially for long gestation crops like Pongamia.
- Development of varieties that can tolerate adverse conditions like frost, saline and alkaline conditions, water logging and etc;
- Development of a package of practices like optimum spacing under various agro- climatic conditions, quantum of inputs needed like irrigation, fertilizers, and pruning protocol.

A balanced approach: targeting both wastelands and agricultural lands

The Indian biodiesel programme needs to adopt a rational approach of targeting both wastelands and agricultural lands As discussed earlier, there would be problems with availability of wastelands, yield of crops grown in wastelands, and also issues related to loss of immediate livelihood opportunities to people depending on wastelands and indirect pressure on forests. Since the country has taken a decision to go ahead with biodiesel crops, the other option left with is to explore agricultural land in way that it does not interfere with crop production. India has around 143 million ha under agricultural crops and around 13 million ha of agricultural land, which are lying fallow, a part of which could be tapped for raising biodiesel crops. While planting of Jatropha along the bunds is an obvious choice, intercropping with agricultural as well as horticultural crops is also feasible. Care should be taken to adopt a wider spacing, say 5x 2m, so that the farmer can continue growing agricultural crops even after introduction of biodiesel crops. Pure block plantation of Jatropha should be discouraged, as it would divert land from agriculture.

Farmer-industry tie up : the key to success of biodiesel programmes

Participation of the private sector in an active way is key to the success of the biodiesel programme, in addition to tie up with farmers. Their participation is important in terms of investing in research activities related to biodiesel crops and also entering into meaningful partnership with farmers. Private companies can enter into contract farming with farmers, where the company improved planting material and technical support to the farmers and also arranges loans and microcredit to the farmers. There could be partnership with out buy-back agreements. Success stories of both models are available within the paper and pulp industry in India.

The approach followed by ITC Bhadrachalam Paperboards Limited for sourcing raw material for its pulp and paper mill is a highly successful model. ITC invested in R&D on developing high yielding, disease resistant clones for Eucalyptus. ITC now produces these saplings using modern nursery technology and these plants are sold to interested farmers. The company also provides technical guidance to the farmers on all aspects (see Saigal *et al* , 2002).

There could be other institutional arrangements for managing biodiesel plantations like formation of farmer's cooperative and producer groups. However, the farmer-industry tie-up is important in terms of investment by private sector in R&D activities related to Jatropha. This is critical considering the poor status of R&D in the sector.

References

Adholeya A and Singh R. 2006., *Jatropha for wasteland development: TERI's mycorrhiza technology*In *Biofuels : towards a greener and secure energy future*, pp 137-154, edited by P P Bhojvaid. New Delhi. TERI Press. 281 pp.

Becker K and Fracis G. 2005., *Biodiesel from Jatropha plantations on degraded land* University of Hohenheim, Stuttgart, Germany.

Benge M. 2006., *Assessment of the potential of Jatrpha curcas, (biodiesel tree,) for energy production and other uses in developing countries* http://www.echotech.org/mambo/_Toc143683346 (accessed on.2/11/08).

FSI. 2005,.*State of Forest Report 2003*. Dehradun. Forest Survey of India. 134 pp.

Gundimeda H. 2004., *How 'sustainable' is the 'sustainable development objective' of CDM in developing countries like India?Forest Policy and Economics* 6 (2004) : 329-343., Kaushik, 2006

Adholeya A and Singh R. 2006., *Quality considerations in Jatropha curcas* In *Biofuels : towards a greener and secure energy future*, pp 173-180, edited by P P Bhojvaid. New Delhi. TERI Press. 281 pp.

Lohia A K. 2006., *Jatropha for sustainable employment, energy security, and for checking soil erosion.* In *Biofuels : towards a greener and secure energy future*, pp 255-262, edited by P P Bhojvaid. New Delhi. TERI Press. 281 pp.

Mandal R and Mithra P. 2006., *The Indian biofuels programme : the National Mission on Bio-diesel.* In *Biofuels : towards a greener and secure energy future*, pp 13-22, edited by P P Bhojvaid. New Delhi. TERI Press. 281 pp.

Planning Commission. 2006., *Integrated Energy Policy:report of the expert committee.* New Delhi. Planning Commission, Government of India.148pp.

Planning Commission. 2003., *Report of the Committee on Development of Biofuel* New Delhi. Planning Commission, Government of India

PRAYAS. 2006., *Jatropha in Horticulture Program of Employment Guarantee Scheme* Pune. Prayas. 56 pp.

Puri S and Swamy S L. 2003., *Does Jatropha Warrant Increased Scientific and Financial Inputs* Paper presented at the Workshop on "Jatropha and Other Perennial Oilseed Species' organised by BAIF, Pune.

Saigal S, Arora H, and Rizvi S S. 2002., *The new foresters: the role of private enterprise in the Indian* *forestry sector Instruments for Sustainable Private Sector Forestry series*. New Delhi, London, Nottingham: Ecotech Services, International Institute for Environment and Development, Russel Press. 192 pp.

Sudha P, Somashekhar H I, Rao Sandhya, and Ravindranath N H. 2003., *Sustainable biomass production for energy in India.Biomass and Bioenergy* (25) : 501-515

TERI (The Energy and Resources Institute). 2005a., *Critical Review of the Indian Biofuels Programme.* New Delhi: TERI

TERI (The Energy and Resources Institute). 2005 b., *Bio-fuel for transportation:India country study on potential and implications for sustainable agriculture and energy*. New Delhi: TERI.107 pp.

Websites

http://cdm.unfccc.int/UserManagement/FileStorage/FS_686206579 (accessed on 10/01/08)

http://cdm.unfccc.int/UserManagement/FileStorage/CDMWF_PDRFCBCPRM5D1NLQF3WR22R18AUNPV (accessed on 10/01/08)

AN OVERVIEW OF BIODIESEL TRANSESTERIFICATION TECHNOLOGY IN INDIA

Anandajit Goswami,
Associate Fellow,
Centre for Global Agreements, Legislation and Trade,
Resources and Global Security Division

The Energy and Resources Institute
Darbari Seth Block
IHC Complex,
Lodhi Road, New Delhi – 110 003
Tel.: 24682100 / 41504900 Extn. : 2355
Fax : 24682144 / 24682145
E-mail : anandjit@teri.res.in

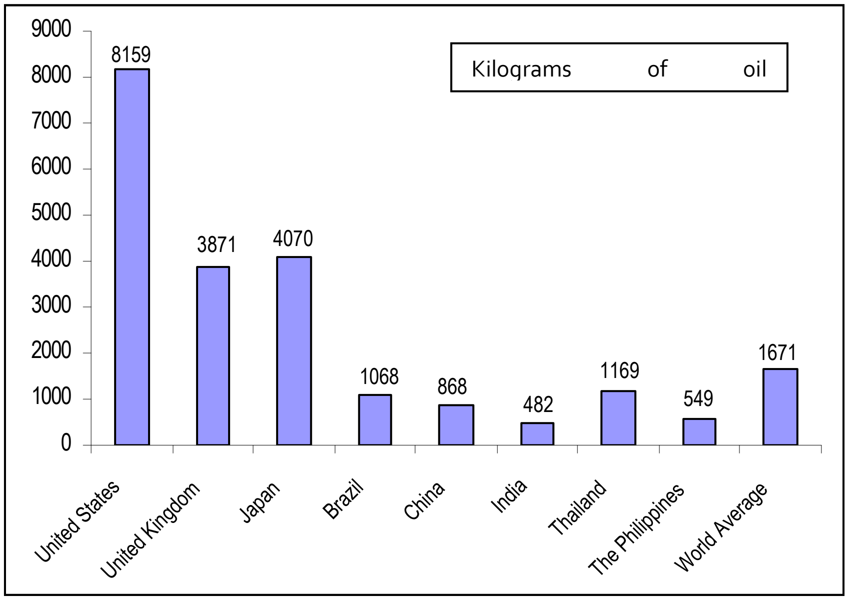
Executive Summary:

Alternative fuels like biodiesel from feedstocks like jatropha, karanja, pongamia are being seen as an option for blending with diesel to mitigate environmental pollution and foreign exchange risks. In India the National Mission on Biodiesel in 2004 stated the importance of biodiesel as a blending option with diesel to reduce environmental pollution and foreign exchange risks of India. In order to produce biodiesel one needs extracted raw oil as a feedstock that is then transesterified to produce biodiesel. An efficient transesterification technology is an important factor for producing biodiesel that matches international standards. In this context this article deals with an overview of the status of transesterification technology for biodiesel production in India. The article highlights the types and features of the available technology for transesterification in India. Further the article highlights the challenges faced by these technologies and thereby concludes with the way forward to move in the transesterification technology front of biodiesel production.

Introduction:

The growing Indian economy faces the critical challenge of meeting rapidly increasing demands for energy for fuelling its economic growth. India ranks sixth in the world in terms of energy demand accounting for 3.61 per cent of global energy. However amongst the countries considered for comparison in the figure below, India has the lowest per capita energy consumption at 482, compared to that of the biggest consumer – the United States at 8159 and the world average of 1671 Kgs of Oil equivalent per capita.

Figure 1. Comparison of per capita energy consumption of countries (1999)



Source. The World Bank 2002

As the Indian economy is projected to grow 7 per cent - 8 per cent over the next two decades and is expected to reach double-digit growth figures, there most likely will be a substantial increase in the demand for energy. Assuming an average GDP (Gross Domestic Product) growth rate of seven per cent, the average annual per capita income would almost double by 2011 leading to a rise in per capita energy consumption. The question is what is the supply side potential to match this demand for energy consumption in India?

On the supply scenario, indigenous production of commercial energy in India increased from 74 MTOE in 1980-81 to about 196 MTOE in 1999-2000, registering an annual average growth rate of about 5.3 per cent. The country's energy supply profile has been primarily dominated by coal. However, the share of oil and gas in the country's primary energy production has been rising rapidly and increasing from 17 per cent in 1970/71 to about 28 per cent in 1999/2000. However, on account of production constraints, coal availability is likely to be well below demand in the foreseeable future. The Working Group on Coal and Lignite for the Tenth Five-Year Plan estimates that by the end of the Eleventh Plan the demand for coal would go to 620 MT as against availability at 515 MT. In fact, recent analysis undertaken by the Central Mine

Planning and Design Institute suggests that current coal reserves may only last another 40–50 years. While India has sufficient reserves of coal for its immediate needs, it is relatively poor in oil and gas reserves. The only major shift in the country's oil import pattern has been reduction in imports of petroleum products due to growth in the number and production capacities of oil refineries. Crude oil imports, today, however, account for over 70 per cent of consumption. The gap between energy demand and domestic production is likely to widen if the present trends continue, leading to a growing dependence on energy imports. The current import dependence in Petroleum is to the tune of 70 per cent and the World Energy Outlook has projected that by 2030, India would be consuming 5.6 million barrels of oil/day, out of which 94 per cent will be met by imports. At that stage, India would become major importer in the global oil market and any fluctuation in price or any problems that affect continuous supply of oil can have serious impact on the national economy.

The country therefore faces a pressing need to examine various options in alternative fuels like biofuels that can not only address the issue of rising oil imports and costs, and reduce import dependence, but also address the growing public concern of climate change due to increasing carbon emissions. It is in this context that domestically produced Biodiesel becomes strategically important for the nation. The availability of biodiesel in the country and its blending with petro diesel will create a positive impact on the nation in terms of energy security and environmental amelioration, in addition to other benefits such as generating large scale employment, and contributing to the overall developmental process in the country, especially in the rural areas. However much of biodiesel sector development depends on the availability of the technology for biodiesel production in India. It is imperative to have efficient technology for biodiesel production that meets international standards. A glimpse of the details of the technology available worldwide for biodiesel production is given in the table below:

Plant		**A**	**B**	**C**	**D**	**E**	**F**
Process		*batch*	*batch*	*cont*	*batch*	*cont*	*cont*
Investment	Ill. DM	3,0	20,0	2,5	25,0	50,0	20,0
Capacity	**t/yr**	**2,000**	**15,000**	**8,000**	**75,000**	**125,000**	**80,000**
Daily capacity	T/d	10	50	20	200	350	250
Oil quality		Ref. Deg.	Ref. Deg.	Crude/ref.	Ref. Deg.	Ref. Deg.	Crude/ref.
Glye prep.	Cont. per cent	60	80/99.9 per cent	80	90	92	80/99.7
Personnel		3	8	6	15	20	12
Veg oil. ref. Deg.		2,100	15,600	8,240	77,250	131,250	77,250
in per cent of		105	104	106	103	105	103
Bio-diesel tonne/yr		2,000	15,000	8,000	75,000	125,000	75,000
Glycerol 99.5/80/60		0	1.295	783	7.339	12.469	6.953
per cent of OIL ref. deg.		0.00	8.30	9.50	9.50	9.50	9.00
Facids 80 per cent		80	480	192	1.800	5.000	1.800
Electr. 0.16 DM/kWh	Kwh/t	105	75	40	60	60	30
Steam 30,0 DM/t	Kg/t	650	650	300	600	1200	350
Methanol 30/26 DM per centKg	Kg/t	156	120	120	120	115	115
Catalyst 85/180 DM per centKg	Kg/t	14	10	4	4	3	4
Phosph. Acid 75 DM per centKg	Kg/t	43	43	10	10	10	10
Adsorbant 1.10 DM/Kg	Kg/t	0	0	5	0	0	5
Deprec. (10 yr)	DM/t	150.00	133.33	31.25	33.33	40.00	26.66
Interest 6.0 per cent (1/2)		45.00	40.00	9.38	10.00	12.00	8.00
Personnel		120.00	42.67	60.00	16.00	12.80	12.00
Methanol		46.80	36.00	31.20	31.20	29.90	29.90
Energy + Chem		93.45	80.25	35.20	41.90	57.30	31.70
Maint. 3 per cent		45.00	40.00	5.00	10.00	12.00	10.00
Overheads		75.00	20.00	15.00	10.00	10.00	10.00
Total operating costs	**DM/t**	**575**	**392**	**187**	**152**	**174**	**128**
- Glycerol 125/60		0	-108	-59	-59	-60	-109
- Facids. 55		-22	-18	-13	-13	-22	-12
- Loss of OIL 90		45	36	27	27	45	25

Surcharge in oil base	**DM/t**	**598**	**303**	**142**	**108**	**137**	**33**

SOURCE: Bio-diesel in Europe 1998, Bio-diesel Processing Technologies by J Connemann, J .Fischer

The front-runners amongst the technology providers who are associated with the mentioned modes of biodiesel production across the world are as follows:

Front-runners in the technological fields

Company	**Technology description**
Ballestra, Italy	Continuous trans-esterification process developed in the early 1980s.
BDT Biodiesel Technologies, Austria	Continuous two-stage alkaline re-esterification in a compact production unit built into a 20-foot (ft.) container.
Biodiesel Industries, U.S.	Modular production units (MPUs) fitting into a standard 40 ft. container, utilizing a wide range of feed stocks to produce upto three million gallons per year.
Biodiesel International, U.S	Process technology including fresh plant oils, waste cooking oils, and animal fats that integrates a fully automatic PLS-controlled production of biodiesel.
Biosource Fuels, LLC, U.S.	Proprietary multi-feedstock technology for the production of methyl esters and glycerol from all feedstocks including vegetable oils, animal fats , recycled fats etc. Process is continuous with biodiesel distillation, full co-product recovery, and fully automated plants.
BIOX Corporation, Canada	A patented biodiesel technology developed at the University of Toronto, capable of converting any lipid-based feedstock containing from zero to 30 per cent FFA into biodiesel on a 1:1 yield.
Crown Iron Works Company, U.S.	Continuous process for base catalyzed trans-esterification of neutral oil.
Energea Biodiesel Technology, Austria	Multi-feedstock continuous trans-esterification and esterification process. Optional pre-esterification module is especially suited for yellow grease. Skid mounted, modular construction with double redundancy on all moving parts. State-of-the-art

	computer automation allows for theoretical one-man operation (safety regulations permitting) and on-the-fly adjustment of variable feedstock.
Imperial Western Products, Inc., U.S.	Batch plant production of esters and glycerin using low temperature and pressure.
Lurgi PSI, Inc. U.S.	Continuous trans-esterification process using patented reactors and glycerin systems.
Pacific Biodiesel, Inc. Hawaii.	Efficient batch process biodiesel plant available in 400,000 gallon per year increments.
Superior Process Technologies, U.S.	Continuous processing plants for production of ASTM D6751-02 and DIN 51606 quality biodiesel from animal, vegetable, and recycled oil feedstocks. Process includes full recovery, purification, and recycle of excess methanol. Batch processing designs available for low capacity plants. Glycerins processing to 99.7 per cent USP grade and biodiesel product distillation are both available if desired.

Source – Author's Compilation

Other than the above-mentioned players some other notable players in this field are Italian processes Novamont and Ballestra, the French IFP, the German Henkel and ATT . A number of units are manufacturing bio-diesel worldwide using sunflower oil, soyabean oil, vegetable oil, used-frying oil, and jatropha oil. A total of 85 plants are operating on a global scale including a few pilot plants, over 30 small capacity plants (500-3000 tonnes) mostly with farmers' co-operative as owner and several big plants in the capacity range of 10,000 to 120,000 tonnes. Of these, 44 plants are in Western Europe with Italy as the leading country with 11 plants, 29 plants in Eastern Europe with Czech being the leading country with 16 plants, 8 plants in North America and 4 plants in the rest of the world. The United States is the fastest growing newcomer and a number of companies are emerging there. Additional capacities are expected in Japan and palm oil producing countries like, Indonesia and Malaysia. The table below gives the number of plants, production capacity and feedstock oil used in various countries.

Country wise capacity of the bio-diesel plants

Country	*Number of plants*	*Total annual capacity 'ooo tonnes*	**Oils used**
Austria	11	56.2 to 60	Used frying oil

Belgium	3	241	
Canada	1		
Czech republic	17	42.5 to 45	Used frying oil
Denmark	3	32	
France	7	311.1	
Germany	8	207	
Hungary	17	111.8	
Ireland	9	5	Used frying oil
Italy	9	779	Sunflower oil
Nicaragua	1		Jatropha
Slovakia	10	50.5 to 51.5	
Spain	1	0.5	
Sweden	3	75	
Switzerland	1	2	
U.K.	1		
U.S.A.	40	190	Used frying oil
Yugoslavia	2	5	

SOURCE - Detailed project report for the National Mission on Bio-diesel New Delhi: The Energy and Resources Institute TERI Report NO – 2004 CM24

However, the Indian scenario for biodiesel production technologies has the following characteristics.

Available bio-diesel production technologies

Company	**Reaction conditions**			
	P (atm)	**Temp(° C)**	**Catalyst**	**Mode of operation**
Transesterification				
Comprimo / Vogel and Noot	1	Ambient	KOH	Batch
Idaho university	1	Ambient	KOH	Batch
Novamont / Technimont	1	> Ambient	Organic	Batch
Conemann / Cold and Hann	1	60-70	NaOH	Continuous
Lurgi	1	60-70	Alkaline	Continuous
IFP / Sofiproteal	1	50-130	Alkaline/ Acid	Batch
Gratech	11.5	95		Continuous
Desmet	50	200	Non alkaline	Continuous
IICT, Hyderabad			Catalyst free	Batch

Company	Reaction conditions			
	P (atm)	**Temp(° C)**	**Catalyst**	**Mode of operation**
IIP Dehradun			a. Base catalyst b. Acid catalyst	Batch
Punjab University	1	55-60	NaOH pellets	Batch

Source: Detailed project report for the National Mission on Bio-diesel New Delhi: The Energy and Resources Institute TERI Report NO – 2004 CM24

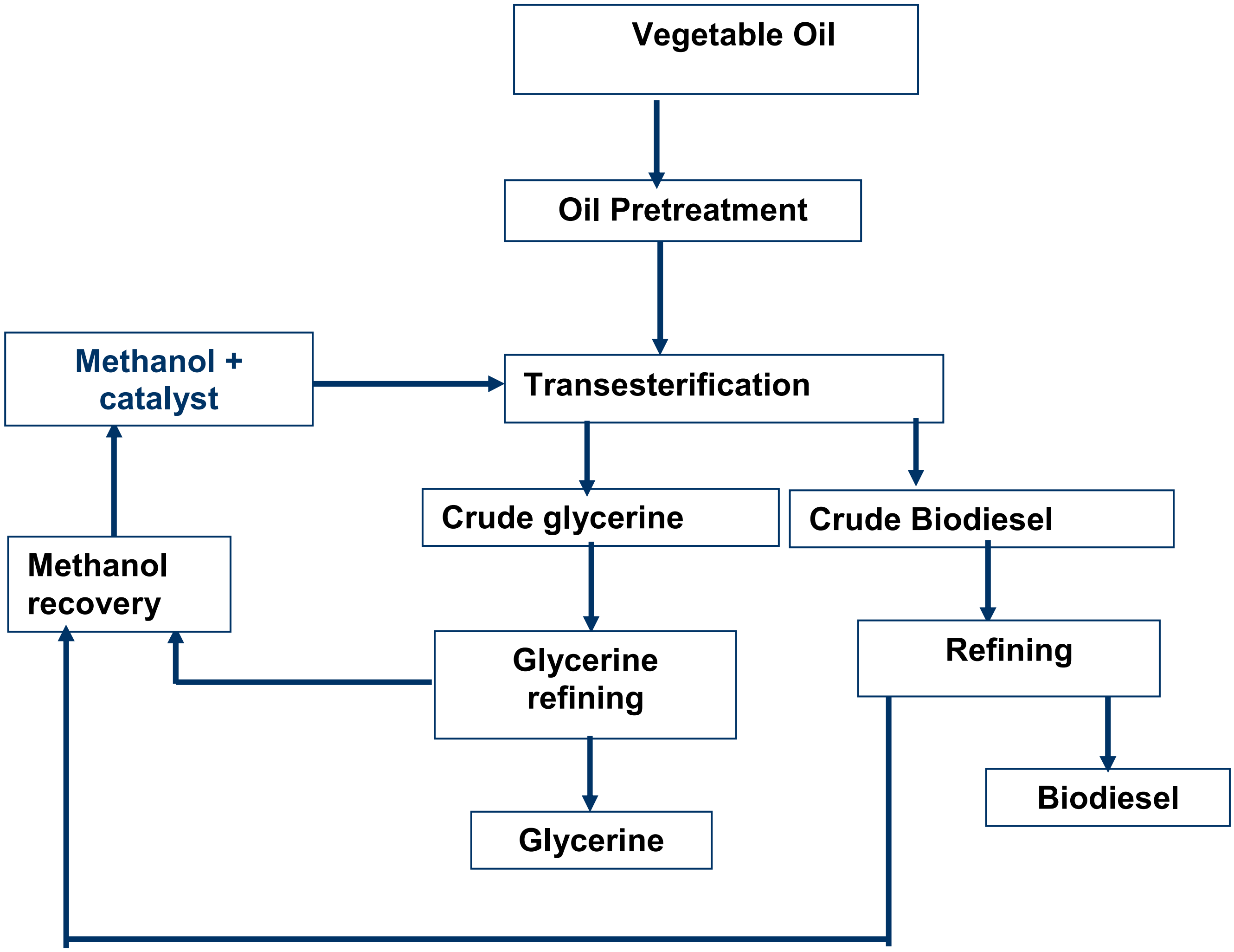
Other than the above-mentioned, there are also many other developments in the scenario of technology development for biodiesel production in India. Biodiesel is mainly being produced in India using various feedstocks like jatropha, karanja, pongamia. However, most of the production chain, which are being set up and are planned to be set up in the country are focusing on jatropha as their feedstock for biodiesel production.

The remaining section of the paper would address the types of technology available in India for biodiesel production. The paper would also highlight the challenges faced by the technology developers in India at the moment. Finally, the paper would conclude by highlighting the way forward in the area of technology development in Biodiesel Production in India.

Types of Technology available in India:

Generally the technology available for Biodiesel production are of two types, batch and continuous mode of operation. The chemical process which these technologies are applying are of the following types – a) Base Catalyzed Tranesterification, b) Acid Catalyzed Transesterification, c) Conversion of oil to fatty acid and its subsequent conversion to esters by acid catalysis. Amongst these processes the producers of Biodiesel find the Base Catalyzed Transesterfication to be economical. Base Catalyzed process is economical for the producers of biodiesel because – a) Larger conversion of raw oil to biodiesel through transesterification, b) Ability of the process to be carried out at a low temperature (60 degree Celsius) and pressure (20 PSI) reducing the costs, c) Larger conversion efficiency of the process, d) Reduction of the side reactions, d) Direct Conversion of raw oil to biodiesel with a reduction in the intermediary steps reducing the cost of production of biodiesel, e) Ordinary material for construction of the transesterification plant reducing the cost of production of biodiesel. Some of the factors which affect the economics of biodiesel production are – a) Moisture in the raw oil, b) Free Fatty Acid Content of the raw oil, c) Molar ratio of the methanol and the raw oil, d) Reaction temperature and duration of the reaction, e) Type of catalyst used and the concentration of the catalyst.

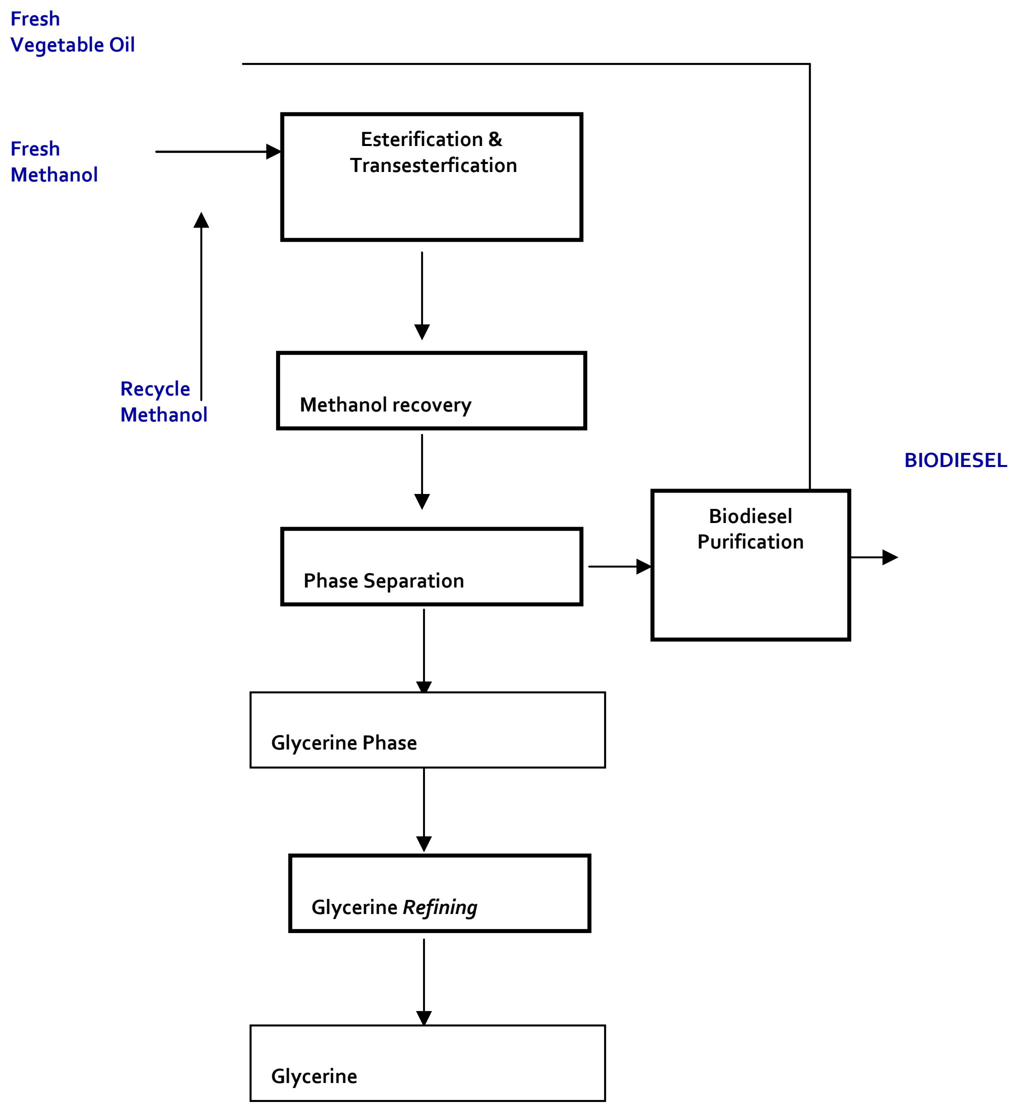
The basic process of transesterification as stated above involves transesterification of the raw oil in a batch mode. Continuous mode of operation might not be suitable if the variation in the quality of feedstock is large. The basic technology used in India has also certain variations. Variations arise as the technology uses different kinds of catalysts, inputs, temperature and pressure conditions. For instance alkaline catalysts like sodium hydroxide, potassium hydroxide could be used. Along with these non - alkaline catalysts, acids, metal complexes, biocatalysts could also be used. In many instances instead of methanol, anhydrous ethanol, isopropanol, butanol are used. Some technologies use higher temperature greater than 60 - 70 degree Celsius. Moreover the pressure used is also higher than the normal atmospheric pressure. Higher temperature and pressure is used mainly in the supercritical range of methanol. High Free Fatty Acid (FFA) content of the oil is treated with acid catalyzed transesterification followed by a base catalyzed transesterification. Another route which the technologies are following is the removal of FFA followed by the transesterification of the raw oil. The problems faced by the production of biodiesel through the use of the existing technologies are – a) Free Fatty Acid formation resulting in loss of catalyst, and biodiesel yield, b) Formation of water deactivating the basic and acid catalysts, c) Formation of soap resulting in emulsion, foam formation and hindering the production of biodiesel. All these factors impact the cost of production of biodiesel in India. At the moment the base catalyzed process technology in India is treating feedstocks having FFA content greater than 1 per cent to about 20 per cent. The technology process is provided below.



Source – Presentation made by IIP (Indian Institute of Petroleum, Dehradun) at Biodiesel Conclave, November 5 2005, New Delhi

The above stated technology could process a variety of vegetable oils and is tolerant to higher level of free fatty acid content in the oil. The glycerin produced, as a byproduct of this technology is approximately 99 per cent pure and could be marketed.

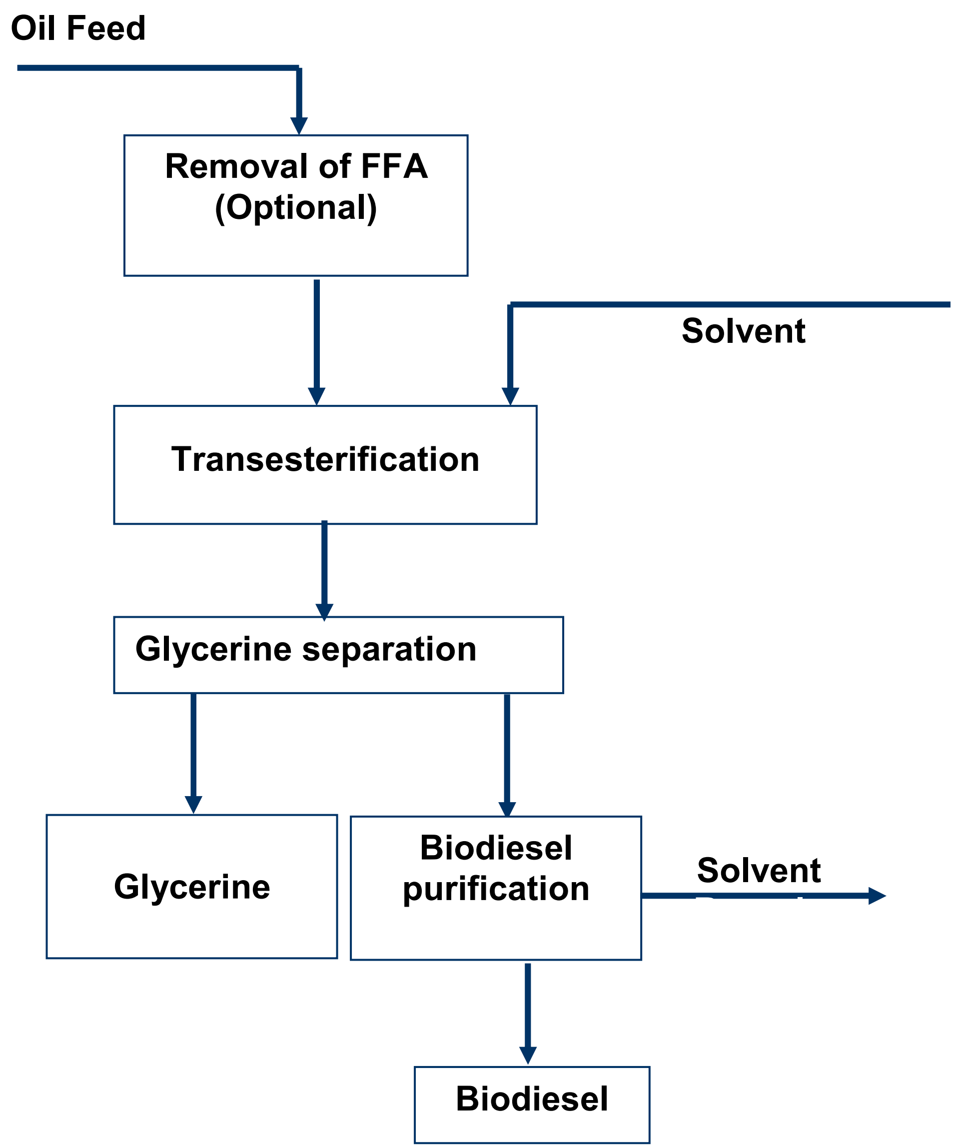
The solid catalyst process using technology has a capacity of a larger amount of FFA in the oil. In this process the transesterification of triglycerides is carried out in a single step over a heterogenous catalyst at a moderate temperature and pressure. The technology is described in the diagram given below.



Source – Presentation made by IIP (Indian Institute of Petroleum, Dehradun) at Biodiesel Conclave, November 5 2005, New Delhi

The technology shown above can process a variety of vegetable oils in mixed or separate form. The technology could process high amount of FFA and doesn't require a pretreatment of the oil and removal of the FFA. This has an impact on the cost of production of biodiesel. The technology also is tolerant to the existence of water in alcohol. So aqueous ethanol could be used which reduces the cost of water removal in the process of Biodiesel production. This technology reduces the soap formation and effluent emission, and could be adopted across various production capacities. Moreover, it also generates pure glycerin. All these have an impact on the cost of biodiesel production by reducing the costs of neutralization, washing, waste and effluent treatment.

There is another type of technology, which uses base catalyst solvent process. The technology is described below.



Source – Presentation made by IIP (Indian Institute of Petroleum, Dehradun) at Biodiesel Conclave, November 5 2005, New Delhi

The above highlighted technology can treat oil to the extent of FFA content of 6 per cent. This process is suitable for small-scale operations and needs glycerin, biodiesel purification through distillation for producing marketable glycerin and biodiesel. Higher FFA could be treated by this technology if a module is added for pretreatment of the oil, which adds to the cost of production of biodiesel.

Another form of technology which is being thought of in India at the moment is the use of hydro processing type process. This technology has not yet been developed in India. This technology aims to reduce oxygen in biodiesel that could mitigate the stability and blending problems associated with the use of biodiesel as a blend in diesel. In general, research shows that for small scale distributed biodiesel plants in India lower capital investments are incurred resulting in lower control sophistication, transportation and distribution costs. The capacity build up is relatively easy with distributed small-scale biodiesel plants due to the easy availability of plant equipment. However, the quality of the final product (i.e biodiesel) could be affected with small scale distributed biodiesel plants. In this regard large scale, centralized plants produce a better and consistent quality of biodiesel. Moreover in case of large scale centralized plant there is a reduction in the number of quality checks. This is advantageous and beneficial as it reduces the processing costs. However an efficient technology is the one which produces biodiesel matching the standards pertaining to a density at 15 degrees Celsius, kinematic viscosity at 40 degrees Celsius, flash point, water content, copper corrosion and acid value. At the moment very few technologies in India have matched the standards with regard to Biodiesel. BIS has introduced the standard – ISI56072005 for B100 variety and ISI460 HSD for B5 specification. An overview of the sector shows that there are both public and private players operating in the technology front to produce biodiesel matching the BIS standard specifications. There are some other technologies also in India associated with Biodiesel production whose goal is to match European, ASTM and BIS standard specifications for B100 and B5 variety of biodiesel.

Other technologies which are under development in India are – a) biocatalyzed transesterification, b) pyrolysis of vegetable oil and non-edible oil and oilseeds, c) transesterification in supercritical methanol.

The next subsection highlights briefly the technology producers associated with biodiesel production in India who are trying to produce biodiesel meeting the ASTM, BIS, European Standards.

- ***Government R& D Institutes***

Institutes	**Capacity**	**Type of Operation**
IIT Delhi, Delhi College of Engineering	5,10,50, 100 litres per day	Batch
NOVOD Board	60 litre per day	Batch
CBDA	1 KL per day	Batch

Institutes	**Capacity**	**Type of Operation**
IICT, Hyderabad		Batch
Department of Bio-energy, Tamil Nadu Agricultural University	250 litres per day	Batch
Central Salt and Marine Research Institute (CSMCRI)	250 litres per day	Batch
Central Salt and Marine Research Institute (CSMCRI)	1000 litres per day	Batch
Southern Railways	1 ton per day	Batch
Oil India	24 MT per day	Batch
IIP – Dehradun, IOCL, IISC	300 MT per day, 30 MT per day, 5 MT per day	Batch

Source - http://pcra-biofuels.org/cht.htm, http://pcra-biofuels.org/sr.htm

- **Private Players**

Transesterification Technology **(Name of the Company)**	**Type of Process**	**Capacity (TPD {ton/day})**	**Cost (Rs.)**
Indigenous (Southern Online)	Batch	30 TPD	14 crores
Indigenous (Harbinson's Technology)	Batch	2 – 5 TPD	1.5 crore

Transesterification Technology **(Name of the Company)**	**Type of Process**	**Capacity (TPD {ton/day})**	**Cost (Rs.)**
Indigenous (Harbinson's Technology)	Batch	144 TPD	60 crores
Foreign (Natural Bio – Energy)	Continuous	300 TPD	120 crores
Indigenous (Alagarh Industries)	Batch	5 TPD	1- 2 crores (approximate value)
Foreign (D1 Oils)	Continuous	24 TPD	7 – 10 crores (approximate value)
Navatha Biofuels - Hyderabad	Batch	15KL per day	3 – 5 crores (approximate value)
Laxman Manwani (Gujrat).	Batch	10KL per day	2.5 – 4 crores (approximate value)
Erada Biofuels (New Delhi)	Batch	10KL per day	2.5 – 4 crores (approximate value)
Sun Microtech (Hydrabad)	Batch	10KL. per day	2.5 – 4 crores (approximate value)
Asian Biofuels Kolkata	Batch	5KL. per day	.75 - 2 crores (approximate value)
Gujrat Future Woods Ltd.	Batch	10KL per day	2.5 – 4 crores (approximate value)
Aatmiya Biofuels Pvt. Ltd (Commercial Scale of Production with small units)	Batch	1000 litres per day	32 lakhs (approximate value)
Biodiesel Technologies India (commercial small scale plant)	Batch	450 litres per day	14.4 lakhs (approximate value)
Kochi Refineries (commercial small scale plant)	Batch	100 litres per day	32 lakhs (approximate value)
Shirke Biohealthcare Pvt. Limited (commercial small scale plant)	Batch	5000 litres per day	1.6 crores (approximate value)
Jain Irrigation (small scale plant)	Batch	3 tons per day	Rs. 50 lakhs (approximate value)
Nova Biofuels Pvt. Limited	Batch	30 ton per day	Rs. 20 crores (approximate value)
Naturol Bioenergy Ltd	Batch	300 ton per day	Rs. 140 crores (approximate value)
Mint Biofuels	Batch	400 litres per day	Rs. 12.8 lakhs (approximate value)
Mint Biofuels	Batch	5000 – 100000 tons per day	Rs. 30 crores (approximate value)

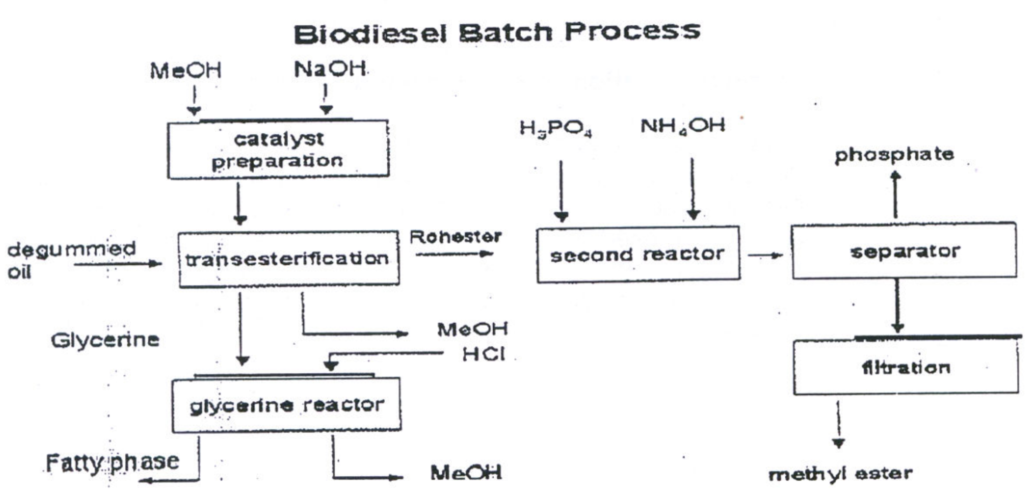
Transesterification Technology **(Name of the Company)**	**Type of Process**	**Capacity (TPD {ton/day})**	**Cost (Rs.)**
Tinna Oils and Chemicals	Batch	50 ton per day	Rs. 20 crores (approximate value)

Source –Author's Compilation by communicating with various manufacturers, experts like Mr. Parveen Mithra , Biodiesel: Technology & Business Opportunities
– An Insight, S Biswas, N Kaushik & G Srikanth, Technology Information, Forecasting and Assessment Council (TIFAC), Department of Science & Technology

Some of the technology providers to the above mentioned private players have been international companies like Lurgi.

Lurgi Technology:

The Lurgi process of biodiesel production in India operates at normal pressure. This process requires the use of a degummed and deacidified feedstock. The refined vegetable oil and methanol are reacted in a two-stage mixer-settler arrangement in the presence of a catalyst. The glycerine produced in the reaction, dissolved in the surplus methanol, is recovered in the rectification column. Most of the entrained methanol and glycerine are recovered from the methyl ester. The methyl ester is further purified by distillation. The technology is not too expensive and can generate sufficient product qualities, but faces difficulties in consistency and safety. However, assisted by modem process control, the technology is suitable for different raw materials and for small quantities of feedstocks for biodiesel production. The Lurgi technology works with a batch mode of biodiesel production that is schematically highlighted below.



Source - Detailed project report for the National Mission on Bio-diesel New Delhi: The Energy and Resources Institute TERI Report NO – 2004 CM24

However, the Lurgi technology has an optimal scale of operation of 30 ton per day as a viable scale. Any capacity below this will affect the yield and purity of biodiesel produced through the process. The challenge therefore lies in the availability of adequate feedstock in India, which could match this seed processing capacity of the Lurgi technology. The technical parameters would however differ for a large-scale continuous transesterification plant. The table below highlights some of the technical parameters of a large scale biodiesel producing continuous transesterification plant. The estimates given below in the table would differ across various capacities of a biodiesel producing plant. The challenge in India at the moment therefore lies in standardizing the capital cost across various capacities of a plant.

Cost Details of a Transesterification Plant

Capacity	100000 tons / annum
Cost	70 –75 crores

Utility Consumption Per Ton of Oil	**Amount (/ ton Bio – Diesel)**	**Cost (Rs./ ton)**
Steam	660 Kg	Rs.198
Power	36Kwh	Rs. 180
Methanol	110 Kg	Rs.1130
Water Circulation	55 m^3	Rs.11
Catalyst Solin	18 kg	Rs. 180
Mineral Acid	6 Kg	Rs.60
Total		Rs. 1759
Interest & Depreciation		Rs.1600
Total		Rs.3359

Source – Author's Compilation through communication with various manufacturers associated with Biodiesel production in India

As mentioned, the challenge lies in standardizing the capital cost of the tranesterification technology across various capacities of a plant for an economically viable scale of biodiesel production. Some of the other challenges faced by the biodiesel manufacturers in India in the technological aspects are highlighted.

Challenges:

- Technology development to treat any undissolved pellets of KOH left in alcohol during the entire subsequent transesterification. This would increase the amount of catalyst taking part in the reaction and would increase the production of biodiesel.
- Technology development which would allow separation of glycerol and reduction of formation of soap during the transesterification process increasing the yield of biodiesel.
- Commercial, Viable UpScaling of production of biodiesel treating the average high content of FFA (>2 per cent) in Indian Feedstocks for Biodiesel production like jatropha oil, pongamia oil, mahua, pilu, sal, nahor, kokam, kamala, rubber seed through a continuous process of transesterification.
- Upgradation of the technology in order to create complete removal of alcohol, catalyst, water, soaps, glycerine, unreacted and partially reacted triglycerides and free fatty acids.
- Technology development for processing large variety of raw and refined vegetable oils with high free fatty acids with low effluent generation which would be adaptable to a large range of production capacities.
- Continuous pilot plant testing of heterogeneous trans-esterification process development of additives for bio-diesel-diesel blends.

These challenges once met could further lead the way ahead in the path of technology development for biodiesel production in India.

Way Ahead:

Some of the technology challenges which lie ahead for biodiesel producers in India are – a) Development of Solid Acid Catalysis technique of transesterification, and b) Development of Lipase – Catalyzed (Enzyme Catalyzed) process. The key challenges for solid acid catalysis technique would be to make a packed bed process and a continuous system of transesterification. Such a technology would reduce the washing in the process of biodiesel production and effluent, free fatty acid generation from the biodiesel production. This would help in reduction of cost of biodiesel production. As of now these operations are going on a pilot scale in India. The challenge lies in commercial up scaling of these technologies. With regard to enzyme catalyzed reaction the main issue of concern is the controlling of catalyst turn over and completion of the reaction. The technology in India needs to be developed with regard to enzymatic process of transesterification with a control on the catalyst turn over. This could contribute to the faster completion of the reaction for biodiesel production. All these would have cost implications for production of biodiesel. According to some technology providers[3] in India an approximate plant size of 4000 ton per annum or 13 ton per day would be commercially viable for a continuous mode of operation. According to some technology producers plant size doesn't affect significantly the process cost of biodiesel production. The impact of plant size on process cost of biodiesel production lies in the range of 10 per cent - 15 per cent. Typically experience amongst Indian biodiesel producers shows that the addition of utilities, tank forms, land, buildings, and office space all contribute to doubling the cost of production of biodiesel. The future challenge amongst biodiesel producers therefore lies in the reduction of these costs. The engineering and installation time for biodiesel producing plants in India is 10 – 18 months, which often contributes in building up sunk costs. One of the challenges that lie ahead for producers of biodiesel is to reduce the installation time of the technology.

Another facet, which lies ahead, is the development of a technology that would create a continuous deglycerolization mechanism. Through continuous deglycerolization process the glycerol formed could be recovered from biodiesel and would help in maintaining the purity and production of biodiesel. The next section briefly describes the continuous deglycerolization process that has to be developed for biodiesel production.

CD PROCESS for Transesterification:

The continuous deglycerolization (CD) process was designed precisely for bio-diesel production using refined or well-degummed crude vegetable oil. The CD PROCESS showed for the first time in 1991 a continuous operating low-pressure transesterification process with a continuous extraction of glycerol and washing purification of the ester. This kind of technology is well developed in Germany. But in the biodiesel production of India, this technology is not used as of yet. The development of this technology could create a compact plant with low-investment operating at ambient pressure and at a temperature of 65-70°C. The capacities of these kinds of plants range from 8,000 to 150, 000 tonnes/yr. These plants generally have low energy consumption, excellent product quality, and very high consistency and safety standards. These plants work in a continuous mode of operation because each would need a continuous supply of feedstock. The availability of continuous supply of feedstock could act as a hindrance towards the development and application of this technology for biodiesel production in India.

Other than this, another way forward in the area of technology development for biodiesel production in India is associated with – a) Lipase – Catalyzed and b) Non – Ionic base catalyzed process.

[3] Personal Communication with experts in Lurgi Technology, Gujarat Oleo Chemicals, Lubrizol India Limited

Lipase-catalyzed processes

Although the enzyme-catalysed transesterification processes are not yet commercially developed in India, new results have been reported in recent articles and patents. The common aspects of these studies consist in optimizing the reaction conditions (solvent, temperature, pH, type of microorganism which generates the enzyme) in order to establish suitable characteristics for an industrial and commercial application of biodiesel production. However, the reaction yields as well as the reaction times are still unfavorable in India compared to the base-catalyzed reaction systems. Once developed on a commercial scale in India, this technology could contribute in conversion of the free fatty acids to biodiesel that would help in getting a larger quantity of biodiesel.

Non-ionic base-catalyzed processes

In order to obtain milder reaction conditions and to simplify manipulations, a great number of organic bases have been developed and used as catalyst or reactant for organic synthesis. The activity and efficiency of such non-ionic base catalysts for the transesterification of vegetable oils have been studied in various places across the world. Research shows that biodiesel production increases with the use of non – ionic base catalysed process. A comparison of the TBD (Transesterified Biodiesel) production through enzyme based method visa vis the alkaline based method shows that no undesirable by-products such as soaps (easily formed when alkaline metal hydroxides are used) are formed in enzyme based method in comparison to the industrial method of biodiesel production using alkaline catalysts. However, in India this technology has to be developed for commercial and continuous scale of operation.

CONCLUSION:

Thus transesterification technology involving batch mode of operation has been developed in India. Technology transfer in this regard has also taken place. But the challenge lies in the upscaling of these batch modes of operation into a commercial scale. Much more research needs to be done in developing continuous mode of transesterification in India for biodiesel production. This would mean additional flow of venture capital funds for upscaling the continuous modes of operation to a commercial scale of operation. There is also a need to develop enzyme based and non – ionic base catalyzed transesterification technology in India with its subsequent commercial and industrial application. Thus the start with regard to technology development for biodiesel production has been initiated. But the success and sustainability of the start would depend on further developments, research, and investments in the above-mentioned fronts of technology development for transesterification in India. This could then contribute significantly towards the energy security of the country.

REFERENCES:

Bio-diesel in Europe 1998, Bio-diesel Processing Technologies by J Connemann, J .Fischer

Detailed project report for the National Mission on Bio-diesel New Delhi: The Energy and Resources Institute TERI Report NO – 2004 CM24

Establishment of a technology for the production of bio-diesel from Jatropha seeds, TERI Report No. – 2004 CM24

The World Bank 2002

http://dbtindia.nic.in/r&d/biofuel.html

http://pcra-biofuels.org/cht.htm, http://pcra-biofuels.org/sr.htm

Report of the committee on development of bio-fuel, Planning Commission, Government of India.

Chatterjee A and Dhadich P. 2004. Bio-diesel: technology assessment, a technology assessment report.Energy and Environment Technology Division, TERI (The Energy and Resources Institute), New Delhi

Ayhan Demirbas. 2003. Bio-diesel fuels from vegetable oils via catalytic and non-catalytic supercritical alcohol transesterification and other methods: a survey. Energy Conversion and Management 44: 2093-2109.

Galen J Suppes, Mohan Prasn A Dasari, Doskccil Eric J, Pratik J Mankidy, Michael J Goff. Applied Catalysis (2003). Transesterification of soyabean oil with zeolite. Metal catalysts. 213-223.

Ulf Schucardta, Ricardo Serchelia and Rogerio Matheus Vargas, J Braz. 1998. Transesterification of vegetable oils: A review. Chemical Society 9 (1): 199-210.

Darnoko D and Munir Cheryan. Kinetics of Palm oil on transesterification in a batch reactor.

E T Akintayo. 2004 Characteristics and composition of Parkia biglobbossa and Jatropha curcas oils and cakes. Bioresources technology 92- 307- 310.

Pramanik K. 2003. Properties and uses of Jatropha curcas oil and diesel fuel blend in compression ignition engine. Bioresource Technology: 239-348.

Zhang Y. 2003. Bio-diesel production from waste cooking oil. Economic assessment and sensitivity analysis. Bioresource Technology 90: 229-240.

CURRENT STATUS OF BIOENERGY DEVELOPMENT IN INDONESIA

Teguh Wikan Widodo and Elita Rahmarestia

Indonesian Center for Agricultural Engineering Research and Development (ICAERD)
Tromol Pos 2 Serpong, Tangerang, Banten 15310 Indonesia
Teguh_wikan_widodo@yahoo.com

Abstract

Because of the effects of high petroleum and natural gas prices, Indonesia is implementing national policies and legislation to encourage bioenergy production as a means to achieve energy security and self-sufficiency and to reduce reliance on fossil fuel reserves. The growing national and international demand of bioenergy is of particular interest to developing countries like Indonesia for seeking opportunities on economic growth and trade. Indonesia has a comparative advantage for bioenergy production because of greater availability of land, favorable climatic conditions for agriculture and lower labor costs. However, Indonesia faces socio-economic and environmental implications affecting the potential to benefit from the increased local and global demand of bioenergy. The interrelationship between land uses and the competing needs of energy and food security is a key issue in bioenergy that should be considered. In addition, the effects of large-scale bioenergy production on global commodity prices are a significant trade concern. Bioenergy production may also entail harmful environmental effects such as deforestation and loss of biodiversity. Regulation is required to reduce the negative impacts of large-scale production, as well as to ensure that the most cost-effective and highest-energy conversion technologies are used. Given the opportunities and risks, criteria for the sustainable development of the bioenergy industry should be clearly established in both international and national regulatory frameworks.

Keywords: energy, bioenergy, alternative energy, renewable, sustainable development

1. Introduction

Indonesia derives the vast majority of its energy consumption from fossil fuels. Of the 95 per cent of fossil fuels energy consumed, fossil oils consumption is 52 per cent. Almost half of the fossil oil is supplied by subsidy. However, since 30 September 2005, the government has reduced the subsidy by increasing the price of fossil oil ranging from 188 per cent up to 286 per cent.

Indonesia, as an oil producer, holds proven oil reserves as 4.7 billion barrels. However, as the oil demand is increased, Indonesia has become a net oil importer since 2004 as described in Figure 1. Indonesian crude oil production averaged 944,000 barrels per day (bbl/d), down from the 2004 average of 967,000 bbl/d and continuing the decline of the past several years. The decline is due mainly to the natural fall off of aging oil fields, a lack of new investment in exploration and development, partially due to regulatory difficulty.

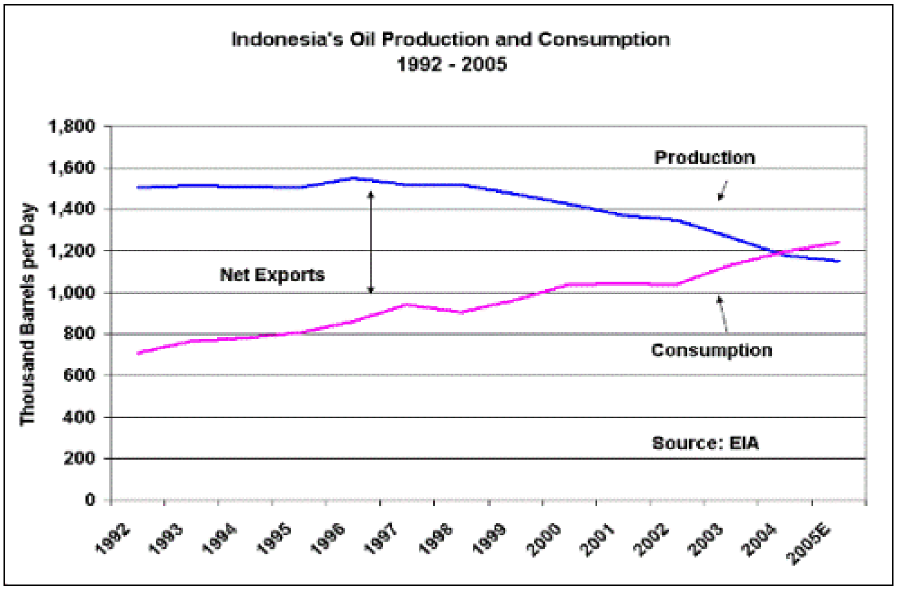


Figure1. Oil production and consumption of Indonesia 1992-2005(Source EIA)

In addition to fossil energy sources, Indonesia is blessed with relatively abundant potential for renewable energy. According to the data, geothermal potential is about 20 thousand MW, hydro power is about 75 thousand MW, biomass is around 50 GW, solar energy is about 1203 TW and 9287 MW for wind energy. However, the utilization of renewable energy in Indonesia is still very low compared to its huge potential.

Energy utilization is always linked to emission generation, and thus fossil energy sources are the major contributors to greenhouse gases (GHGs) emission and climate change. Studies have showed that around 60 per cent of GHGs emissions come from fossil energy utilization. In order to minimize global warming as a result of the increase of GHGs emission, Indonesia looked into the use of clean energy such as renewable energy sources and clean fossil fuel. One of the barriers in developing renewable energy technology and clean energy technology is related to its high investment cost due that most of the technologies are still imported. Therefore, research and development activities to produce locally proven technology with lower cost are very important.

The growing national and international demand of bioenergy is of particular interest to developing countries like Indonesia for seeking opportunities on economic growth and trade. Indonesia has a comparative advantage for bioenergy production because of greater availability of land, favorable climatic conditions for agriculture and lower labor costs. However, Indonesia faces socio-economic and environmental implications affecting the potential to benefit from the increased local and global demand of bioenergy. The interrelationship between land uses and the competing needs of energy and food security are key issues that should be considered. Such issues have directed the Government of Indonesia to take steps at regulating bioenergy development.

2. Policy and Programmes on Bioenergy in Indonesia

2.1. National Policy on Bioenergy

Indonesia is the world's second largest palm oil producer after Malaysia, but it was not until after global fuel prices soared and Indonesia became a net fuel importer that the Indonesian Government began to actively pursue alternative energy industries, including biofuels produced from palm oil. The government reduced and then eliminated fuel price subsidies in 2005, allowing the biofuel industry to become economically viable. Since then, the government has enacted legislation to encourage the use of biofuels, including Presidential Regulation No. 5/2006, Presidential Instruction No. 1/2006 and Presidential Decree No. 10/2006 (ESDM; 2006; Sudradjad,2006).

In 2005, the Minister of Energy and Mineral Resources issued a National Energy Management Blueprint (NEMB) in support of the National Energy Policy (NEP). Article 4 of the NEMB establishes national strategies for the management and use of energy resources including a roadmap for each alternative energy sector. It provides a target for biodiesel use of 1.5 million kilolitres in 2010 (10 per cent of national transportation diesel oil consumption) and targets an increase of up to 6.4 million kilolitres in 2025 (20 per cent of national transportation diesel oil consumption, or 5 per cent of total national diesel oil).

Presidential Regulation No. 5/2006 implements the NEMB. It states that the purpose of the NEP is to ensure a secure domestic energy supply and to encourage sustainable development. Article 2 establishes a target for biofuels to contribute at least 5 per cent of the total national energy consumption by 2025. Presidential Instruction No. 1/2006 establishes the framework for coordination among ministries to promote the supply and use of biofuels. It designates ministries responsible for formulating and implementing policies, including incentives, tariffs and trading systems, as well as standards and procedures for cultivation methods, processing, quality testing, the supply and distribution of biofuels, the provision of land and the development of research and technology. Specific to agricultural production, articles 3 and 4 provide that the Ministry of Agriculture shall encourage the provision and development of bio-fuel plants including seeds and seedlings, whereas the Ministry of Forestry shall provide licenses regulating the use of unproductive lands for biofuel plantations.

Indonesia established the biodiesel standard SNI 04-7182-2006 which was approved by the National Standardization Agency on 22 February 2006. The biodiesel standard was formulated by taking into account similar standards already applied in other countries such as ASTM D6751 in the United States and EN14214:2002 in the European Union. On 17 March 2006, the Oil and Gas Directorate-General of the Department of Energy and Mineral Resources issued a decree regarding the quality and specification of two types of diesel oil. This decree regulates the use of fatty acid methyl ester up to the maximum of 10 per cent of the volume of automotive diesel fuel with which it is to be blended. The biodiesel to be mixed has to meet the biodiesel standard SNI 04-7182-2006.

2.2. Village Self-Sufficiency Energy programme (Desa Mandiri Energi)

Indonesia is an island country where many villages are isolated and remote. Forty five per cent of them have minimum access to roads, education, health, electricity and national distribution of fuel oil. The difficulty of transportation to remote locations causes some populations to not access the highest allowable retail price (HET) of oil subsidy. Further, those in remote areas are usually categorized below the poverty line. As an example, in Wamena Papua, the price of household kerosene is Rp 20.000/litre, while the highest allowable price for subsidized kerosene is Rp 2.300/litre. To overcome this problem, the government has developed a programme of village self-sufficiency energy or " Desa Mandiri Energy (DME) " .

The DME programme is a participatory rural approach programme. There are several arrangements of the DME programme (*Tim Nasional Pengembangan BBN*, 2007):

1. The project of DME in the village has aims to open job opportunities, reduce poverty and produce biofuel.
2. The location could be placed at agricultural based areas, fisheries based areas or transmigration areas.
3. The plant is managed by local farmer corporation or small and medium scale of business.
4. The central government and local government provide contributions for plantation (seed, mother stock seed, machineries etc) through the government budget.
5. The location of DME is nominated by the local government. However, it is still possible that the location of the DME is nominated by an entrepreneur, NGO or local people.

Because many villages are eligible for DME, the government performs this project gradually from 2007 to 2010. The funding contribution for DME project is as follows (Figure 2):

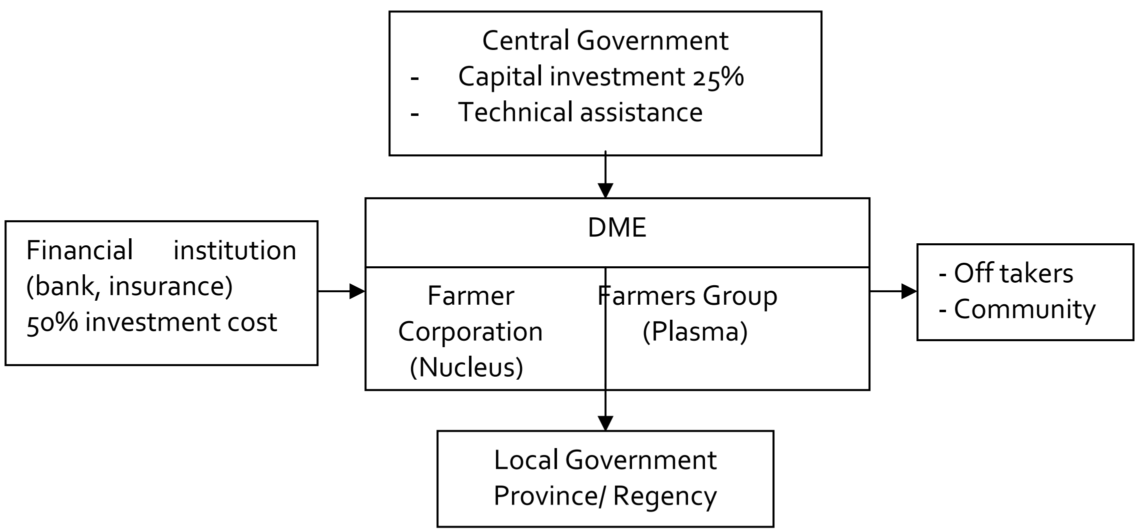
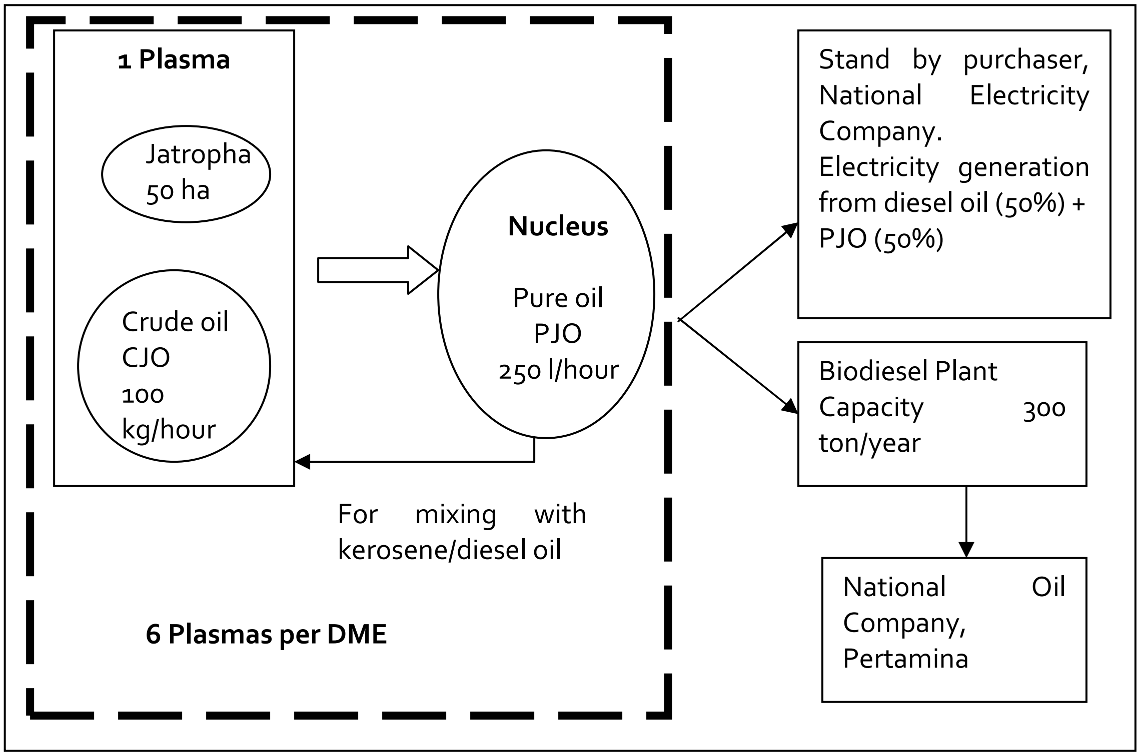


Figure 2. The scheme of DME funding

The DME is developed by the networking system of a nucleus and several plasmas (Figure 3). The nucleus could be the processing plant at a village scale while the plasma consists of farmers or farmers groups who produce the feedstock. To be sustainable, it should be preceded by the feasibility assessment (technical, socio-economical). In this feasibility assessment, it evaluates the relation between the agro ecosystem and socio-economic feasibility. There are five models of development of commodities for DME such as *jatropha curcas*, palm oil, coconut, cassava and sugar cane. However, other potential commodities such as corn, sorghum, *arengga pinnata* are also accepted.

DME or special region for biofuel development is one of the programmes to open job opportunities and reduce absolute poverty at isolated or remote villages by empowering the society to fulfill their energy needs. The DME programme can exploit marginal land of 5 million hectares to produce several kinds of biofuel feedstock and able to create job opportunities for 3–5 million people.

An example of networking between stakeholders in a DME based on *jatropha curcas* is as follows:



Remarks: Crude Jatropha Oil (CJO), Pure Jatropha Oil (PJO)

Figure 3. DME based on *jatropha curcas*

3. Research and Development

3.1. Biodiesel

Efforts in biodiesel development for Indonesia have been made for over the past ten years. However, the activity was not a priority due to the cheap price of oil in the country. Research activity was limited only at the laboratory scale and in performance testing. Several Indonesian research institutions have been pioneering work on biodiesel development including LEMIGAS (Oil and Gas Technology), PPKS Medan (Indonesian Oil Palm Research Institute, Department of Agriculture), ITB (Bandung Institute of Technology), and BPPT (Agency for the Assessment and Application of Technology). At that time, biodiesel developments were mainly focused on production process technology, engineering, biodiesel property and performance testing, as well as standardization and promotion. To accelerate the information exchange among biodiesel stakeholders and to promote biodiesel development, a national forum for biodiesel called *Forum Biodiesel Indonesia* (FBI) was established in 2002. The forum members comprise of scientists from universities and research institutes, automotive industry associations, palm oil associations, engineering industries, biodiesel producers, relevant government offices (Ministry of Transportation, Ministry of Energy and Mineral Resources, Ministry of Agriculture) and several non governmental organizations. The following are some activities of several research institutions that work on biodiesel:

• LEMIGAS (Oil and Gas Institute), in cooperation with Pertamina (a state owned oil company), has tested biodiesel blended with automotive diesel oil (ADO) at a ratio of 30:70 for commercial diesel engine vehicles in 1996. The programme was intended to support the national policy on energy conversion and diversification. This early research unfortunately showed that biodiesel gave a negative impact on engine performance despite of its positive results on the engine's emission. Currently, LEMIGAS specializes in the testing methods for biodiesel fuel properties.

• Ministry of Agriculture, Indonesian Center for Agricultural Engineering Research and Development (ICAERD) has worked on biodiesel for several years. ICAERD has partly modified the seed oil extractor made by RRC for a *jathropha* oil extractor. The capacity is 70-80 kg seed/hour. Depending on the seed quality, the oil extracted averages from 25 per cent - 28 per cent (Handaka and Hendriardi, 2005). PPKS Medan has also carried out research on biodiesel production from palm oil. In cooperation with ITB, they have conducted a road test in Java-Sumatra in 2004 which covered a total distance of 2,020 km (Reksowardojo, *et al.*, 2005; Prastowo, 2006).

• ITB (Bandung Institute of Technology) has focused its research and development on macroeconomic studies of biodiesel, developing technology for jatropha oil extraction and its conversion to methyl ester. The institute is also focusing on standardization of fuels and on diesel engine test series. The pilot scale biodiesel plant with the capacity of 150 L product per batch was developed by ITB.

• Engineering Center–BPPT has been developing biodiesel since 2000 and the center has focused its work on the process technology and engineering of biodiesel production. The center uses various raw materials, such as various CPO grades, Palm Fatty Acid Distillate (PFAD) and Coconut Fatty Acid Distillate (CFAD). The property and performance tests of the biodiesel produced are carried out in Thermodynamics and Propulsion Engine Research Center (BTMP), another BPPT laboratory, that is focusing its work on diesel engine bench and non-stationary operation tests for performance with emissions of fuels including biodiesel. Until now, the Engineering Center–BPPT has constructed and is operating a pilot plant with a daily capacity of 1.5 tons since 2003. In cooperation with the Riau Provincial Government, the Engineering Center–BPPT has completed the construction of a biodiesel plant with daily capacity of eight tons. The continuous system with three ton per day capacity plant is now under construction at the Science and Technology Research Center in Serpong, Banten.

In addition to the development of biodiesel production, the Engineering Center-BPPT has also carried out two road tests. The first one is the Java - Sumatra road test carried out in 2002 covering a distance of 5,000 km. The second one is the Java - Bali road test in 2004 that covered a total distance of 20,000 km. Both tests were carried out in cooperation with leading automotive companies in Indonesia. The first one was PT. Toyota Astra Motor that supplied the vehicle and emission testing facilities. In the second road test, PT. Pantja Motor worked actively in the vehicle performance test along with BTMP-BPPT while JIF – Japan Indonesia Science and

Technology Forum, provided a sponsorship. As a promotion activity, Engineering Center-BPPT also conducted a similar road test for the BPPT's 23 diesel buses for three months. The test has received a warm response from the bus drivers and the qualitative test has shown that the biodiesel is responsible for the reduction in the quality of engine exhaust; engine noise was less and the acceleration was much better.

As a response to government seriousness in supporting biofuel development as a national priority programme, a number of research institutions such as IPB (Bogor Institute of Agriculture, BPPT Biotechnology Center, Center for Plantation Research and Development, Ministry of Agriculture now have actively started on biodiesel development, especially in the field of farming technology. Several private and state companies such as PT. Energi Alternatif Indonesia, PT. Rekayasa Industri, PT. Eterindo Wahanatama, and PT. Rajawali Nusantara Indonesia have also moved into the biodiesel business.

Diesel oil consumption in Indonesia ranks first as compared to other sources of oils (Table 1). Diesel oil consumption increased from 22 072 ML in 2000 to 27 466 ML in 2005. In 2006, the consumption fell to 25 092 ML due to increases of the selling price of up to 205 per cent (DESDM, 2007).

Table 1. Oils consumption of Indonesia year 2000-2006 (000 kL)

Oils	2000	2001	2002	2003	2004	2005	2006
Automotive diesel oil	22 072	23 357	24 276	24 046	26 488	27 466	25 092
Lighting kerosene	12 458	12 280	11 676	11 753	11 846	11 370	10 018
Premium gasoline	12 429	13 067	13 630	14 647	16 418	17 459	17 067

Source: DESDM, 2007

Diesel oil is used widely in the transportation sector, industry and agricultural machineries. The programme of biodiesel, B-5 (blending 5 per cent biodiesel with diesel oil) has been introduced by the government as of 2006. Currently, B-10 has been applied, but only at several pump stations in Jakarta and Surabaya. However, the government has set a target to apply B-10 in more big cities from 2011-2015. Bio-oil and biokerosene are also intended to be applied as alternative sources of lighting kerosene and power station fuel oils. In 2015, it is planned that the O-10 (blending 10 per cent bio-oil with lighting kerosene) will be applied as an alternative source of kerosene for households and O-50 (blending 50 per cent bio-oil with fuel oil) will be applied for power generation by the national electricity company (Timnas Energi, 2006).

The feedstock for bio-oil and biodiesel production has been planned mainly from palm oil and jathropha curcas. However, other potential feedstock such as unused frying oil, rubber seed, and coconut is also encouraged. As stated previously, the development is based on the suitability of specific locations. For a good standard quality of biodiesel, the national standard of biodiesel is issued as SNI Biodiesel No. 04-7182-2006.

Palm oil

Indonesia is the second largest producer of palm oil in the world. Palm oil and its derivatives have been used widely as edible oil, industrial material and export commodities including crude palm oil (CPO). The process of transesterification is mainly used to convert the oil as FAME (fatty acid methyl ester) as a cheap and viable technology. On a larger scale, the alcohol (e.g. methanol) could be recovered for the next process of transesterification.

A pilot plant of biodiesel production from palm oil has been built for capacity up to 10 ton per day. Productions of biodiesel are supplied to *PT Pertamina*, the national company of oils and gas. Other foreign investors are also interested to develop biodiesel production plants in Indonesia, with the government formulating regulations that should enable foreign companies to set up plants as early as 2008.

The barrier to expand the production of biodiesel feedstock from palm oil is that this commodity is used for other purposes. Therefore, it may have potential conflict as a feedstock of energy, industry and food stock. However, the expansion area of cultivation is growing rapidly. If left uncontrolled or mismanaged, such production could place increased pressure on the environment in the form of deforestation and other negative environmental consequences.

Jathropha curcas

Jathropa curcas is promoted as feedstock of bio-oil and biodiesel in Indonesia. It is not an edible oil and not used by the industry sector at present. Therefore, it may offer the potential to reduce conflicting uses outside of the energy sector. *Jathropha curcas* is also growing well at a wide range of soil textures such as soil with high mineral content, sandy soil or clay soil with good drainage. This plant is also appropriate for land conservation.

Jathropha curcas is a shrub plant with a fruit kernel containing 3 seeds each. A mature seed contains 35-45 per cent oil. Some of the cultivars are known as non edible plant. Research also finds that oil contents of the cultivars are also varied. Compared with biodiesel from palm oil, the oil from *jathropha* has lower pour point (-2.5°C); therefore it may be used in some four seasons countries. In Indonesia, *Jathropha curcas* previously was used as natural fencing. After being promoted as bio-oil feedstock, it is cultivated on the farm as monoculture or hetero culture (Prastowo, 2006).

The pathway of the growth of *jatropha curcas* is mainly being considered for developing community self production of energy (DME) especially in rural areas. It will be further used as an alternative source of lighting kerosene, marine diesel oil or fuel oil. The plant of oil production is also encouraged only in small and medium scale with low to middle complexity of technology. The plant may process on average a capacity of 0.5 - 1 ton seeds/per day. Typical process of oil extraction from *jatropha* seed is by mechanical extraction that is screw press or hydraulic press. The barriers of application of jathropha curcas as bio-oil at the moment are:

- Kerosene is still subsidized up to 2007; therefore the price of *jatropha* oil is not competitive with subsidized kerosene.
- The productivity of the plant is still low; therefore farmers are more interested to plant other crops such as corn.
- The best cultivar (high yield, high oil content, adaptable and tolerance) is still under investigation.
- The viscosity of *jatropha* oil is higher than lighting kerosene. Igniting the jatropha oil is not as easy as household kerosene. Simple technologies are still under development.

Transesterification of *jatropha* oil in rural areas may be difficult to perform, because it is not easy to find a catalyst and alcohol in such areas.

- At present, people in rural areas not only use kerosene for cooking but also cook with firewood, coconut husk and charcoal. The *jatropha* oil may be used only for lighting in places with no electricity.

Other sources of feedstock bio-oil that are in research and development stages are coconut, rubber seed, cotton seed, rice bran and unused frying oil. All of them will be used in suitable locations based on local commodities available. Unused frying oil transesterification is applied in big cities such as Bogor, where the local government collects unused frying oil from restaurants for use as biodiesel for the *TransPakuan* city circle bus system.

3.2. Bioethanol

Bioethanol can be produced by converting the starch content of biomass feed stocks (e.g. cassava, corn, potatoes, beets, sugarcane, and wheat) into alcohol. The fermentation process is essentially the same process used to make alcoholic beverages. Yeast and heat are used to break down complex sugars into more simple sugars, creating bioethanol. There is a relatively new process to produce bioethanol which utilizes the cellulose portion of biomass feed stocks like trees, grasses and agricultural wastes. Cellulose is another form of carbohydrate and can be broken down into more simple sugars. This process is relatively new and is not yet commercially available, but potentially can use a much wider variety of abundant, inexpensive feed stocks.

The production of bioethanol by fermentation involves four major steps: (a) grow, harvest and delivery of raw material to an alcohol plant; (b) pre-treatment or conversion of the raw material to a substrate suitable for fermentation to bioethanol; (c) fermentation of the substrate to alcohol, and purification by distillation; and (d) treatment of the fermentation residue to reduce pollution and to recover by-products.

Fermentation technology and efficiency has improved rapidly in the past decade and is undergoing a series of technical innovations aimed at using new alternative materials and reducing costs. BPPT has been involved in the technological assessment since 1983 supported by bioethanol pilot plant facilities located in Lampung. The many and varied raw materials for bioethanol production can be conveniently classified into three types: (a) sugar from sugarcane, sugar beet and fruit, which may be converted to bioethanol directly; (b) starches from grain and root crops, which must first be hydrolyzed to fermentable sugars by the action of enzymes; and (c) cellulose from wood, agricultural wastes, which must be converted to sugars using either acid or enzymatic hydrolysis.

Bioethanol can be used as a liquid fuel in internal spark ignition combustion engines either purely or blended with petroleum. Therefore, bioethanol has the potential to change and/or enhance the supply and use of fuel (especially for transport) in Indonesia. There are many widely-available raw materials from which bioethanol can be produced, using already improved and demonstrated existing technologies. Bioethanol has favorable combustion characteristics, less pollution emissions and high octane-rated performance.

Premium gasoline is mainly used in the transportation sector. The national consumption of gasoline is the second highest after Automotive Diesel Oil (ADO). It is predicted that growth consumption will be 7 per cent by 2009, at about 21 millions kL. The road map of biofuel development in Indonesia declares that bio-ethanol will be blended with gasoline gradually from E-5 to E-15 by 2015 for non-flexible fuel vehicles while up to 40 per cent for flexible fuel vehicles (FFV). Based on those assumptions, prediction of bioethanol consumption in Indonesia is as shown in Table 2.

Table 2. Prediction of bioethanol consumption (millions kL) year 2006-1010

Year	Bioethanol consumption (millions kL)
2006	1.71
2007	1.75
2008	1.78
2009	1.82
2010	1.85

Source : Prihandana *et al.*, 2007

The feedstock of bioethanol in Indonesia is planned mainly from sugarcane and cassava. However, other sources have potential as bioethanol feedstock in Indonesia (Table 3).

Table 3. Potential sources of bio-ethanol feedstock (Prihandana, *et al.*, 2007)

	Yield	Ethanol (l/Ha/year)
- Corn	1– 6 Ton/Ha/year	400 – 2500
- Cassava	10 – 50 Ton/Ha/year	2 000– 7 000
- Sugarcane	40 – 120 Ton/Ha/year	3 000 – 8 500
- Sweet potato	10 – 40 Ton/Ha/year	1 200 – 5 000
- Sorghum	3 – 12 Ton/Ha/year	1 500 – 5 000
- Sweet sorghum	20 – 60 Ton/Ha/year	2 000 – 6 000
- *Arrenga Pinnata*	0.6 – 1.2 million litre/ha/year	40 000 litre/ha/year
- Molasses	2000 litre/ha/year	500 litre/ha/year

Table 3 shows that *arrenga pinnata* has the highest production of ethanol. However, the ecosystem of this plant is limited. Sugarcane and cassava are the second and third highest in ethanol production. Although sugarcane and cassava are also used for food stock, the area extensions of the plantations are promising noting that cassava should be a rotational crop to avoid soil nutrient depletion. Research and development are also working to increase productivity yield and starch content with government support. Sweet sorghum could also serve as a potential feedstock of national bio-ethanol in the near future.

At present, Indonesia has 11 bio-ethanol manufacturers. All of them are big scale with production capacity ranging from 3.6 millions l/year to 50 millions l/year. The expansion of big capacity manufacturers will produce a total of 940 million litre/year by 2010. Production of bio-ethanol at 95 per cent will be used mainly for industrial supplies. Since 2006, only PT Molindo Raya, has produced fuel grade bio-ethanol at 99.5 per cent. It is said that converting 95 per cent bio-ethanol to fuel grade requires a high investment cost of Rp 5-7.5 trillions, capacity 7 millions l/year. The technology adopted is molecular sieve (Prihandana *et al*, 2007). Besides large scale manufacturing, small scale distillers are also expected to grow, especially for the development of DME. Several pilot plants have been built and are in operation for commercial purposes. The investment cost is varying from Rp 2 millions to Rp 100 millions (Prihandana *et al*, 2007). For feasibility reasons, it is recommended that small scale plants produce ethanol between 90-96 per cent, while dehydration to 99.5 per cent is done by medium and big scale distilleries. This allows the quality of fuel grade ethanol to be maintained as required by the national standard for fuel grade, SNI Bioetanol No. DT-27-0001-2006.

3.3. Agricultural Waste

Estate Crops Waste

Estate crops that generate biomass waste in this regard are those of rubber, oil palm, coconut and sugarcane plantations (estates) where the areas and their main crop production tend to significantly increase year by year. Further, such estate crops wastes (Table 4) offer woody biomass matter such as woody trunks, shell, bunch, and also organic rich liquid waste.

Food Crops Waste

Waste of food crops that have the potential as energy sources are paddy (rice straw and hull). Potential sources of waste from other food crops are: maize (stem, leaves, hairs, and fruit core), cassava (stem, leaves), peanut (stem, leaves, and fruit shell), soybean (stem, leaves, fruit shell). Table 5 shows estimation in the potency of food crops waste.

Direct burning of biomass either for daily cooking or production of heat/steam in industries is a part of the combustion technique. This classic technology is still used in Indonesia and many other countries, particularly developing countries, because of its ease and low cost technology. In Indonesia, firewood consumption for cooking and small scale or home industries remains high at about 50 per cent of national energy consumption. Direct burning inside a furnace allows heat to pass into a heat exchanger for generating heat in the drying process of agricultural products. Gasification of rice husk is already developed for electrical generation of up to 0.5 MW. Several sugarcane factories utilize bagasse for heating boilers of electrical generators.

Integrated charcoal processing means processing of biomass into charcoal and activated charcoal with maximum waste utilization i.e. char powder for briquette charcoal and smoke is condensed into wood vinegar or smoke liquid. This technology adapts cleaner technology processes because of zero waste achievement, where solid waste is converted to char-briquette and polluted gas exhaust is condensed and converted into wood vinegar. This technology offers high effectiveness and efficiency in processing that could decrease production costs. Moreover, selling value of activated charcoal is about 10 times higher than charcoal, with wood vinegar about 5 times (crude) to 50 times higher (refined).

Table 4. Estimation of estates crops waste potency (Sudradjad, 2004; MOA, 2005)

No	Kind of waste	Area (ha)	Conversion factor (per cent)	Potency (m^3/ha)	Total Potency (ton/yr)
1	Rubber trunk	3,279,391	3.33*	35	3,279,391
2	Oil palm	6,370,217			11,861,615
	Trunk		5.46*	78	16,277,688
	Shell		5**		593,080
	EFB		20**		2,372,323
	Ditch CPO		15**		1,779,242
3	Coconut	3,803,614			3,096,845
	Trunk		2.0*	80	3,651,469
	Shell		12****		371,621
4	Sugarcane	381,786			2,241,806

	Bagasse		4****		76,357.2
	Molasses		3****		57,267.9
Total					45,658,705

Remarks: * Rate of tree replantation per year, ** percentage from FFB
**** Percentage from the whole fruit, ***** percentage from sugarcane

Table 5. Harvesting areas, productions and waste potency of some food crop products

No	Kind of Agricultural Products	Harvesting area (10^3 ha)	Production (10^3 ton)	Yield Rate (quintal/ha)	Conversion Factor (ton/ha)	Potency (10^6 ton)
1	Paddy**	11,786.430	54,454.937	46.20	5.1	60.110
2	Maize	3,345.805	11,609.463	34.70	5.2	17.398
3	Cassava	1,227.459	19,986.640	163.00	6.1	7.487
4	Peanuts	706.753	838.096	11.86	2.0	1.413
5	Soybeans	580.534	747.611	12.88	1.8	1.045
	Total					87.453

Source: (Sudradjad, 2004; MOA, 2006)

Agricultural Industry Waste

Waste management is an important factor regarding the agricultural industry. Wastes of the farm or agricultural industry increase environmental pollution degrading soil, water and air. They have been implicated as a cause of decreased quality of life for neighboring communities, with additional possible negative consequences on human health and welfare. Outputs of wastes should be managed to minimize adverse effects and maximize beneficial effects in the production system and environment. Pilot projects for waste management are needed to initiate and persist in environmentally friendly practices. One of many methods of waste handling is delivery liquid waste into central water treatment and/ or biogas digester systems by anaerobic fermentation processes. Several benefits of biogas digester systems are eliminating greenhouse gas, reduction of nuisance odors, betterment of fertilizer, and production of heat and power (electrical and mechanical power). These utilizations would be economically viable because of the rising price of fossil fuel and inorganic fertilizer. Moreover, managing waste wisely can generate new business opportunities by empowering rural communities.

In a palm oil factory, production of 1 ton Crude Palm Oil (CPO) will result in 2.5 tons of waste. Cassava, sugar mill factories also have large amounts of waste water. Animal husbandry farming, such as cattle, dairy and buffalo with amount of 13.7 million heads, produces 12 kg waste/head/day on average with a total of around 164.2 ton waste per day. This feedstock could be utilized for biogas production by anaerobic fermentation inside a biogas reactor.

ICAERD in 2005 developed a digester for small farming. The digester was designed to have a 18 m^3 holding capacity for cattle dung of 10-20 heads. The digester produces 6 m^3/ day of biogas. Biogas is utilized to generate stove, mantle lamp, and engines for mechanical power / electrical generators. Effluent from digesters could be used for fertilizer and fish ponds. Based on feasibility studies, the biogas installation was feasible technically and economically for development. Benefits of the biogas installation are (1) digesters are made of locally available materials, easy to operate and low maintenance cost, (2) dual-fuel engine for electric generator (mixture of 90 per cent biogas with 10 per cent diesel oil), simple biogas filter, long duration of operation time and low gas emission of exhaust gas engine. (3) By integrated model development of biogas installation, the process is more effective, efficient for optimal profit achievement.

Digester produces biogas continuously, therefore storage and biogas bottling are considered to be important research for development.

Figure 4. Biogas reactor, dual-fuel engine for electric generator and biogas bottling

4. Challenges and Opportunities of Bioenergy Development in Indonesia

4.1. Biodiesel

Global biodiesel production capacity in 2001 was 900,000 tons (approximately 1,000 million litres). Of this amount, Europe supplied 850,000 tons and the United States 50,000 tons. In Europe, Germany, France, and Italy are major producers with Germany contributing about 400,000 tons of biodiesel whilst France and Italy produced 330,000 and, 75,000 tons of biodiesel respectively in 2001. Within the last few years, biodiesel production capacity is expanding worldwide due to soaring oil prices and greater concern on environmentally sustainable economic growth causing individuals and nations to seek alternative and more environment-friendly fuels such as biodiesel. 2005 shows global biodiesel production capacity has been quadrupled since 2001. Germany continues to lead world biodiesel production with many Asian countries such as Malaysia, India and Indonesia taking the initiative and contributing to the world total biodiesel production.

To assess the potential of the worldwide biodiesel market, one could consider world fossil diesel consumption that reached 637,405.8 million litres for transportation only as of 2001. Based on the increase of world middle-distillate oil consumption, the aforementioned number is estimated to have grown by at least 700,000 million litres at the beginning of 2006. Considering only 5 per cent biodiesel substitution into fossil diesel (B5), the required biodiesel capacity would be 35,000 million litres for transportation only. Hence, there is still more than 30,000 million litres of worldwide biodiesel potential market up for grabs. Moreover, increased biodiesel production is envisaged since B20 is foreseen by many countries as their future target.

Considering the abundance of raw material and the increasing domestic consumption of diesel oil to satisfy the target as projected by the National Energy Policy, developing biodiesel in Indonesia has a good prospect. The country's National Energy Policy states that biofuels as a part of renewable energy sources are targeted to contribute at least 5 per cent of the total national energy consumption by 2025. According to the biodiesel roadmap, the total biodiesel produced for such a programme could reach around 1.5 million kL per year by 2010, 3 million kL per year by 2015 and at least 6.4 million kL per year by 2025.

Transportation Sector

The renewable energy policy, especially biofuels, states that the target of biodiesel use in 2010 is 10 per cent of the total diesel oil for transportation consumption. Table 6 shows potential of biodiesel substitution in the transportation sector, where a figure of 10 per cent equates to an amount of 1.337.000 million tones biodiesel per year. To meet this target, Indonesia should develop 15 to 40 units' biodiesel plants at commercial scales with plant sizes of 30,000 to 100,000 tones per year.

Industrial Sector

To fulfill the industrial demand of biodiesel, the regulation is not restricted to the blending regulation of 10 per cent biodiesel. Thus, pure biodiesel can be marketed without any trade limit (Table 7). The price of biodiesel will compete with the market price of many types of industrial fuels. The Department of Energy and Mineral Resources (July 2006) noted that the price of industrial diesel fuel is in the range of IDR 6,014.91 per litre to IDR 6,227.27 (DESDM 2006). Meanwhile, the price of crude palm oil (CPO) per kg was about IDR 3,628 in January of 2006, with the real potential price possibly reaching IDR 4,000 per kg. The price of CPO processing to produce biodiesel is approximately at IDR 1,500.00 per litre for any plant with production capacity of 500 tones per year, and at IDR 550.00 per litre for a plant with a production capacity of 120,000 tones per year. Assuming that oil density is 0.8, the price of CPO can be around CPO IDR 3,800 per litre and the price of biodiesel for industrial sectors between IDR 4,300 and IDR 5,300 per litre. Biodiesel demand as an industrial raw material or additive has not been calculated, mainly due to the lack of domestic demand for biodiesel as a raw material for other chemical production.

Table 6. Potential biodiesel substitution in the transportation sector

Year	Automotive Diesel Oil (Thousand kL)	Biodiesel (Thousand kL)	Total (Thousand kL)
2005	11,791	0	11,791
2006	14,411	87	14,498
2007	12,669	167	12,836
2008	13,101	377	13,478
2009	12,949	1,203	14,152
2010	13,522	1,337	14,859

Source: DESDM, 2006

Table7. Projected Biodiesel Consumption for Industrial Sector up to 2010 with various Blending percentage (Thousand kL)

Year	Diesel oil for Industry	10 per cent Biodiesel-Fossil	20 per cent Biodiesel-Fossil	30 per cent Biodiesel-Fossil	40 per cent Biodiesel-Fossil
2005	8320	8327.488	16 646.656	24 965.824	33 284,992
2006	8570	8577.713	17 146.856	25 715.999	34 285.142
2007	8827	8837.944	17 657.062	26 486.179	35 315.296
2008	9091	9098.182	18 187.273	27 276.364	36 365.455
2009	9364	9368.428	18 737.491	28 096.555	37 465.618
2010	9645	9658.681	19 297.716	28 946.752	38 585.787

Source: DESDM, 2006.

As a state-owned company which carries out business in oil, gas, LNG, energy and petrochemical industries, PERTAMINA has announced its intentions to produce and sell biodiesel in Indonesia. The target of PERTAMINA is to gradually substitute diesel oil especially used as transportation fuel. Since 20 May 2006, PERTAMINA has been selling a blend of 95 per cent diesel fuel (ADO) and 5 per cent SNI standard biodiesel with the trade name of BIOSOLAR Currently, PERTAMINA has been selling BIOSOLAR with the price of IDR 4.300, same with the subsidized automotive diesel oil at around 170 diesel fuel public filling station (SPBU) in Jakarta and more than 5 SPBU in Surabaya (East Java) with a total volume around 1.400 kL per day (Pertamina, 2006) With continuous growth of domestic biodiesel production, PERTAMINA will open the BIOSOLAR's SPBU in all big cities in Indonesia and increase the biodiesel blending content (B10, B15, etc). Table 7 shows the Projected BIOSOLAR and FAME Estimation.

4.2. Bioethanol

Besides diesel fuel, gasoline is also consumed widely in Indonesia. Decreased consumption of gasoline can be done by bioethanol mixing with gasoline. In this case, the government has stopped the regulation of gasohol mixture at 10 per cent of gasoline fuel (E-10). Bioethanol could be produced easily from crops, such as sugar cane, sago, corn and cassava. Molasses as a by-product of the sugar milling process has an opportunity for mass production of ethanol.

The current total consumption of gasoline in Indonesia is about 15 million KL per year. If 2 per cent of the gasoline consumption in 2010 is substituted by ethanol, the requirement of gasohol at 10 per cent blend ratio works out to 4.2 billion litres. The requirement of fuel grade ethanol on the national basis is estimated at 420 million litres per year. As an example, cassava feedstock of about 2.73 million tons requires a cultivated area of 100,000 ha. Cassava is seen as a potential resource of bioethanol. It is very easy to be planted and familiar to farmers. Based on the research result, 1 ton of cassava can produce 167 litres of ethanol. Development of a new variety of cassava can improve this yield by up to 250 litres. Comparing to corn as an ethanol source material, cassava can be planted on marginal soil and does not require special treatment.

In addition, every year, in Indonesia, there are around 365 thousand tons of sugar milling by-products that can be turned into ethanol. With such potential resources, the government target of 2 per cent bioethanol substitution could be met by 2010. It is possible that this target could be increased beyond 2 per cent in order to greatly reduce gasoline consumption and government subsidies that are part of national budgets.

4.3. Agricultural Waste

The utilization of renewable energy in Indonesia is still very low compared to its huge potential. Biomass is around 50 GW but utilization is less than 1 per cent. The barriers in developing renewable energy technology and clean energy technology are related to high investment costs as most technologies are still imported. Given such realities, it is important to conduct research and development activities to produce locally proven technologies that are able to reduce costs.

Kerosene consumption is dominated by household need. In 2005, household consumption of kerosene was around 11,233 million litres or 99.2 per cent of total national consumption. The Government of Indonesia (GOI) subsidizes around 67 per cent of the market price of kerosene. To reduce costs, the government is now conducting a programme to convert kerosene to LPG. This programme will be considered profitable to all parties because utilization of 1 litre of kerosene is equal to 0.4 kg of LPG.

By this fact, there is an opportunity to develop conversion energy technology of biomass such as furnace, gasification, charcoal and briquette. In addition, methane gas enrichment technology for biogas bottling also has the potential to succeed with due to government initiatives.

5. Conclusions

1. Indonesia has a comparative advantage for bioenergy production because of greater availability of land, favorable climatic conditions for agriculture and lower labor costs. However, Indonesia faces socio-economic and environmental implications affecting the potential to benefit from the increased local and global demand of bioenergy.

2. The interrelationship between land use and the competing needs of energy and food security are key issues in the area of bioenergy that should be considered. In addition, the effects of large-scale bioenergy production on global commodity prices are a significant trade concern. Bioenergy production may also entail harmful environmental effects such as deforestation, degraded lands and water resources, desertification and loss of biodiversity. Regulation is required to reduce the negative impacts of large-scale production, as well as to ensure that the most cost-effective and highest-energy conversion technologies are used.

3. The stages of bioenergy development from research to commercialization have been done. These include how to accelerate the construction of new bioenergy plants, and sustainable plantations in the continuity of raw material supported by government policy and regulation commitments.

4. Opportunities to market biodiesel and gasohol are now widely accepted as the current government fully supports biofuel development. This support is manifested into several government regulations regarding fuel blending and conversion of kerosene to LPG.

5. The village self-sufficiency energy programme (Desa Mandiri Energi or DME) promotes biofuel development in designated regions to create job opportunities in impoverished, isolated or remote villages by empowering society to fulfill their energy needs.

References

DESDM. 2006. *Direktorat Jendral Minyak dan Gas* (Directorate General of Gas and Fossil Fuel). http://www.esdm.go.id

EIA. 2005. Country Analysis Brief: Indonesia. http://www.eia.doe.gov

Handaka. 2003. *Prospek Penggunaan dan Penelitian Teknology Energy untuk Pertanian di Indonesia. Seminar Nasional dan Ekspose Mekanisasi Pertanian* (Prospect of Research and Utilization of Energy Technology for Agriculture in Indonesia. National Seminar and Expose of Agricultural Mechanization). Jakarta 12 August 2003.

MOA.2007. Ministry of Agriculture (MOA) the Republic of Indonesia. http://www.deptan.go.id

Prastowo, Bambang. 2006. *Pengembangan Komoditas Pertanian untuk Bahan Bakar Nabati Mendukung Industrialisasi Pertanian*. *Seminar Nasional Mekanisasi Pertanian: Bioenergi dan Mekanisasi Pertanian untuk Mendukung Pembangunan Industri Pertanian.* (Development of Agricultural Commodity for Biofuel to Support Agricultural Industrialization. National Seminar on Agricultural Mechanization: Bioenergy and Agricultural Mechanization to Support Agricultural Industry). Bogor-Indonesia, 29-30 November 2006.

Prihandana, R. 2007. *Bioethanol Ubikayu, bahan Bakar Masa Depan* (Bioethanol from Cassava, the Future Fuel). Agromedia, Jakarta.

Sudradjad. R. 2004. The Potential of Biomass Energy Resources in Indonesia for Possible Development of Clean Technology Process (CTP). Proceeding The International Workshop on Biomass & Clean Fossil Fuel Power Plant Technology: Sustainable Energy Development & CDM, Jakarta-Indonesia, January 13-14,2004.

Sudradjad, R.2007. Non-Edible Plants for Bioenergy: National Policy Perspective on the Use of Natural Resources in Indonesia. World Renewable Energy Regional Congress and Exhibition (WRERCE). Jakarta-Indonesia, 5-7 November 2007.

Timnas Energi (National Team) 2005. *Blue Print Pengembangan Bahan Bakar Nabati untuk Percepatan Pengurangan Kemiskinan dan Pengangguran* (Blue Print of Biofuel for Acceletaion and Elimination of Unemployment and Poorness) 2006-2015.

Tim Nasional Pengembangan BBN (National Team for Biofuel Development). 2007. *Bahan Bakar Nabati: Bahan Bakar Alternatif dari Tumbuhan Sebagai Pengganti Minyak Bumi & Gas* (Biofuel: An Alternative Fuel from Plant for Replacing Gas and Fossil Fuel) . Penebar Swadaya. Jakarta.

THE CURRENT STATUS OF BIOFUEL IN KOREA

Dr. Hee-Chan KANG

Senior Researcher

Samsung Economic Research Institute
#124-702 SK Apt. Mia-dong, Kangbuk-Gu, Seoul, Korea
Tel: +82-2-10-6313 1973, Fax: +82-2-3780 8008, Email: hckang@seri.org

Executive Summary

Biofuel production is a unique opportunity to provide a renewable, reliable and self sufficient source of energy to the Republic of Korea. In recent years, the Korean government implemented several policies to encourage production of biofuels because of its environmental friendliness and increase of secure stability of long term energy supply. With advanced governmental supports on biofuel, Korea has become the first country in Asia to mass produce Biodiesel. In July 2006, the Korean government allowed all gas stations across the nation to sell fuel consisting of 5 per cent biodiesel and 95 per cent petroleum diesel. As for bioethanol, the government has invested 2.6 billion Won in 2006 in order to evaluate the effectiveness of bioethanol, seeking to commercialize bioethanol by 2008. During 2008~2011, The Pilot project for bioethanol will begin and test the technical feasibility and acceptability in Korean market.

Considering the current market expansion of biodiesel and bioethanol in Korea, by 2030, the portion of biofuel in gasoline and diesel consumption will be 20 per cent. Provision of biodiesel will grow 0.5 per cent annually and be increased by 1.0 per cent in 2008, and 3.0 per cent in 2012 of total diesel consumption

However, Korean government has faced a problem in implementation of biofuels: the secure supply of feedstock. Currently, the biodiesel plants are using imported vegetable oils as feedstocks. As a result, biodiesel production costs about 1.5 times higher than that of diesel fuel. To solve this problem, the Korean government is considering two domestically available sources of feedstocks: waste (used) frying oil and the rapeseed and executing R&D on feasibility and technical improvement. Beside the domestically available feedstock, the Korean government is also considering the feedstock available from foreign countries as a

way of direct investment on foreign plantation. As the appropriate way for feedstock diversification, the various feedstocks such as jatropha, palm, castor are being considered.

To support the dissemination of biodiesel, the Korean Ministry of Commerce, Industry and Energy (KMOCIE) adopted a tax exemption. With the current tax exemption policy on alternative energy, biodiesel is expected to have cost competitiveness over diesel. Besides the tax exemption policy on Biodiesel, subsidies on farmers who produce feedstock of biodiesel are being considered as a part of agricultural policy. The Korean government allocated $2.8 million earlier 2007 for rapeseed production as part of its effort to cut the country's dependency on foreign raw materials.

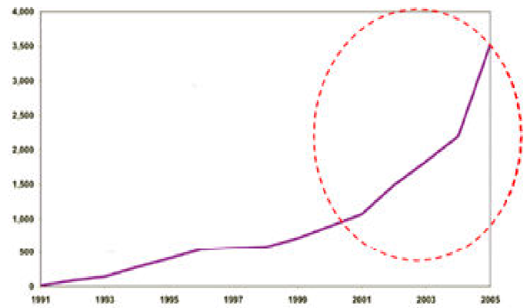
1. Introduction

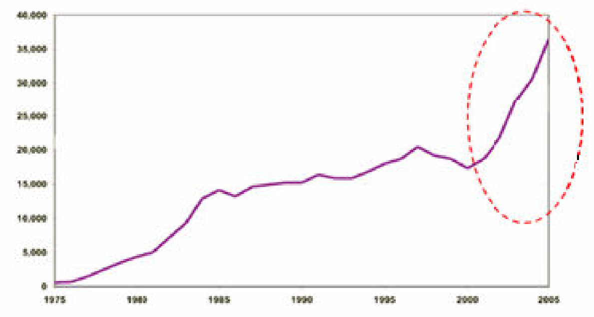
Biofuels are made from biomass consisting of plant and animal substances that can be used as an alternative to common fossil fuels such as diesel oil and gasoline. Biodiesel refers to diesel-equivalent, processed fuel derived from biological sources such as vegetable oils, rice grains, and soybean and rapeseed oils which can be used in unmodified diesel-engine vehicles. Bio-ethanol, made from feedstock with a relatively larger amount of starch and sugar content such as corn or sugar cane can be also used in conventional gasoline.

In recent years, an increasing number of firms have produced biofuels due to growing concern over global warming and rising oil prices (waning supplies of fossil fuels) because of its environmental friendliness and increase of secure stability of long term energy supply.

Between 2000 and 2005, total global production of bioethanol has almost doubled, with production of biodiesel increasing 3.5 times. The volume of global biofuel production has steadily risen since the United States (US), European Union (EU), and Brazil have expanded production volume against the backdrop of soaring oil prices.

Figure1. Global Production of Biodiesel **Global Production of Bioethanol**





Source: Worldwatch Institute

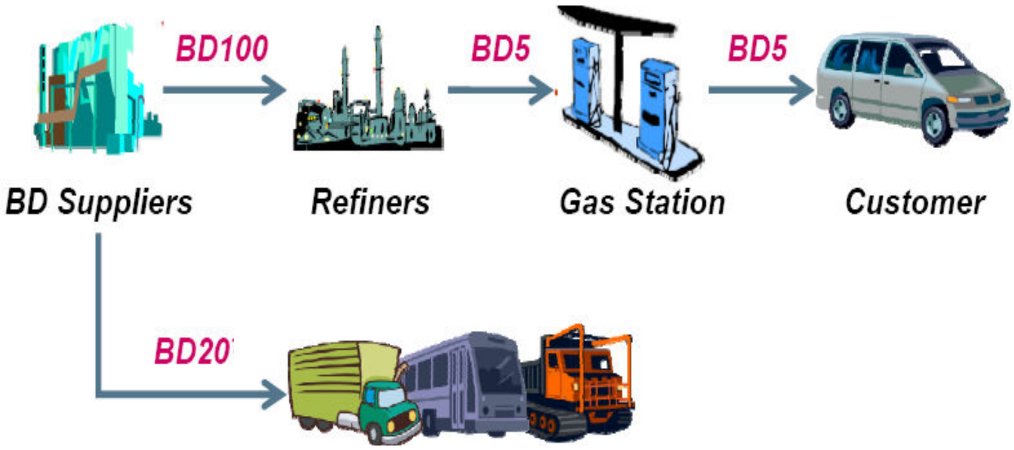
Industrialized countries currently develop biofuels in order to: 1) use it as an alternative energy source to replace fossil fuels 2) strengthen overall energy security, 3) reduce negative impact on the environment; and 4) help farming households raise income levels. In order to capture positive externalities associated with these benefits, industrialized countries promote biofuels despite prohibitive production costs.

2. Current state and Outlook of Biofuel in Korea

2.1 Current Status

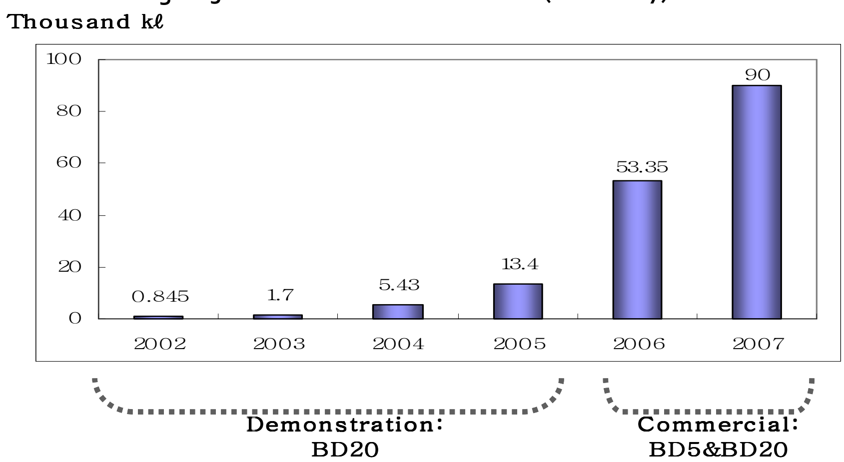
Korea is the first country in Asia to mass produce Biodiesel and also commercialize BD5 (5 per cent Biodiesel+95 per cent diesel). Historically, in 2002, the government launched a pilot project authorizing 168 gas stations in Seoul, Gyeonggi province and North Jeolla province to sell fuel mixes containing 20 per cent biodiesel with petroleum diesel labeled BD20 to commercial vehicle operators specializing in maintenance facilities. From July 2006, the Korean government and Korean Refineries agreed on voluntary biodiesel supply. According to this agreement, Korean Refineries shall utilize biodiesel 90,000 kℓ(corresponding to 0.5 per cent of total petrodiesel sales) annually for 2 years. The biodiesel products supplied by only Korean refineries are BD5 which is subject to diesel fuel spec. In addition, Bus, truck and construction equipment operators can use BD20 on their own accord only if they are equipped with 'certified storage tank' and 'self-repair shop'.

Figure 2. BD5 and BD20 Supply Chain



In 2006, the total production of Biodiesel was 53.35 thousand kℓ and will be expanded to 90 thousand kℓ in 2007. From 2008, the Korean government is considering mandatory blending of BD reflecting a tightened policy over voluntary agreements.

Figure 3. Biodiesel Production in Korea (2002~2007)



Source: MOCIE, 2006 and Korea Biodiesel Association, 2007

Currently, a total of 16 domestic firms, including SK Chemicals and Aekyung have 400 thousand ton annual production capacity. As of January 2007, nine suppliers are registered as certified suppliers, and they are aggressively expanding their capacity. For technical concerns with biodiesel, special attention has been paid to cold flow property and oxidation stability. Also since characteristics of biodiesel can affect the performance of newly developed engine (common-rail diesel engine), the policy for technical improvement such as after-treatment devices has bee established with special care.

Table 1. Suppliers and Production Capacity of Biodiesel in Korea

Suppliers	Capacity(kl/yr)	Source
Kaya Energy	100,000	Soybean, Waste Oil
B&D Energy	50,000	Soybean, Waste Oil
Econertech	33,000	Waste Oil
BASKO	27,300	Soybean, Waste Oil
BDK	20,000	Soybean, Waste Oil
Others	84,000	Soybean, Waste Oil, Palm
Total	314,300	

Source: Korea Biodiesel Association, 2007

As for bioethanol, the government has invested 2.6 billion Won in 2006 in order to evaluate the effectiveness of bioethanol, seeking to commercialize bioethanol by 2008. During 2008~2011, The pilot project for bioethanol will begin and test the technical feasibility and acceptability in the Korean market.

2.2. Outlook

Considering the current market expansion of biodiesel and bioethanol in Korea, by 2030, the portion of biofuel in gasoline and diesel consumption will be 20 per cent.

Provision of biodiesel will grow 0.5 per cent annually and be increased by 1.0 per cent in 2008, and 3.0 per cent in 2012 of total diesel consumption

Table 2. Outlook of supply of biofuel (1,000toe)

Year	2005	2010	2015	2020	2025	2030
Diesel	16,301	18,635	20,016	22,437	24,531	25,942
Biodiesel	8	373	1,001	2,244	3,680	5,188
per cent	0.05	2	5	10	15	20
Gasoline	7,512	7,818	8,945	9,001	9,158	9,403
Bioethanol	-	78	447	900	1,374	1,881
per cent	0	1	5	10	15	20

Source: MOCIE, "long-term dissemination plan of Biodiesel" 2007.7

2.3 Challenges and Opportunities

Most of all, market competitiveness is the crucial issue in production of biodiesel. In July of 2007, the average production cost of biodiesel using imported feedstock(soybean) is $1.05/liter and that of biodiesel using waste oil is $0.89/liter, and weighted average production cost of biodiesel in Korea is $1.01/liter since supply share of imported soybean used in biodiesel is 77.3 per cent and that of waste oil is 22.7 per cent. On the other hand, the diesel production cost without tax is $0.62/liter

Table 3. Structure of BD production Cost

Cost		Imported soybean	Domestic Waste Oil
Feedstock Cost		69 per cent	63 per cent
Capital Cost	Material Cost	8 per cent	10 per cent
	Operation Cost	15 per cent	18 per cent
	Others	8 per cent	9 per cent
Total		100 per cent	100 per cent

Source: KEEI, "Biofuel Promotion Policy and Economics in Korea", 2007.9

Currently, biodiesel plants are using imported vegetable oils as feedstocks. As a result, biodiesel production costs are about 1.5 times higher than that of diesel fuel. As the feedstock for biodiesel production is expensive imported soybean oil, biodiesel could not be competitive to diesel without strong support from the government. To reduce the biodiesel cost, lower cost feedstock should be used because the imported vegetable oils take major portion of total biodiesel production costs. Since all feedstock should be imported and accounts for major portion of biodiesel production costs, it is worthwhile to utilize the biomass resources domestically available. Now, the Korean government is considering two domestically available sources of feedstocks: waste(used) frying oil and rapeseed. As a part of the R&D policy for increasing production of rapeseed, the Korean government has launched "the pilot project for rapeseed of biodiesel ('07~'09)". Three farm areas were selected: North Jeolla province, South Jeolla province, and Jeju province. The main goal of this project is two fold: 1) test of supply chain of rapeseed and productivity and market competitiveness and 2) test of the domestic production of feedstocks and test for the grant of money that can maintain current income level of farmers who want to switch to production of rapeseed over barley.

Table 4. The production plan of rapeseed during the pilot project

Year	2007	2008	2009	2010
Area (Thousand ha)	1.5	1.5	1.5	-
Amount (Thousand kℓ)	-	2.4	2.4	2.4

Source: MOCIE, "long-term dissemination plan of Biodiesel" 2007.7

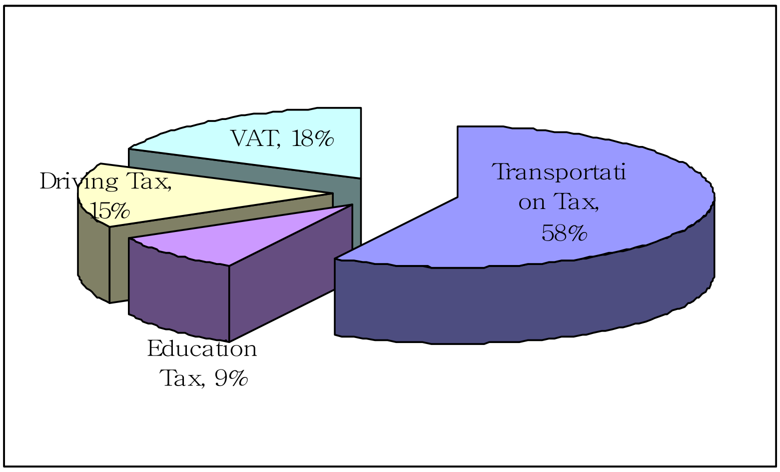
As for waste frying oil, the Korean Institute of Energy Research (KIER) has established a bench-scale process of biodiesel production from waste frying oil. During the work, the institute got some innovative technologies to enhance significantly productivity of the current commercial plant.

Beside the domestically available feedstock, the Korean government is also considering the feedstock available from foreign countries as a way of direct investment on foreign plantation. As the appropriate way for feedstock diversification, the various feedstocks such as jatropha, palm, and castor are being considered. A lot of conversation with various companies in Brazil, and South-East Asia is underway.

3. National Policies and Action Plan

To support the dissemination of biodiesel, the Korean Ministry of Commerce, Industry and Energy (KMOCIE) adopted biodiesel-blended fuel (BD5), the fuel mixture of Biodiesel 5 per cent and diesel 95 per cent. As a result, biodiesel in the fuel mixture is exempt from various taxes imposed on all fossil fuels. With the current tax exemption policy on alternative energy, biodiesel is expected to have cost competitiveness over diesel. While the retail price of diesel is $1.53/ℓ (2007.12.31~2008.1.4) in Korea, the price of biodiesel blending fuel at the pump is currently the same. The items included in the tax exemption on biodiesel are three folders: transportation tax, education tax and driving tax. Korea now expects the same policy effect as in Germany, where the German government implemented a strong tax exemption and succeeded in increasing the share of BD from 0.3 per cent in 1993 to 3.8 per cent in 2005.

Figure 4. Structure of Taxes on Diesel



Source: Petroleum Industry Division, MOCIE

Besides the tax exemption policy on Biodiesel, subsidies on farmers who produce feedstock of biodiesel are being considered as a part of agricultural policy. The Korean government allocated $2.8 million earlier in 2007 for rapeseed production as part of its effort to cut the country's dependency on foreign raw materials.

4. Three National Experiments

4.1 Brazil

Following two rounds of oil shocks in the 1970s, Brazil developed bioethanol in an effort to reduce dependence on foreign energy sources. In 1975, the Brazilian government launched the "ProAlcohol Programme" which encouraged both oil refineries and carmakers to support the government's efforts to promote bioethanol. Under the programme, the government pressed gas stations to sell bioethanol, offering subsidies to bioethanol producers. Helped by the government's support, Brazil has leveraged its rich natural resources such as sugarcane to become the world's largest bioethanol producer.

4.2 United States (US)

The US has also strived to develop the biofuel industry in order to break its heavy dependence on foreign energy resources. In his January 2006 State of the Union address, US President George W. Bush stated that the US was "addicted to oil" and needed to actively develop alternative sources of energy. He stated the US would aim to reduce oil imports from the Middle East by a total of 75 per cent in the year 2025.

4.3 European Union (EU)

In an effort to reduce greenhouse gas (GHG) emissions, the EU has also proposed plans to develop the biofuel industry. According to the European Commission's "An EU Strategy for Biofuels," the EU aims to increase the share of biofuels in its total energy mix to 20 per cent by 2025. The EU has also increased efforts to produce biodiesel through use of oil derived from rapeseed more suitable for countries in the EU. The EU is also providing policy support for member countries in order to accelerate biofuel development. For example, the EU encourages member countries to set aside 10 per cent of their total arable land in fallow. But, in an effort to promote biofuel development, it allows farmers to plant energy crops (crops planted to be used as raw materials of biofuel) in the fallow lands. Also, the EU provides tax credits and subsidies, and encourages member countries to use fuel mixed with a certain proportion of biofuels.

5. Feasibility Analysis

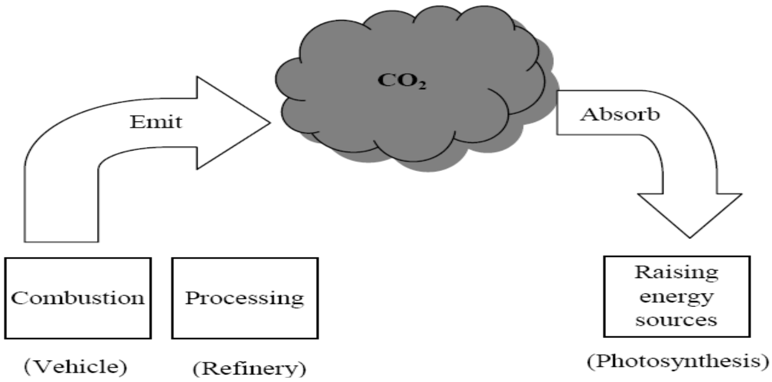
Biodiesel has emerged as one of the major alternative energy sources to fossil fuels such as oil and coal in recent years because it emits less carbon dioxide, sulfur oxide and minute particulate materials that pollute the atmosphere and contribute to global warming.

If Korea only considers market price in its feasibility analysis, it should import Bioethanol and avoid using Biodiesel. But, the Korean government should also consider the positive externalities associated with biofuel production that is not reflected in the market price. If Korea encourages domestic farming households to raise energy crops, it can substitute current oil imports with locally produced Biofuels. Also, farming households can boost current income levels. Biodiesel's import substitution benefits are larger than those associated with Bioethanol. If Korea substitutes 1 per cent of petroleum diesel import with locally produced Biodiesel, national income would increase by US$96.4 million a year. But, if it substitutes 1 per cent of gasoline import with Bioethanol, its national income would only increase by US$37.2 million a year.

If Korea wants to reduce GHG emissions, it should produce Biofuels domestically instead of importing them. In order to evaluate biofuels' effect on GHG emission reduction, GHG emissions should be measured at each stage of the life-cycle model. The life-cycle model consists of three stages: raising energy crops, processing and combustion. According to "A

Worldwide Review of the Commercial Product of Biodiesel," released by the European Environmental Bureau in 2004, the amount of carbon dioxide (CO2) produced as a result of biofuel combustion is almost same as that produced during the process of fossil fuel combustion. In other words, Biofuels, whose raw materials are produced through the process of photosynthesis, help reduce GHG emissions at the stage of raising energy crops, not at the stage of combustion. Therefore, Korea can reduce its GHG emissions only when it produces Biofuels domestically.

Figure 5. CO2 Neutrality of Biofuels



Note: *Biofuels are CO_2 neutral since raw materials of biofuels absorb CO_2 produced during the process of combustion. As a result, the total volume of GHG existing in the atmosphere does not change.*

An analysis of the life-cycle model shows that biodiesel is more efficient in reducing GHG emissions than bioethanol. Given that CO2 emission permits (or reduction credits) were traded at 26 euros per ton of CO2 in the EU's emission trading markets for the first five months of 2006, a one ton reduction in GHG emissions is worth approximately US$31. If Korea had substituted 1 per cent of the petroleum diesel consumed between 2000 and 2004 with biodiesel, it could have reduced GHG emissions by a total of 543,000 tons worth US$170 million. Similarly, if the nation had substituted 1 per cent of gasoline consumed between 2000 and 2004 with bioethanol, it could have reduced GHG emissions by 113,000 tons worth US$35 million. In order to assess the value of biofuels' effect on air pollution reduction, Samsung Economic Research Institute conducted a survey of 1,047 subscribers on our website (www.seri.org). Unlike GHG emission permits which can be traded on the open market, air pollutant emission permits are not traded on the market, making it difficult to assess their market value. According to the survey, the amount of air pollutants which can be reduced by using biofuels is worth 69.12 Won or 7.2 cents per litre. Since biofuels' effect on air pollution reduction appears at the combustion stage, a country can reduce air pollutant emissions not only when it produces biofuels domestically, but also when it imports them from other countries.

Korea can diversify energy sources and reduce its heavy dependence on foreign energy sources by domestically producing biofuels. However, if it imports biofuels instead of producing them domestically, it would not reduce overall dependence on foreign energy sources. If Korea chose to use biofuels without domestic production, it would become dependent on biofuel producing countries such as Brazil, and not the Middle East. According to our analysis, Korea would gain the largest benefit if it produces Biodiesel domestically. The total social benefit would be derived from (in descending order): 1) when Korea begins to produce bioethanol, 2) when Korea begins to import bioethanol, and 3) when Korea imports biodiesel. Our analysis shows that the social benefit is larger when Korea produces biofuels than importing them. However, any decision should also take into account production costs required to raise energy crops and refine biofuel. Against this background, Korea should only produce biofuels domestically when the positive externalities outweigh negative externalities in addition to production cost. To this end, Korea needs to reduce its production cost of biodiesel below US$0.59 per litre and that of bioethanol below US$0.5 per litre.

Table 5. B/C result of biodiesel and bioethanol

(US$ mil.)

	Biodiesel		Bioethanol	
	Produce	Import	Produce	Import
Total benefit	1289.2	-411.8	486.5	109.5
Income increase	963.6	-569.4	381.4	39.1
GHG reduction	168.0	0.0	35.0	0.0
Air pollution reduction	157.6	157.6	70.4	70.4
Unit production cost at which social benefit is larger than total production cost	US$0.59/liter	-	US$0.5/liter	-

Source: SERI, "Biofuel as Korea's alternative fuel", 2006.11

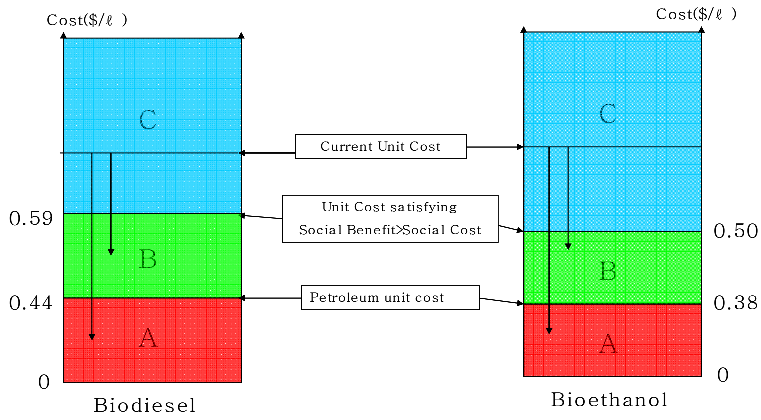
Note: In the case of biofuel imports, the production cost is 0.

6. Conclusions and Recommendations

Biodiesel can be a good choice for Korea's Biofuels since it can reduce GHG emissions and air pollutants, and boost farming household income. However, Korean firms should aim to lower biodiesel production costs below US$0.59 per litre in order to reap maximum social and fiscal benefits. The optimal side considering the social benefits is that Korea would not need to lower the unit cost of biodiesel lower than $0.44/ℓ which is current unit cost of diesel production. As long as the unit cost of biodiesel production is lower than $0.59/ℓ, the introduction of biodiesel in Korea is socially and fiscally beneficial. EU member countries serve as a good example for Korea to emulate. In particular, the Korean government and firms should take a page from Germany whose environmental conditions are similar to that of Korea.

On the other hand, Korean firms do not pursue bioethanol due to its high production cost. Since Korean farmers do not mass produce bioethanol's basic constituent materials such as sugarcane and corn, it would be difficult to reduce Bioethanol production cost below US$0.5 per litre.

Figure 6. Biofuel Unit Cost



If Korea decides to produce bioethanol, it should consider establishing large-scale farms raising corn and sugarcane in Asian countries such as Indonesia and Bangladesh and importing bioethanol's constituent products from those countries. Also, it should develop new energy crops which can be locally raised, thus lowering production cost.

Certainly, biofuels are not price competitive vis-à-vis other fuel types. Therefore, the government needs to provide fiscal subsidiaries and tax concessions for producers. In the case of biofuel import, import tariffs should be lowered. At the same time, regulations should be considered to have oil refineries mix a certain proportion of biofuels with petroleum.

In an effort to increase demand for biofuels, more diverse biofuel products should be released on the market. Currently, the only option for Korean consumers who want to purchase Biofuels is BD5 (the mix of 5 per cent Biodiesel and 95 per cent petroleum diesel). Requiring government agencies to use biofuels can also be a good measure to boost overall use. Also, the government and refineries should cooperate to strengthen product quality management in the process of production and distribution so as to ease consumers' worries over product quality.

In order to successfully develop a biofuel industry, Korean farmers need to secure arable lands which can be used to raise energy crops. They can use reclaimed lands and fallow lands in the near term. From a long-term perspective, farmers need to plant energy crops in arable lands used to produce rice and barley, which are abundant in Korea. The government has to set up effective policies to encourage farming households to raise energy crops. To this end, it needs to make up for losses if the price of energy crops falls below a certain level at which farming houses make losses. What should come along with effective policies is systemic support. For example, the government needs to make efforts to improve the productivity of energy crops, establish complexes attracting farming households raising energy crops, and enhance the distribution system.

References

Heechan Kang. "Biofuel as Korea's alternative fuel", Korea Economic trend, Samsung economic research institute, No.501, Nov 2006.

Heechan Kang, "Evaluation and Implication for the Validity of Korean-type Biofuels" Korea Industry Report, Samsung economic research institute, Jan 2007

InHo Cho, "The Usage of Biofuels in Korea and Future Issues", Fuels Lab, Energy R&D Center, SK Corporation. Feb 2007

JeongHwan Bae, "Biofuel Promotion policy and Economics in Korea", International conference on commercialization of Biofuels, Korea Energy Economics Institute, Sep 2007.

Sungyoung Yang, "The current trend and outlook of bioenergy industry in Korea",

Worldwatch Institute.「Bio-Fuel for Transportation」Global Potential and Implications for sustainable Agriculture & Energy in the 21st Century, Suzanne Hunt WorldWatch Institute, 2006

BIOGAS SUPPORT PROGRAMME OF NEPAL: CURRENT SITUATION ANDEXPERIENCES/LESSONS LEARNT

Raju Laudari
Alternative Energy Promotion Centre (AEPC)
Khumaltar, Lalitpur, Nepal
P.O.Box: 14237
Tel: 977-1-5539391
Fax: 977-1-55
Email: raju.laudari@aepc.gov.np

Executive Summary

Biogas technology, one of the most reliable and popular sources of cooking energy in rural and semi-urban areas of Nepal, was introduced in 1955 for the first time. The support of the Directorate General for International Cooperation of the Netherlands government through the Netherlands Development Organisation in Nepal (DGIS/SNV) through Biogas Support Programme (BSP) since 1992, became the cornerstone in the development of biogas sector in Nepal. Then after, the installation of household biogas plants increased with some fluctuation after 2001/02. By December 2007, the number of household biogas plants installed reached 186,172. The present BSP phase IV is running until 2009 with the technical support of SNV/N and the subsidy support of the Kreditanstalt fur Wiederaufbau of Germany (KfW), DGIS/SNV and Government of Nepal (GoN). The fixed dome design is implemented/installed with the subsidy support under the current subsidy policy - Subsidy on Renewable (Rural) Energy 2006, which has provision of additional subsidy to smaller size plants as a result. The subsidy is accessible to the poor farmers. The amount of subsidy is categorized based on the geographical situation of the country, with more subsidy to the high hill areas.

The Alternative Energy Promotion Centre (AEPC) is the executing agency of all renewable and alternative energy programme including biogas in Nepal. Biogas Sector Partnership Nepal (BSP/N) is the implementing agency of the Biogas Support Programme (BSP) phase IV. SNV/N has provided both programme management and subsidy support, and KfW provides more than two-thirds of the subsidy amount. Biogas companies (BCs) play a key role in the sector by installing quality biogas plants; visiting the users; building awareness about biogas and working as a bridge between the farmers and the implementing agencies. Along with a few banks, Micro Finance Institutions (MFIs), those who have received fund as wholesale lending from AEPC, are providing credit to the farmers to install the plants.

The price of imported fossil fuel is increasing and the cost of cooking energy is becoming expensive, which prompted, the country to spend big amounts of foreign currency. Most of the rural Nepalese use firewood as a source of energy for cooking, and as a result, deforestation has become a major problem. The use of non-renewable biomass as a source for cooking, produce CO_2 and increase the greenhouse gases in the atmosphere. In the present day, biogas seems to be the most popular cooking source of energy in Nepal, which is clean and sustainable. Nepal has immense market of household biogas plants, but only around 10 per cent of total potential plants have been installed.

The biogas programme has positive impacts at the local, national and global levels. The programme has contributed in minimizing climate change and global warming caused by greenhouse gas emissions. It has also contributed to the sustainable development of the country, and has played a role in minimizing deficit balance of payment by reducing the import of kerosene and the LPG. Individual households are enjoying better health, as well as socio-economic, agricultural, sanitation, and other benefits from the biogas plants.

The BSP has a strong monitoring and quality control system, and the quality control standard is well developed. BCs installed quality plants, whereas regular field monitoring is done on a sample basis by BSP/N. Third party monitoring and annual users' survey are also done to assess the user's satisfaction, impact of the plants, functional status of the plants, etc. which form the basis for the annual emission reduction (ER) and community benefits in the reporting of the CDM project. Two biogas CDM projects have registered and the first ER payment in the history of Nepal from carbon trading was also received. Because of the methodological problem, further progress on the CDM front could not take place and additional CDM projects have not been developed, although a Memorandum of Understanding MOU was signed in October 2006 with KfW to develop the new methodology. The COP 13, with the recommendation from the 34th Executive board (EB) meeting, has resumed the methodology resulting from the development of other biogas projects. The revenue from carbon trading seemed to be the sustainable financial source for the sustainability of the biogas sector in Nepal.

Introduction

Nepal has a history of over 50 years of biogas technology development. The first historical biogas system was introduced in 1955, which has become the cornerstone in the development of biogas technology in the country. After this pioneer venture attempted by Reverend Sauboile, it took almost 20 years to draw the attention of the government towards biogas technology. On the auspicious occasion of the "Agriculture Year" in 1975/76, the government as a special programme launched a biogas plant. The occasion was marked as mobilization of interest-free loan for bio-digester. This marked the beginning of the growth in the implementation of biogas system. Further moment of development took place in 1977 with the establishment of Gobargas Tatha Agriculture Equipment Development Company (GGC), a pioneering and leading biogas construction company in Nepal.

A new impetus was added to the biogas programme with the initiation and establishment of the Biogas Support Programme (BSP) in 1992-93. With the success of biogas development programme as well as the availability of government subsidy and involvement of NGOs and donor agencies, several private companies started working in the promotion of biogas.

More achievements have been gained after the establishment of Alternative Energy Promotion Centre (AEPC) in 1996, which is an apex organization in the promotion and development of renewable/alternative energy technologies, including biogas, in the country.

The Biogas Support Programme (BSP) started in July 1992 with funding from the Directorate General for International Cooperation (DGIS) of the Netherlands government through the Netherlands Development Organisation in Nepal (SNV/N). The Government of Nepal (GoN) and the Kreditanstalt fur Wiederaufbau of Germany (KfW) also started funding the BSP from the Phase–III, which started in March 1997.

The Biogas Sector Partnership (BSP) Phase–IV (July 2003-June 2009) is being implemented after successful completion of the first three phases. The programme (phase IV) had originally aimed to install 200,000 biogas plants during the programme period. This is also a target envisaged in the Tenth Plan (mid-July 2002 to mid-July 2007) of the GoN.

AEPC has been executing biogas programme including other renewable energy technologies (RETs) since its establishment in 1996. The Biogas Sector Partnership - Nepal (BSP/N), a Non-Governmental Organization (NGO), is implementing the BSP-IV with financial and technical support from AEPC and SNV/N. The subsidy component for BSP-IV has been co-funded by KfW, DGIS and GoN.

Various designs have been experimented from a Coffee Can in early 1950s within the office of Jesuit in Godavari to the present day modified GGC 2047, which can be operated even at an altitude of 3000 meters. Various experimental models are Floating Steel Drum Design, Deenbandhu Model Biogas System, Floating High Density Polyethylene Drum System, Ferro-cement Gasholder, Fixed Dome Design, The tunnel design, Mud digester, TED Model Fixed Dome, and Puxin Biogas System.

Fixed dome plants of capacities 4, 6, 8 and 10 m3 designed by GGC has been adopted in Nepal and known as GGC 2047. The sketch of the existing fixed biogas plant is shown in Figure 1.

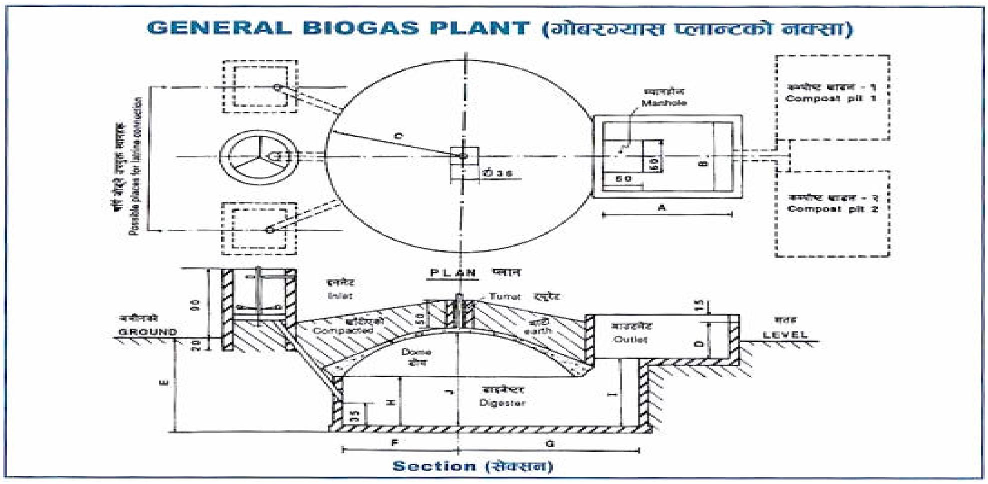


Figure 1. General Biogas Plant

2. Current Situation and Outlook of Biogas

2.1 Current Status

Present Energy Consumption Scenario of Nepal: Nepal relies to a large extent on the traditional energy resources; as no proven significant deposits of fossil fuel is available. Based on the studies, the total energy consumption in Nepal was 8,616 TOE (about 15 GJ per capita) in 2005. Traditional energy comprise 86.71 per cent, commercial energy-12.72 per cent and renewable energy /others only 0.56 per cent of the total estimated energy consumption in 2005/06. Though the composition of the traditional energy has decreased by 6 per cent in the last 14 years, its consumption has increased by almost 33 per cent during the period (MOF, 2006). This is mostly due to the unavailability of other affordable fuel supply within the country along with population growth. If this trend continues, there might be excess pressure on the forest and agricultural product thus decreasing their sustainability and creating adverse impact on the environment. Similarly, the composition of the petroleum products and coal has increased from 6 per cent to 11 per cent in the last 14 years, mostly due to the increase of the demand in transportation and industrial sectors. At the same period, the consumption of petrol has increased by 131 per cent and coal by 161 per cent. This increment has resulted in the draining out of the hard-earned foreign currency of the country and at the same time created the environmental pollution.

In this context, the importance of renewable energy/alternative technology including biogas has increased. With the launching of BSP in 1992, necessary fund and infrastructure became available in order to implement the national biogas programme smoothly. Since then, BSP has been the only national programme and major driving force in the biogas sector. In order to document major events in the development of biogas sector in Nepal, efforts have been made to focus on the biogas development activities in three aspects, viz. institutional development, policy/programmes, and technological development.

Due to the concerted efforts of various stakeholders, a total of 186,172 biogas plants have been installed in the country until December 2007, covering almost all districts. These include 11,855 systems constructed before advent of BSP, 172,505 systems constructed under BSP and 1,733 constructed under the World Wildlife Fund (WWF) Gold Standard CDM project. After 1992, the number of systems installed each year increased until 2000/01. Since then, the number of systems constructed per year has fluctuated with minimum installation in the year 2003/04. However, there is still a long way to go to achieve the desired goal as only about 10 per cent of the technically feasible potential has been exploited so far considering a total potential of about 1.9 million. The data on year-wise construction of biogas plants is given in Figure 2.

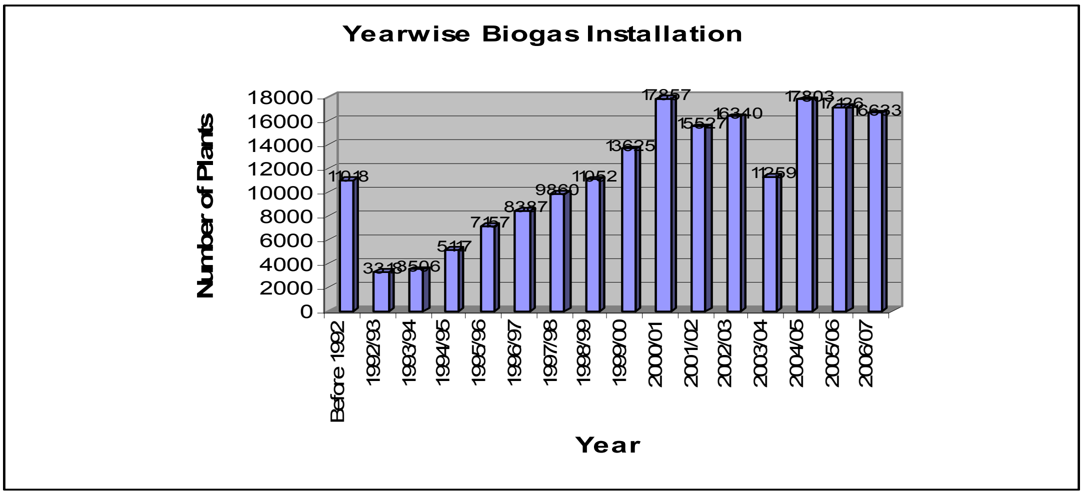


Figure 2. Yearly Biogas Installation

Major/Key Institutions involved in the promotion of biogas in Nepal: AEPC is a government entity that acts as the apex body to promote, execute, coordinate, monitor and evaluate the biogas programme and other renewable/alternative energy programmes. AEPC was established in 1996 under the Ministry of Environment, Science and Technology as an apex body executing renewable energy programmes in the country. Its main objectives are directed towards disseminating and promoting renewable energy technologies (RETs) including biogas for improving the living standard of rural people, providing clean energy, and conserving environmental degradation. AEPC is responsible for carrying out the Annual

Biogas Users' Survey, which is in line with the requirement of the CDM projects. It is also responsible for coordinating with national level financial institutions and other relevant government agencies promoting the biogas technology. Besides administrating the subsidy, AEPC has also established a biogas credit fund with the objective of providing wholesale lending for biogas installation through micro finance institutes especially for low-income people in the remote areas.

BSP-N is an implementing agency for Biogas Support Programme-IV together with Nepal Biogas Promotion Group (NBPG) and other partners as per the agreement signed jointly with AEPC and SNV/N, started in 2003. BSP/N conducts R & D for optimization of biogas system operation and new designs; facilitates and provides technical assistance to NBPG and biogas companies (BCs), process the subsidy applications and recommends AEPC for subsidy reimbursement to the users through BCs; assists AEPC in developing appropriate modalities or organizations for credit fund flow; carries out quality control and regular monitoring of the subsidized biogas; develops skill enhancement package and implements it jointly with NBPG; coordinates with other development partners for the biogas promotion at micro and meso levels, and carries out overall market development of the sector through various promotional activities.

The German Financial Cooperation (KfW) provides subsidy support and credit fund to the programme. Netherlands Development Agency (DGIS/SNV) through SNV/N provides technical support, programme management support and subsidy support.

Nepal Biogas Promotion Group (NBPG), an umbrella organization of biogas companies, has been involved in launching the biogas promotional programme in close cooperation with AEPC, BSP/B and SNV/N, through motivation and coordination of biogas companies since its establishment in 1994. NBPG advocates and promotes biogas programme at micro and meso levels; executes skill enhancement packages for masons and supervisors; imports the main gas valves and distribute them to the BCs, carries out promotional activities, checks the cost of the biogas system and accessories required for installation; executes slurry promotion programme and making of organic compost; provides business promotion services to BCs; promotes interests of the BCs and regulates them through the code of conduct and other appropriate mechanism and arrangement; supplies biogas system materials, especially to BCs that have low business volume; and coordinates with BSP/N and BCs to develop partners at micro and meso level.

BCs construct quality biogas plants as per the demand of farmers, and work closely with biogas users. Biogas construction companies and the biogas appliance manufacturers have been pre-qualified. The construction companies are involved in demand collection, construction and providing after sales services. The appliance manufacturing companies produce biogas appliances such as dome gas pipe, stove, mixture, etc. Under the present subsidy policy, only pre-qualified companies are eligible for construction of biogas systems and manufacturing of biogas appliances. BCs disseminate information; promote market and construct quality biogas plants; train users on operations and maintenance of the plants; train users on proper composting and use of slurry; cooperate and accompany quality control (QC) team in the field for quality control and other verification purposes; deliver after sales service and other services during guarantee period, and also after guarantee period on a "need" basis; facilitate and coordinate with banks, MFIs and other CBOs/NGOs to ease credit flow to beneficiaries, and undertake activities that help to promote the technology by linking it with other rural development agencies at the local level to better benefit the users by improving their livelihood.

The Agricultural Development Bank and Rastriya Banijya Bank have been providing loan to farmers on collateral basis. Similarly, the MFIs established at the local level, have been mobilizing credit fund of AEPC, providing loans to farmers to construct biogas plants. The Nepal Renewable Energy Development Company (P) Ltd. manages and supplies biogas valve, paint and necessary appliances to BCs as per the requirement to construct biogas plants. Appliance manufacturers supply biogas appliances to BCs and farmers on a regular basis.

Biogas System by size: The standard size of GGC 2047 biogas systems promoted for households are 4, 6, 8 and 10 m^3. Both BSP and the subsidy policy have encouraged the promotion of small-sized system in order to make the technology accessible to the poorer section of the community. In the earlier period, some larger size (15 and 20 m^3) systems were also installed. So far, the 6 m^3-size system (53 per cent) seems to be most popular among the users (Figure 3).

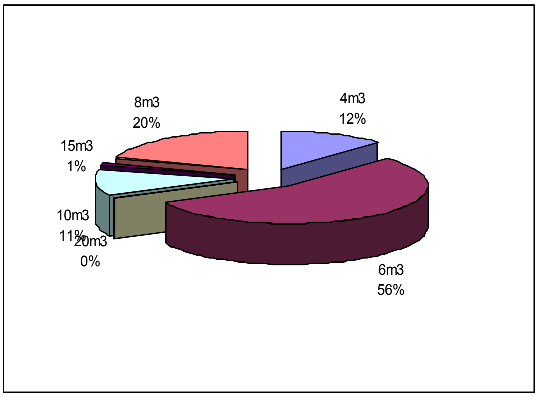


Figure 3. Per cent Distribution of Biogas Systems Based on Size

Contribution of Biogas in Residential Energy Consumption Pattern: The use of biogas has resulted in savings of fuel wood by 52 per cent. Kerosene, dung cakes and agricultural residues as energy sources were also significantly reduced by 60 per cent, 37 per cent and 21 per cent, respectively, as compared to the scenario before installation of biogas systems (CMS, 2006).

According to the 2006 Energy Synopsis Report 6 published by the Water and Energy Commission Secretariat (WECS, 2006), the contribution of biogas systems in the consumption of energy in residential sector has been gradually increasing over the past few years, as shown in Table 1.

Table 1 Contribution of Biogas Systems in Energy Consumption in Residential Sector

Fuel type	2001/02	2002/03	2003/04	2004/05	2005/06
Biogas (in 000 GJ)	1392	1620	1731	1903	2078
All (Traditional, commercial, renewable) (in 000GJ)	314,655	320,269	326,321	331,567	338,696
per cent Consumption of biogas	0.44	0.51	0.53	0.57	0.61

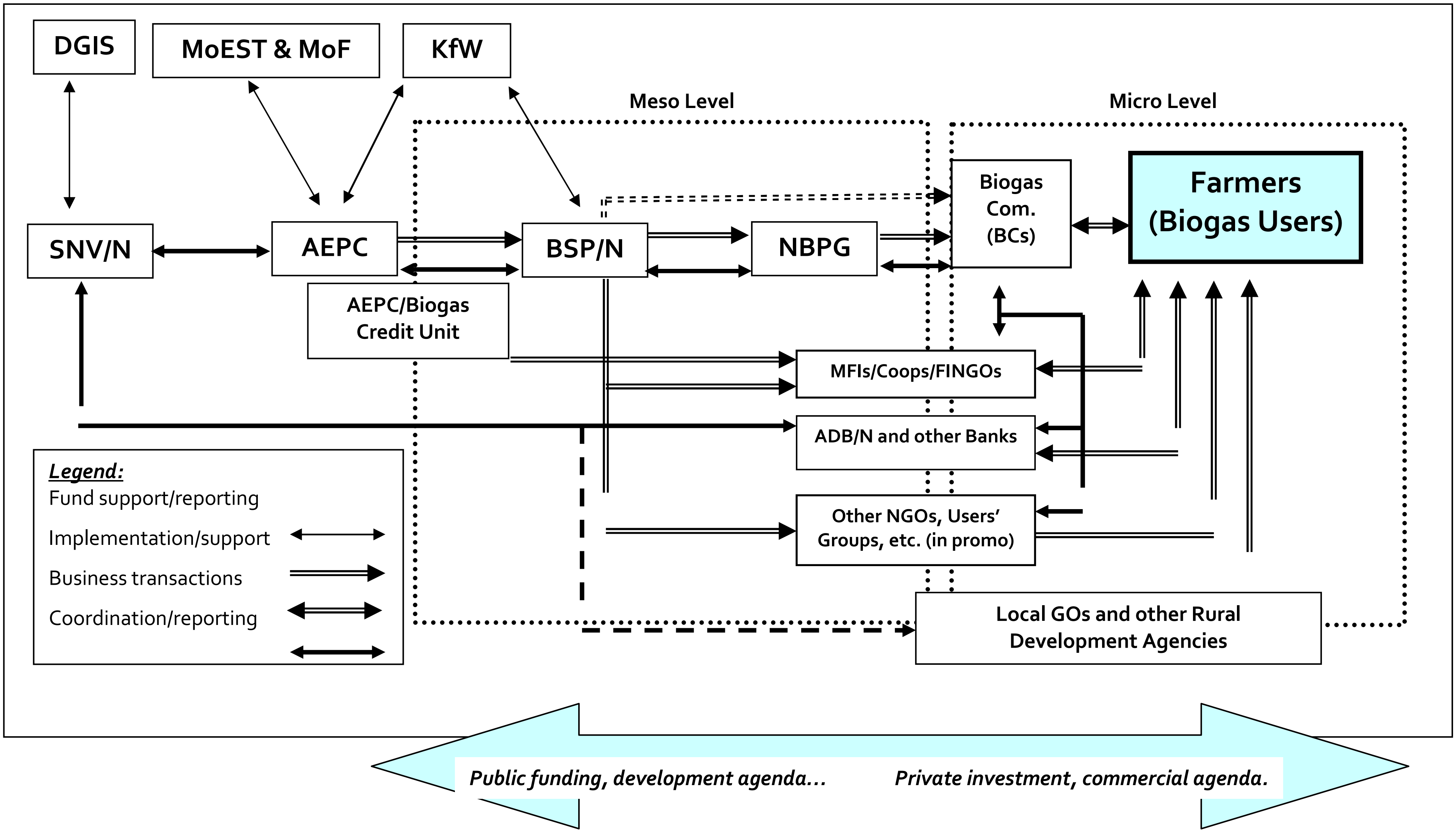


Figure 4 Institutional Set-up of Existing BSP

2.2 Challenges and Opportunities

Opportunities: The Biogas Support Programme has been implemented as one of the most popular and successful RET programmes in Nepal. For the last fifteen years, the programme has received financial as well as technical support from donors and also supportive policy from the Government of Nepal

The importance and popularity of bio-digester have increased with increasing prices of imported cooking fuels such as kerosene and LPG.

Two CDM projects have already been registered and additional projects are being developed. The programme is sure to receive more funds which will assure further extension of its activities. Moreover, the revenue can be used to address the pro-poor high hill issues. In the context of registration of biogas CDM projects, the quality of bio-digester has to be improved in order to ensure that it will function effectively during its lifetime.

Around 70 per cent of the biogas users have attached the toilet into the plant. This proves that the programme not only meet the cooking need but also has important role in improving the sanitation of the rural families. Because of its multiple uses, it has gained high popularity. The programme has developed linkages with other sanitation programme which helped the poorer households to install the plant as the additional support to build the toilet to reduce the equity contribution of the farmers/users.

Based on the study of the technical and geographical feasibility, it is estimated that a total of 1.9 million biogas systems can be installed in Nepal (BSP 2004). Economically the potential number of the smaller fixed dome design (4 and 6 m^3) in Nepal is estimated at about half a million units. So far, only 10 per cent of the total potential biogas plants is built. This data shows the immense market of bio-digester in Nepal. Besides, slurry compost, the by-product of the process is a good nutrient for the agriculture and has gradually become popular among farmers.

The annual installation of 15,000-17,000 biogas systems should be increased to around 30,000 to meet the target of BSP and the interim plan of GoN as well. This is possible by strengthening the overall capacity of the private sector especially BCs and appliances manufacturers.

The positive impact of the biogas programme can be taken as its opportunities. From the socio-economic point of view, the biogas programme is found to be inclusive, time saving, cost intensive, and affordable to the poor due to the provision of additional subsidy for these sections. It is also helpful in upgrading the overall socio-economic status of the users by increasing their literacy status, improving their knowledge and receiving additional revenues through involvement in income generating activities, allow them to utilize the time saved thereafter. From agriculture perspective, slurry compost, which is very rich in nutrient content, is slowly replacing FYM and hence the use of organic manures is becoming more popular among the biogas users. This trend is positive for the sustainable development, biogas being an environmentally sustainable technology that uses locally available renewable resources for the production of renewable form of energy. It has significantly helped in reducing fuel wood and kerosene consumption, thereby reducing the indoor air pollution and GHG emission. Besides, biogas has also benefited the country through carbon trade in international market by contributing in global carbon emission reduction. Biogas has had a positive impact especially on the health of women and children, who are the prime beneficiaries, through the provision of clean fuel, thus indirectly contributing to the upgrading of their socio-economic status. The biogas technology has benefited rural women, especially in reducing their work burden of household chores, improving their health and saving their time.

Women are able to utilize the time they saved by using biogas for other activities such as social work, income generation and other community related activities. The shortage of firewood seems to be the main reason for installing biogas. Users of biogas plants are satisfied with the plant operation. The reasons for the satisfactions are smokeless kitchen, efficiency in cooking and washing utensils, saving fuel wood and tasty food. The key impacts of the programme to the households (hh) are the following (CMS 2007):

- On an average, a household saves 3 hours and 40 minutes due to biogas installation which is utilized in different activities. Out of these household users, 30.8 per cent found themselves involved in income generating activities.
- The installation of biogas plant has overwhelmingly reduced the expenditure of the household users on fuel purchase, thereby saving NRs. 2125[4] monthly, which is equivalent to an annual saving of NRs, 25,499 (US$400), thus contributing to a large extent to uplifting their economic status.
- The use of fuel wood has reduced by 162 kg/month/hh which accounts for the saving of nearly 2 tons/year/hh.
- On an average, reduction in greenhouse gas (GHG) emission per year is 812,592 g-C from fuel wood, 12,139 g-C from kerosene, 9218 g-C from dung cake and 2,286 g-C from agriculture residue.
- 69.2 per cent of the households have latrine connected to the biogas plants. Initially, only 58 per cent of the households have latrine before biogas installation. This has increased to 97 per cent after biogas installation.
- Majority of female members of the households (46.1 per cent) utilize their saved time in recreation like watching TV, listening to radio, reading newspaper, books and magazines.
- 96.2 per cent of the installed plants are operational.

Biogas, in relation to environment and CDM seemed to be one of the major opportunities of the sector. Biogas, a sustainable renewable energy, has positive environmental impacts at local, national and global levels. From a local perspective, the use of biogas has significantly improved the indoor air quality of homes employing biogas stoves in place of wood stoves. In addition, installation of biogas systems resulted in better management and disposal of animal dung and night soil.

From a national perspective, biogas systems have helped reduce the pressure on forests. This in turn has important implication for watershed management and soil erosion. In addition, biogas systems where the slurry is collected and returned to the fields have reduced the depletion of soil nutrients by providing organically rich nutrients. The saving of firewood helps in reducing the rate of deforestation in rural Nepal, while the savings from kerosene and fertilizer reduce expenditure of foreign currency. With the installation of biogas systems, the annual reduction of fuel wood per household of 2 tons was achieved. With the assumption that 2.5 trees are being cut annually per household, the national impact of using biogas on the protection of forest is highly evident. The annual consumption of kerosene per household per year is 32 liters and the dry bio-fertilizer is 1.70 tons per year per household.

Biogas helps reduce greenhouse gas emission by displacing the consumption of fuel wood, agricultural residues and kerosene. The biogas used in a sustainable basis assures that the CO_2 associated with biogas combustion will be reabsorbed in the process of the growth of the fodder and food for the animals. All the CH_4 and CO_2 emissions that are associated with the combustion of fuel wood can be associated as being replaced by a biogas system. According to recent studies, the available carbon reduction per year per system from the displacement of fuel wood, agricultural wastes, dung and kerosene is nearly 4.6 tons of carbon equivalent, excluding greenhouse gas reduction from forest use.

[4] 1 USD = 63.75 Nepalese Rs. (NRs.)

The net CO2 saving available in the use of biogas against the use of fuel wood and kerosene in different geographical region is shown in Table 2.

Table 2. Net CO_2 Savings in Different Geographical Regions, in tCO2

Size of System, m^3	Terai	Hills	Mountain
4	2.56	2.68	2.77
6	5.85	3.92	4.00
8	7.56	4.59	4.70
10	5.98	3.67	3.37
Average size	4.60		

Two CDM projects have been developed from a total of 19,396 biogas plants, which were registered on December 27, 2005, despite the scrapping by the Executive Board of the previously-approved methodology on biogas CDM project. Initially, it was estimated that each biogas system would reduce as high as 7.40 tons of GHGs but the rate has been capped at 4.99 tons of GHG per year per system due to limitation of a Small Scale Methodology of CDM.

Four more CDM projects would have been registered, if the old methodology was still valid. COP13 has resumed the methodology of developing biogas CDM project which has opened the door for making biogas sector sustainable. Also, on October 17, 2006, KfW has signed a MoU with AEPC for development of biogas CDM project III and trading of CERs.

Challenges/Problems in the Development of Biogas Sector: Out of the potential 1.9 million households, only 186,172 households who are medium and upper level farmers have installed the plants. The poorer farmers are yet to be reached. On the one hand, donors are gradually phasing out support in the sector and the GoN is reducing the financial subsidy, which seemed to be the bigger challenge. The biogas market has yet to be commercialized.

The programme has reached only the farmers who own cattle and land, i.e., those who generally belong to the middle and upper income bracket. The subsidy policy treats users equally. The farmers should invest more than 50 per cent of the total cost on their own. As a result, the subsidy has not become accessible to the poor farmers not having their own cattle. Besides, more than 80 per cent of the total area is hilly and mountainous and out of this, the 15 per cent which is hilly has very low temperature. The GGC 2047 design is favorable in an average and above average temperature, though the design is modified and successfully piloted up to the 3000-meter altitude. The cost of installing a plant is very high in those areas and the subsidy covers only not more than 25 per cent of the total cost. In the future, the target of the programme should be poorer families and those located in hilly areas.

The BSP obtained an ISO 9001-2000 certification as a result of its quality standard and implementation in the field. To enforce its quality standard, subsidy payments are made only for biogas systems that meet the established standard. Some other problems identified, include:

- Capacity limitation within the biogas companies, mainly due to poor financial situation, poor management capabilities and poor profitability also relates with general lack of entrepreneurial sprit and self-regulation within the biogas companies.

- Overall lack of incentive in institutions in the sector, particularly with the private sector companies resulting in poor motivation and attrition of masons, supervisors and other staff.

- Lack of easy road access in rural areas contributes a lot in increasing cost of construction materials, mainly cement, rods, pipes, etc.

- Continued lack of enthusiasm among rural population to go for modern technologies like biogas seemed to be due to conflict and other socio-economic situations. This problem has also been aggravated by lack of incentive among biogas companies to go out for promotion of business.

- Lack of adequate inter-linkage with local level planning, at least for promotion and linkages with other rural development activities like income generation, health, education, agriculture, poverty alleviation, etc;

- Lack of adequate information in remote rural areas on the biogas technology and its benefits; other socio-cultural like indifferent attitude to suffering of women and children; disinterest to adapt new and cleaner technologies that address many health, education and environmental issues, etc;

- Continued blanket subsidy for fossil fuel like kerosene, LPG, etc; and

- Decreasing subsidy for biogas are major threats in the sector.

Lessons Learnt from the programme: BSP has gained experiences after more than 15 years and the popularity and usefulness of biogas has increased day by day. As a result of the successes and experiences of the BSP, there are a number of important lessons that emerge regarding the design and implementation of rural energy services that can ultimately be applied to not only in biogas programmes but also other rural energy service options in Nepal and other developing countries.

The programme assessed the needs and capabilities of the end users and the available biogas technologies to determine the suitability of these technologies for Nepalese conditions. Similarly, the programme carried out a targeted research and development effort and an iterative pilot demonstration to first adopt the biogas technology to the local conditions. Based on the information, the BSP selected the fixed dome biogas technology and embarked on a process to adapt this technology to the needs of the Nepali users. It continues to learn and improve on the design of the biogas units so as to lower cost, improve output and increase reliability.

The programme established and enforced design, quality and service criteria that have ensured the reliable and cost-effective operation of installed systems. The design was developed in collaboration with farmers/users and construction staff of the BCs and manufacturers. The high participation level in the design phase ensures a consumer friendly and reliable product. A certification process and financial incentives were introduced to ensure that the biogas producers meet the quality and design standards.

Though the development of a single design proved essential at the outset to ensure uniform quality and performance, it has become evident that the single design will not serve the purpose especially in the high altitude. Now the BSP has carried out research and piloted the modified design in the high hill areas which has become successful even in the 3000 meter altitude.

The government has provided subsidy to support the biogas users according to the existing subsidy policy. The subsidy is not sufficient to install the plant, either the users themselves should manage the additional fund or borrow the money from different sources. Financial institutions have yet to expand their branches in the rural areas on the one hand; the poor farmers are not able to show the collateral to receive the loan from financial institutions on the other. To address this issue, local micro-finance institutions (MFIs) are provided with financial support as loan from AEPC with the support of KfW, to disburse loan to the farmers to install the plants.

The successful demonstration of biogas of BSP attracted the participation of the KfW in co-financing biogas in Nepal. The demonstration of the positive impacts improved human health, increased employment, and reduced deforestation, which lead the Government of Nepal to include the biogas programme in its renewable energy policy.

Despite the cultural and religious taboos relating to night soil from toilet, 69.2 per cent of the biogas household users now connect their toilet to the biogas system. This has become possible because of the different benefits that the users enjoy as well as the impact of educational activities conducted by the programme to the farmers.

The programme has designed and applied uniform, transparent and careful administration of subsidies, which has become the important factor in convincing the farmers to purchase biogas systems.

Biogas Users' Survey is conducted annually through independent consultant that processed hundred of questions, covering a balanced cross section of the user population, where important feedback from the users as well as non-users is obtained. This feedback is used to assess impacts and improve product and services.

3. National Policies and Action Plan

3.1 Policies

Periodic plan: Until the sixth five-year plan (1980-1985), the energy policy covered only hydropower and forestry sectors. Since the seventh plan (1985-90) renewable energy technologies (RETs) have increasingly received due attention in periodic plans where for the first time, a targeted approach among other policy measures was established for its development. The plan recognized the role of RETs in the conservation of forests and providing alternative sources for meeting the energy needs of the rural population. The plan incorporated few policies addressing RETs like biogas, solar thermal, wind energy, improved cook stoves (ICS), and small water turbines/improved water mills.

The Eight Plan (1992-1997) envisaged the need for a coordinating body for large scale promotion of alternative energy technologies in Nepal, and the Alternative Energy Promotion Centre (AEPC) was thus established, to promote the use of RET and act as an executing body. The plan incorporated separate energy policy which emphasized promotion of renewable energy technologies in order to reduce dependence on traditional and imported fuels. Furthermore, the private sector was encouraged to conduct technology transfer, adaptive research and development, indigenization of hydropower, biomass and other renewable energy sectors. The establishment of the Ministry of Science and Technology and the Alternative Energy Promotion Centre are the major achievement in promoting renewable/alternative energy technologies.

The Ninth Plan (1997-2002) formulated a long term vision in the science and technology sector. This Plan has the fundamental goal of developing rural energy systems so as to increase employment opportunity through gradual replacement of traditional energy by modern energy. The plan envisaged the necessary arrangement for research, information flow, training and financial services in order to make market economy and people's participation strong, capable and meaningful for energy development. Along with these policies and strategies, the plan sets out programmes to continue the existing BSP with a new target of installing 90,000 biogas systems. During the plan period, Renewable Energy Subsidy Policy – 2000 and the Renewable Energy Subsidy Delivery Mechanism – 2000 were formulated and implemented to realize the objectives set out in the plan.

The Tenth Plan gave priority to suitable and relatively smaller size systems. It also encouraged researches on expansion of biogas systems in the Himalayan region while reducing the cost of installation.

The National Planning Commission prepared the Perspective Energy Plan (1991-2017) for Nepal. The plan has recommended the development and promotion of alternative energy resources and technologies including biogas, as an integral part of overall rural development activities. It has further recommended to internalize RET development projects, decentralize RETs planning, development, promotion and dissemination, and also to take measures for maximum involvement of local people, especially women.

The current three-year plan has targeted to install additional 100,000 plants in three years and focused on providing additional financial support to increase the accessibility by the poor people; promotion of the appropriate and small plants; and carrying out research and development activities to promote the biogas programme in the remote high hill areas and reduce the cost of plants. The plan has recognized the importance of biogas programme as major source of energy for clean cooking, organic slurry for agricultural production, environment conservation, etc.

Rural Energy Policy: The government of Nepal has promulgated Rural Energy Policy for the first time in 2006. The policy has envisioned linking renewable energy, including biogas, to economic activities. This includes promotion of renewable energy in coordination with local agencies, including non-governmental organizations, and encouraging the involvement of private sector in the promotion of renewable energy technologies, and the inclusion of renewable energy in the programme of educational institutions. The policy has also encouraged R & D in renewable energy technologies. Specific to biogas, the policy has provision to conduct promotional activities in low penetration areas.

Subsidy policy: Amongst all the RETs promoted in Nepal, biogas was the first to attract attention to policy makers. As early as 1975/76, farmers were offered interest-free loan to construct biogas systems. In 1977, soft loan at six per cent interest was provided to the farmers. In 1982/83, four Terai districts received capital subsidy of NRs 5,500 per system. During the seventh plan period (1987-92), subsidy per system was provided at the rate of 25 per cent on construction cost and 50 per cent in interest. Although all subsidies were suspended in 1990, the government announced a new subsidy scheme in

1991. For the first time, the capital subsidy was differentiated according to physiographic region where separate rates were applied for the Terai and the hills.

Although subsidy was provided to the RETs, there was no formal subsidy policy of the government. The provisions, amendments and withdrawals of subsidies took place on an ad hoc basis. With the growing application of RETs, including household biogas, the need for subsidy policy is felt and the government announced a subsidy policy for Renewable Energy, 2000. The policy made separate subsidy provisions for biogas systems. The subsidy available was differentiated based upon physiographic region and capacity of the system. An additional subsidy was designated for low biogas penetration districts.

The government of Nepal recently approved a new subsidy policy – Subsidy for Renewable (Rural) Energy, 2006. The policy acknowledges the important role of biogas in meeting household energy requirements and also in mitigating degradation. The subsidy rates address the economic situation and accessibility to the districts. The policy commits to continue subsidy even after completion of the current biogas programme by mobilizing new donors and investors. The current subsidy policy is applicable for GGC 2047 model biogas system of capacities ranging from 4 to 10 m^3. Feasibility study and pilot project of the community biogas systems to explore possibility of using biodegradable solid waste and other vegetable waste feed stock in addition to the cattle dung for biogas generation, is also subsidized under the policy.

Additional subsidy has been announced for the poorer population in the Terai, Hills and remote Hills respectively on an experimental basis. The subsidy is applicable only for 4 and 6 m^3 size systems with the objective of promoting biogas plant in the poorer segment of the society.

Fiscal Incentives: In addition to the direct capital subsidy on the biogas systems, the government has granted some other fiscal incentives for biogas promotion and development. Value added tax is exempted on imported biogas appliances. Similarly, there is provision of only one per cent import duty plus 1.5 per cent local development tax imposed on biogas appliances.

3.2 Action Plan

Strategic Approach: The following are the main strategic ingredients of the programme:
Carrot and Stick Approach: To maintain quality of work in the programme, it enforced quality assurance systems to improve and continue the "carrot and stick" approach. Supporting the private sector BCs and other partners to improve their performance through counseling, capacity building, motivation and business promotion is undertaken.

Inter-Linkages for Synergy and Complementarities: There has been a good progress to create a demonstration effect of the biogas technology and its benefits, especially in the Terai and middle hill areas. The programme has been given due attention to make it more holistic by linking it up with other rural development activities for synergy and complementarities.

Financial Sustainability of the Programme: As donors financial support come to an end, the programme is likely to face an abrupt closure. While, the private sector (BCs) is not yet capable of sustaining the business in a fully commercial ground, this situation demands continuation of the subsidy and technical assistance for continued dissemination of the technology, while attempting to better commercialise the sector. Fortunately, there is a good prospect of the programme raising its own revenue through the

Clean Development Mechanism (CDM). The CDM revenue is likely to be instrumental in sustainability of the programme.

Implementation Strategy: The following strategies will be adopted in the implementation of the programme to improve its coverage, effectiveness and efficiency.

Demand-driven approach: The BSP has been a pioneer in making demand-driven model work in dissemination of rural energy solutions promoting the private sector as prime movers while maintaining a strict "carrot-and-stick" approach.

Poverty Reduction, Gender Mainstreaming and Social Inclusion: The programme works with a demand-driven approach, making the private sector as prime movers. This approach has inherent limitation in targeting beneficiaries and directly addressing issues like poverty and social inclusion. The biogas programme practiced such as linking with other rural development programmes, providing additional subsidy to the poor, reducing plant construction as pragmatic ways towards better addressing poverty and other dimensions of the Millennium Development Goals (MDGs).

The programme has established the baselines for the gender mainstreaming and social inclusion issues in the programme and developed and implemented a strategy to comprehensively address them, with advisory support of SNV/N.

Promotion of Micro Credit for Availability of Loan to Farmers: In the context of having banking vacuum in the rural areas, the only hope of providing credit to rural people for biogas plant and other activities is increasing access to micro credit through MFIs. A household needs to contribute around NRs. 10,000 upfront in cash, even for construction of the smallest size (4 m3) biogas plant in the Terai or middle hill. Availability of micro credit in the area is the only pragmatic way to improve affordability of such rural households and the programme must work for it. This not only helps increase the market size but also helps reach the poorer households.

Capacity Building for Enhanced Self Sustainability: With a sector support approach, programme takes capacity building of sectoral players particularly that of the private sector service providers as a major support area. This includes not just technical capacity building of biogas companies but also overall strengthening of their management capabilities, including better management of their finances.

Capacity building of NBPG is important to improve the collective bargaining, advocacy and self-regulation abilities of the companies in the private sector. Moreover, enhanced capacity of NBPG is also imperative to ensure gradual transfer of responsibilities of BSP/N on capacity building of the biogas companies for sustainability of the sector. NBPG can and should expand its scope of work in conducting awareness building and training programmes to biogas companies and other players at the local level for better promotion of the biogas plants. It can also gradually develop the capacity to handle the slurry extension and promotion activities, which is currently done by BSP/N.

Capacity building of private sector, BSP/N and other sectoral players in the public sector is felt crucial for more effective and efficient service delivery and the players' institutional sustainability which is again important for perpetual service delivery to the biogas sector.

Promotion of Biogas Programme in Low Penetration District: To ensure a more equitable promotion of the biogas technology, the programme continues to review Low-Penetration Districts (LPDs) annually and focus its promotion activities in these districts in coordinating with other development partners. Another approach is to provide additional marketing cost to BCs to construct minimum number of biogas plants per year in selected LPDs. The presence of BCs and the demonstration effect created will boost the latent market.

Good Governance: Necessary improvement in the previous systems and practices is made to ensure good governance through increased transparency, accountability, responsibility participatory planning and ownership feeling. This of course, starts with improved and transparent standards, criteria and mechanisms for quality assurance, including company qualification and disqualification, penalty, and improved efficiency in terms of administration of subsidy applications and subsidy payment etc. Besides, the BSP partners have introduced and institutionalized public auditing and pubic hearing systems in the programme.

Involvement of District Development Committees (DDCs), VDCs and Other Local Development Organizations in planning networking, monitoring has increased. Now AEPC has district unit, District Energy and Environment Section/Unit in all districts except the capital city within the district development committee. The district unit will assist the DDCs in planning, monitoring, networking, coordination of rural energy technologies including biogas. The reason for cooperation or collaboration could be for synergy or complementarities in jointly promoting biogas plants together with health and sanitation, income generation and market access, forest management, agriculture promotion, etc.

R&D and Other Studies for Alternative Designs: Though the existing design (GGC-2047) is a proven design that is in use right from the beginning of the programme, there is room for improvement of the design to address the issues of applicability to colder areas, methane escape, gas pipe blockade, etc. There have also been remarkable developments in the biogas technology in recent years with new designs, new feed materials, new construction materials, etc. On the other hand, the existing model is not able to expand the market beyond the household customers with relatively better off socio-economic conditions even in the Terai and middle hill areas. Ways to reduce the plant construction costs (maintaining the quality), reduce dependency on cow or buffalo dung, appropriate larger designs for institutions and businesses with different feed materials, better use of slurry and compost manure, etc. are some of the areas where R&D an other studies have to be carried out. The expanded product line and hence market base, does not just better address the issue of more equitable dissemination of the solution but also the issue of more sustainable commercialisation of the sector.

Quality Control and Monitoring: BSP enforces quality standards in various ways. There is a published document on quality standards which all companies need to follow while constructing biogas plants. The quality standard document, published in 2004, has 82 criteria to be met for being qualified and providing quality product. Construction companies interested to work with BSP and benefit from the subsidy scheme by constructing more plants are required to seek recognition and approval from BCC. The conditions are laid down in an agreement between BSP and the biogas companies.

The quality of the services provided by construction companies is ensured through a system that consists of rewards and penalties. Firstly all companies need to check their own quality. Next the programme on the basis of penalty system controls the quality of constructed biogas systems. The system consists of four steps: (1) Agreement on quality standard, (2) Agreement of penalties, (3) Control visits (random sample of 5 per cent of all systems) and (4) Calculation of the penalty.

Qualified biogas appliance manufacturing companies supply components to biogas construction companies. The biogas companies provide after sales services to costumers through the provision of warranty. Biogas construction companies are obliged to provide a 3-year guarantee on the biogas systems.

BSP-Nepal provides training of trainers to the staff of the biogas construction companies. The construction company is responsible for providing the users with on site training on the use and maintenance of biogas systems.

Biogas performance index (BPI) has been developed to grade biogas companies. The BPI is calculated company-wise on the basis of seven quality indicators – production, average default and average penalty, and average feeding per cent, accuracy on after sales service reporting, maintenance and after sales service progress. The companies are thus graded in five categories, 'A' (excellent) to 'E' (very poor). The grading has direct relevance in the allocation of quota, penalty, enforcement, quality control by companies, certification, training, etc.

Various guidelines and manuals have been developed for ensuring better and effective service to the biogas users. The manuals include quality standard guideline, users manual, construction manual, and guidelines for companies, after sales service manuals and various training manuals. At least 5 per cent of the newly installed systems as well as those receiving ASS (after sales service) are sampled for quality assurance and monitoring in the field. Third party is used in quality assurance and monitoring in the field as and when needed. AEPC monitor and evaluate the performance of the programme including the implementing agency, carries out biogas users' survey through third party annually which gives the satisfaction of users, performance status of the plants, overall impact of the biogas plants, etc. This report is used in monitoring the community benefit and verification of the biogas CDM project.

4. Conclusions and Recommendations

4.1 Conclusions

Although the first historical biogas system was introduced in 1955, a new impetus was added to the biogas programme with the initiation and establishment of the Biogas Support Programme (BSP) in 1992-93. Further on, more achievements have been gained after establishment of the Alternative Energy Promotion Centre (AEPC) in 1996.

The Programme started in July 1992, and currently, the BSP Phase–IV (July 2003-June 2009) is being implemented after successful completion of the first three phases and targets installing 200,000 biogas plants during the programme period.

Fixed dome plants of 4, 6, 8 and 10 m3 capacities known as GGC 2047 have been adopted in Nepal. The subsidy is provided only for this design and the subsidy policy encouraged promotion of small-sized system in order to make the technology accessible to the poorer section of the community. Only the qualified biogas construction companies and the biogas appliances manufacturers can work under the subsidy policy of the programme.

Though the banks and MFIs are providing credit to the biogas users, the service is yet to be reached by poor farmers who are depending on the local lenders with high rate of interest.

The contribution of biogas systems in the consumption of energy in residential sector has been gradually increasing over the past few years. The production of biogas also provides multiple benefits to the users in terms of saving of fuel wood, and significantly reduction in the use of kerosene, dung cakes and agriculture residue as energy source.

Socio-economically, the programme is found to be inclusive, time saving, reachable to poor due to provision of additional subsidy for these sections and helpful in upgrading the overall socio-economic status of the users by increasing their literacy status, information and knowledge and revenue through involvement in income generating activities utilizing the time saved thereafter.

Biogas is considered as an environmentally sustainable technology which uses locally available renewable resources for the production of energy. It has significantly helped in reducing fuel wood and kerosene consumption thereby reducing the indoor air pollution and GHG emission. The biogas technology has benefited rural women, especially in reducing their work burden of household chores, improving their health and saving their time.

Two CDM projects have been developed on biogas for a total of 19,396 plants, which were registered on December 27 2005. AEPC has planned developing other CDM project in 2008 as the latest COP held in Bali has opened the door for the same which was scrapped by the COP 11.

The programme faces the challenge of reaching to the poor farmers and high mountainous region, maintaining quality standard and updating the technology to ensure successful operations of plants until its lifetime in the context of registering it as CDM project. Other challenges include capacity limitation within the biogas companies, mainly due to poor financial situation, poor management capabilities and poor profitability; increase in costs of construction materials; continued lack of enthusiasm among rural population to go for modern technologies; limited availability of micro credit facilities; continued blanket subsidy for fossil fuel like kerosene, LPG, etc.; and the concept of reducing subsidy for biogas.

The subsidy support has not become accessible to the poor farmers not having their own cattle. The existing design is favorable in an average and higher temperature, although the design has also been modified and successfully piloted in high altitude areas. The cost of installing a biogas plant is very high in those areas.

Renewable Energy Technologies have increasingly received due attention in periodic plans since the Seventh Plan (1985-1990) where, for the first time, a targeted approach amongst other policy measures was established for its development. The Eighth Plan (1992-1997) envisaged the need for a coordinating body for large-scale promotion of alternative energy technologies in Nepal and the Alternative Energy Promotion Centre (AEPC) was thus established as an executing body. The Ninth Plan (1997-2002) formulated long term vision in the science and technology sector which has the fundamental goal of rural energy systems developed as to increase employment opportunity through gradual replacement of traditional energy with modern energy. Renewable Energy Subsidy Policy-2000 and the Renewable Energy Subsidy Delivery Mechanism-2000 were formulated and implemented to realize the objectives set out in the plan. The Tenth Plan gave priority to suitable and relatively smaller size systems. It also encouraged research on expansion of biogas systems in the Himalayan region and towards reducing the cost. The Perspective Energy Plan (1991-2017) has recommended for development and promotion of alternative energy resources and technologies including biogas as an integral part of overall rural development activities.

The current three-year plan has targeted to install additional 100,000 plants in the next three years. The government of Nepal has promulgated the Rural Energy Policy for the first time in 2006. The policy has envisioned linking renewable energy including biogas to economic activities. The Government of Nepal for the first time, announced a subsidy policy for Renewable Energy, 2000. The GoN recently approved a new subsidy policy – Subsidy for Renewable (Rural) Energy, 2006. The policy acknowledges the important role of biogas in meeting household energy requirements and also in mitigating environmental degradation.

The BSP has adapted demand-driven model in dissemination of rural energy solutions promoting the private sector as prime movers while maintaining a strict "carrot-and-stick" approach, which is one of one of the most successful development model in Nepal.

The programme has started linking with other rural development projects providing additional subsidy to the poor, reducing plant construction as pragmatic ways towards that end of better addressing poverty, gender mainstreaming and social inclusion issues and other dimensions of the MDGs.

Capacity building of private sector, BSP/N and other partners is felt crucial for more effective and efficient service delivery and the players' institutional sustainability. Involvement of local government such as DDCs, VDCs in planning, networking and monitoring has increased. Currently, AEPC has a district unit, District Energy and Environment Section/Unit in all districts except the capital city within the district development committee. Now onwards the section/unit will work in this line which will ensure the biogas planning and monitoring in the local level.

The biogas companies provide after sales services to costumers through the provision of warranty. Under the current system, biogas construction companies are obliged to provide three-year guarantee on the biogas systems. The monitoring and service to the users for longer time seems essential.

Further research and development has to be done to promote the biogas in low temperature areas, reducing the cost of plant and increasing the efficiency of the system.

The upfront cost is high to install the plant. The current subsidy covers about 50 per cent of the cost and the farmer himself should manage the remaining cost. On the one hand the subsidy itself does not meet the cost, and on the other hand, subsidy is not a sustainable way of providing support in promoting biogas systems. Therefore, the need of micro-credit facilities is emerging.

4.2 Recommendations

In order to advance further the development and implementation of biogas systems in Nepal, the following recommendations are proposed:

- Develop additional biogas CDM projects and take it as sustainable financial source for the further promotion of the bio-digesters in preparation for a scenario where donors may discontinue their support.

- Further enhance the quality of biogas plants and introduce after sales service and monitoring mechanism at least for the crediting period of the CDM project.
- Research and introduce low cost, high efficient and other appropriate designs so that other biodegradable wastes can be used as feeding material.
- Develop mechanisms for the promotion of bio-digesters in institutions like Army barracks, Police offices, Hostels, etc. where fire wood is used as cooking source but night soil has badly impacted the local environment.
- Enhance the capacity of private sector including the implementing partners to increase the number of bio-digesters installed annually.
- Develop easy and reliable credit mechanisms in financing the installation of biogas plants.
- Promote the mechanism of planning and monitoring from the local government/district development committee.
- Develop targeted subsidy policy focusing on poor users and high hill regions.
- Develop linkage with other development and sanitation programmes/activities.

References

AEPC, 2006: Subsidy for Renewable (Rural) Energy 2006, Lalitpur, Nepal

AEPC, 2007: Annual Progress Report 2006/07, Lalitpur, Nepal

Bajgain, S. and Shakya, I., 2005: The Nepal Biogas Support Programme-A successful Model of Public Private Partnership for Rural Household Energy Supply, Ministry of Foreign Affairs, The Netherlands; and BSP-N

BSP-N, 2006: Biogas Sector Partnership Nepal: Highlighting Historical Heights and Present Status, Kathmandu, Nepal

BSP-N, 2006a: Multi Annual Plan (Jan 2006-June 2009), Biogas Support Programme, Phase IV, Kathmandu, Nepal

CMS, 2007: Biogas Users' Survey 2006/07, Kathmandu, Nepal

MOEST, 2006: Rural Energy Policy, 2006, Ministry of Environment, Science and Technology, Kathmandu, Nepal

Silwal, B.B., 1999: A Review of Biogas Programme in Nepal, Winrock International, Kathmandu, Nepal

NPC 1991: Perspective Energy Plan 1991-2017, Kathmandu, Nepal

NPC, 2002: Tenth Five Year Plan, 2002-2007, GoN, National Planning Commission, Kathmandu Nepal

NPC, 2007: Interim Three-Year Plan, 2002-2007, GoN, National Planning Commission, Kathmandu Nepal

WECS, 2006: Energy Synopsis Report 2006, Kathmandu, Nepal

Winrock and Eco Securities, 2004, Nepal Biogas Programme, PPP, Dec 2004

A YEAR AFTER: STATUS OF PHILIPPINES BIOFUEL ACT

Ms. Maya Lyn C. Manocsoc

Carbon Finance Solutions, Inc. (CaFiS)
2/F Mayo Hall, Social Development Complex
Ateneo de Manila Campus, Loyola Heights
Quezon City 1108, Philippines
Tel. +63.2.426.6001 loc 4664 / Fax +63.2.426.6070
Email mmanocsoc@cafisinc.com

Executive Summary

In January 2007, Philippine President Gloria Macapagal-Arroyo signed into law the Biofuels Act of 2006. It is now exactly a year since its approval. This paper examines the status of the Act, presenting a brief timeline of events leading to the implementation of the Act. Then, it discusses some key provisions of the Act. It also presents responses of industry players based on interviews with them. Finally, it describes a future outlook of biofuels development in the country, specifically in view of the Clean Development Mechanism (CDM).

The Biofuels Act of 2006 requires the mandatory use of locally sourced biofuels: 5 per cent blend for bioethanol and 1 per cent for biodiesel blend. Both have provisions for increasing their blend as recommended by the National Biofuels Board (NBB), which is created by the same Act. To encourage production, the Act provides several incentives. As a result, there is already a list of companies who have signified interest in investing in bioethanol and biodiesel production. Research into the feasibility of jatropha as a feedstock is likewise being conducted.

Some of the key observations and issues in the implementation of the Act include having 1) two sets of lobby groups; 2) aggressive national policy; 3) equally aggressive private sector; 4) conflicting views on the development of jatropha as a feedstock; 5) pre-mixed biofuels access in the province; 6) monitoring of compliance; and 7) ensuring the feedstock farmers' welfare.

As a final note, the country's involvement in CDM as a way to gain carbon credits for additional funding is hampered by the absence of approved baseline and monitoring methodologies specific to biofuels use in the transport sector. A biodiesel producer likewise mentioned the issue of ownership of credits.

1. Introduction

In January 2007, Philippine President Gloria Macapagal-Arroyo signed into law the Biofuels Act, the first in Southeast Asia. The Act is a key component in the Philippine government's Energy Independence Agenda. This paper examines the larger context of the Act, some key provisions of the Act, responses from industry players, and issues in its current stage of implementation. As a final note, this paper remarks on the Act's special clause on the Clean Development Mechanism (CDM).

2. The larger context: Energy independence agenda

The development of the country's Biofuels Programme has not been made in a vacuum. Due, on the one hand, to the low world prices of sugar and, on the other hand, the increasingly high prices of crude oil, the creation of a National Biofuels Programme has become a key agenda of the Arroyo administration through its Five-Point Reform Package,[5] which includes energy independence. This particular agenda for the energy sector covers increasing the use of alternative fuels, among others.[6]

The Biofuels Programme has the aim to "achieve energy independence and fuel diversification while meeting environmental challenges through the utilization of biofuels." The primary biofuels currently being developed are ethanol, coco methyl ester (CME), and jatropha methyl ester (JME). This last, however, is still in the research phase.

Table 1.a and 1.b show the potential fuels displacement from ethanol and CME, respectively.

Table 1.a
Potential Fuel Displacement (Ethanol)

Blend	Gasoline Displacement (million liters)	FOREX Savings (million US $)
5 per cent	255 (2008)	168
10 per cent	565 (2010)	406
	721 (2015)	519

[5]This includes (1) economic growth and job creation; (2) anti-corruption through good governance; (3) energy independence; (4) social justice and basic needs; and (5) education and youth opportunity.

[6]Other elements of the agenda include increase reserves of indigenous fossil fuels; aggressively develop renewable energy potential such as biomass, solar, wind, and ocean resources; strengthen and enhance energy efficiency and conservation programme.

Table 1.b
Potential Fuel Displacement (CME)

Scope	Blend	Diesel Displacement (million liters)	FOREX Savings (million US $)
Government	1 per cent	0.882	0.42
Nationwide	1 per cent	78 (2007)	50
	2 per cent	173 (2010)	110
	2 per cent	209 (2015)	133

Assumptions: Diesel price: P32/liter. Gasoline price: P36/liter; Exchange rate: P50/$
Source: Department of Energy (2007)

3. The road to the Biofuels Act

The issuance of Memorandum Circular No. 55 in February 2004 that mandates all government agencies[7] to replace at least one per cent of their diesel requirements with coco methyl ester (CME) signaled the commencement of the National Biodiesel Programme. Results from compliance[8] of this directive support the benefits of using CME, including improvement in engine emission, easy engine start and fast acceleration, increase in mileage per liter of diesel consumed, and improvement in overall engine performance and emissions with continued use.

Following the positive results and compliance in this pilot-testing phase, the Department of Energy (DOE) issued Department Circular (DC) No. 2005-04-003 promoting the use of coco-biodiesel as an alternative clean fuel. In this regard, oil companies were enjoined to make available CME as a retail shelf item provided they have been issued a Certificate of Fuel Additive Registration (CFAR) number.

Meanwhile, for the sugar industry, it started to explore ethanol opportunities in consideration of the low world prices of sugar and prospects of lower sugar tariffs in the future (Apañado n.d.). In April 2004, the industry created the Ethanol Programme Consultative Committee (EPCC), composed of the Sugar Regulatory Administration (SRA), planters group, and millers group to "supervise the conduct and review of studies pertaining to the viability of ethanol production from sugarcane" (ibid.). It likewise created a Technical Working Group (TWG) composed of the technical staff of the members of the EPCC to "provide technical know-how and assistance" (ibid.).

[7] To include "all departments, bureaus, offices and instrumentalities of the Government, including government-owned and controlled corporations"

[8] The January 2006 Compliance Report show that 59 government agencies nationwide with approximately 1,100 diesel vehicles were complying with MC 55.

In July 2004, the TWG released its first report, outlining the following findings (ibid.):

- The Philippine sugar industry is capable to meet requirements of a nationwide National Fuel Ethanol Programme;
- The bioethanol volume requirement at 5 per cent and 10 per cent can be supplied by the projected surplus production of sugarcane, starting in 2008;
- Other feedstock options (e.g., corn, cassava, and sweet sorghum) should be explored in order to support feedstock supply should the ethanol blend be increased.

In August 2004, the sugar industry's initiative led to the creation of the Philippine Fuel Ethanol Alliance, with membership from the SRA (government), Sugar Master Plan Foundation, Inc., Philippines Sugar Millers Association (both of the sugar industry), Center for Alcohol Research and Development (alcohol industry), and Petron Corporation (an oil company). Its aim was "to coordinate efforts of the stakeholder industries by way of information sharing and regular dialogues" (ibid.).

In 2006, the initiatives of both the coco-biodiesel and sugar industries were combined into one Biofuels Act. Both the Senate and the House of Representatives ratified Republic Act 9367, otherwise known as the "Biofuels Act of 2006," on 29 November 2006. President Gloria Macapagal-Arroyo, in turn, approved this on 12 January 2007. The DOE likewise promulgated the Implementing Rules and Regulations (IRR) in its DC 2007-05-0006 in 17 May 2007.

4. The biofuels mandate

The Biofuels Act of 2006, or Republic Act 9367, is formally entitled "An act to direct the use of biofuels establishing for this purpose the biofuels programme, appropriating funds therefore, and for other purposes." The IRR covers the "production, blending, storage, handling, transportation, distribution, use, and sale of biofuels, biofuel-blends, and biofuel feedstock in the Philippines."

The following are some of the key aspects of the IRR:

a) Section 2 – Declaration of Policy

> *It is hereby declared the policy of the State to reduce dependence on imported fuels with due regards to the protection of public health, the environment, and natural ecosystems consistent with the country's sustainable economic growth that would expand opportunities for livelihood by mandating the use of biofuels as a measure to:*
>
> *a. develop and utilize indigenous renewable and sustainably-sourced clean energy sources to reduce dependence on imported oil;*
>
> *b. mitigate toxic and greenhouse gas (GHG) emissions;*
>
> *c. increase rural employment and income; and*

d. ensure the availability of alternative and renewable clean energy without any detriment to the natural ecosystem, biodiversity and food reserves of the country.

b) Section 5 – Mandatory Use of Biofuels

Pursuant to the Section 5 of the Act, all liquid fuels for motors and engines sold in the Philippines shall contain locally-sourced biofuels components as follows:

5.1. Bioethanol

a. Within 2 years from the effectivity of the Act, at least 5 per cent bioethanol shall comprise the annual total volume of gasoline fuel actually sold and distributed by each and every oil company in the country, subject to the requirement that all bioethanol blended gasoline shall contain a minimum 5 per cent bioethanol fuel by volume

b. Within 4 years...the NBB...is empowered to determine the feasibility and thereafter recommend to the DOE to mandate a minimum of 10 per cent blend...

5.2 Biodiesel

a. Within 3 months...a minimum of 1 per cent biodiesel by volume shall be blended into all diesel fuels sold in the country

b. Within 2 years...the NBB is empowered to determine the feasibility and thereafter recommend to DOE to mandate a minimum of 2 per cent blend of biodiesel by volume which may be increased after taking into account considerations, including, but not limited to domestic supply and availability of locally sourced biodiesel component

5.3. Other Biofuels

In the event that fuels derived from biomass other than bioethanol and biodiesel are developed pursuant to the Act as technically validated by the DOST, the DOE shall issue, upon consultation with the entities concerned and upon the recommendation of the NBB, the appropriate department circular to promote the utilization o such fuels and provide the appropriate incentives consistent with the provisions of the Act.

The focus of the Act then is mainly on the use of biofuels in the transport sector. For bioethanol, a 5 per cent in the total volume of gasoline is mandated. In addition, a 5 per cent blend in 2009, and 10 per cent in 2011 will be required. Likewise, for biodiesel, a minimum of 1 per cent blend within three months and 2 per cent in 2009 will be enforced. Similar standards for other biofuels may be developed.

c) Section 6 – Importation in case of supply shortage of locally-produced bioethanol

> *…In the event of a supply shortage of locally produced bioethanol during the first four-year period of implementation of the Act…oil companies shall be allowed to import bioethanol to the extent of the shortages …*

d) Section 7 – Incentives under the Act

> *To encourage investments in the production, distribution, and use of locally produced biofuels at and above the minimum mandated blends…:*
>
> a. *Specific Tax. The specific tax on local or imported biofuels component of the blend per liter of volume shall be zero.*
> b. *Value Added Tax. The sale of raw material used in the production of biofuels such as, but not limited to, coconut, jatropha, sugarcane, cassava, corn, and sweet sorghum shall be exempt from the value added tax.*
> c. *Water Effluents. All water effluents, such as but not limited to distillery slops from the production of biofuels used as liquid fertilizer and for other agricultural purposes are considered "reuse" and are therefore, exempt from wastewater charges under… the Philippine Clean Water Act.*
> d. *Financial Assistance. Government financial institutions…accord high priority to extend financing to Filipino Citizens or Entities…that shall engage in activities involving production, storage, handling, and transport of biofuels and biofuels feedstock, including blending of biofuels with petroleum.*

e) Section 8 – Creation and Organizational Structure of the National Biofuels Board (NBB)

The NBB is tasked to 1) monitor and evaluate the implementation of the National Biofuels Programme; 2) monitor the supply and utilization of biofuels; review and recommend minimum blends; 3) recommend a programme for ensuring availability of alternative technology; 4) recommend use of biofuels in air transport; and 5) recommend actions concerning the implementation of the NBP, including its economic, technical, environment and social impacts.

The NBB is headed by the secretary of Department of Energy while its membership will be composed of the secretaries of Department of Trade and Industry (DTI), Department of Science and Technology (DOST), Department of Agriculture (DA), Department of Finance (DOF), Department of Labor and Employment (DOLE), and administrators of Philippine Coconut Authority (PCA) and Sugar Regulatory Administration (SRA).

5. Perspectives from biofuels producers

At least P12 billion in total amount of investment has been identified for the production of bioethanol in the country. This comprises investments from four companies with DOE endorsements for Board of Investments (BOI) approval, which will allow them tax incentives under pioneer status category (see Table 2).

Table 2
Bioethanol producers with DOE endorsements and BOI approval

Companies	Location	Capacity (million liters/year)	Investment (Philippine Pesos)
1. San Carlos Bioenergy, Inc.	San Carlos City, Negros Occidental	30	2.5 billion
2. JG Summit	Manjuyod, Negros Oriental	30	800 million
3. Biofuels 88 / Flying V	Mariveles, Bataan	9	500 million
4. Leyte Agri Corp	Ormoc, Leyte	9	35.9 million

Sources: www.gmanews.tv; One Alternative Energy Blog

Likewise, the following companies have received DOE endorsements for registration with the Securities and Exchange Commission (SEC):

1. First Pampanga Biofuels Corp
2. South Bukidnon Bioenergy Inc
3. Zambo Norte Bioenergy Corp
4. Renewable Alternative Fuel Inc
5. Kanlaon Alcogreen
6. Negros Green Resources
7. Pampanga Industrial Park
8. Hope 8 Manufacturing and Trading Corp
9. Eastern Renewables Fuels Corp
10. Petrolift Holdings, Inc.

Finally, the following are those who sent letters of intent to the DOE:

1. Negros Southern Integrated Biofuels Corp
2. J.G. Itochu
3. Tamlang Valley Ethanol
4. Pampanga Industrial Park
5. B.M. SB Integrated Biofuels
6. Negros Biochem Corp
7. Fuel Inc

8. Ginebra San Miguel Inc.

Meanwhile, for the biodiesel producers, seven companies are in various levels of engagement in the production of biodiesel. Table 3 shows CME manufacturers with DOE accreditations.

Table 3
CME Manufacturers with DOE Accreditations (as of 28 August 2007)

Company	Capacity (liters/year)	Location	Brand name
Chemrez, Inc.	75,000,000	Quezon City	Bio-activ
Senbel Fine Chemicals	36,000,000	Muntinlupa	Estrol
Romtron	300,000	Romblon	Romtron
Pure Essence Intl., Inc.	60,000,000	Pasig City	Bio Pure
Freyvonne Milling Services	-	Davao City	Power Z
Golden Asian Oil Intl., Inc.	-	Pasig City	Clean Air Biodiesel
Mt. Holly Coco	4,000,000	Quezon	-

Adapted from: www.doe.gov.ph; Palad (2008)

3.1 From a bioethanol producer

One of the first five companies granted with a DOE accreditation for bioethanol production is Leyte Agri Corp (LAC) located in Ormoc, Leyte in the Eastern Visayas region. LAC has been in existence as a distillery since 1992. It manufactures food-grade alcohol for liquors and perfume. In 2003, when the market for liquors went down, LAC started to explore other markets for their alcohol products, particularly fuel ethanol. With the passage of the Biofuels Act, the company is a part of the government's agenda for the development of the bioethanol industry. Interestingly, LAC's resident manager, mentioned that even without the Biofuels Act, LAC would still engage in bioethanol production. Nonetheless, the tax incentives, particularly on imported equipment, have helped make their way to bioethanol production easier.

Still, one main obstacle LAC faces in their planned expansion is the high price of electricity for the distillery which they get from the grid. This is in addition to the rice hull they use to power their offices. In spite of being in close proximity to the geothermal plant in Tongonan, Leyte, LAC pays P5.20 per kilowatt for the distillery's use. This is comparably higher than Manila electricity priced at only P4.97. The resident manager cites the channeling of locally produced electricity to Metro Manila and Cebu as the reason for the expensive electricity costs.

In terms of community relationships, LAC has strong community support in the form of scholarships and computer literacy programmes at the local high school. LAC was conferred the International Green Apple Award for Environment Best Practice in November 2006 at the House of Commons, London. LAC is scheduled to begin manufacturing on February or March 2008.

3.2 From a biodiesel producer

Chemrez Technologies, Inc. is one of the stronger voices in promoting coco-biodiesel in the country. This is not surprising as it commands 55 per cent of the coco-biodiesel market in the country. The remaining 45 per cent is shared among the six other companies itemized in Table 3. Chemrez, Inc.'s capacity is at 60 million litres per year. Recently, it has announced its expansion that will increase its annual capacity to 90 million litres.

Since 1987, Chemrez, Inc. has been engaged in plant oil manufacturing under its mother company, D&L Industries. In 2006, Chemrez, Inc. evolved into Chemrez Technologies. During the 2000 coco oil crisis, Chemrez turned to manufacturing coco methyl ester (CME) with fuel specifications. In 2003, Chemrez has already started to market bottled CME for retail.

3.3 Others

3.3.1 Coco-biodiesel

The Palm Oil Technological Center at the Visayas State University (VSU, formerly Leyte State University) in Baybay, Leyte is engaged in producing small quantity biodiesel for use of VSU vehicles. Initial results show about 20 per cent increase in fuel efficiency in terms of mileage per liter of diesel consumed. However, as it is only in its pilot testing phase, the biodiesel produced is not yet accredited with the DOE.

3.3.2 Jatropha

The Philippine National Oil Company – Alternative Fuels Corporation (PNOC-AFC) is tasked with the "identification and development of low-cost biofuel feedstock, i.e., jatropha for biodiesel and sweet sorghum and cellulosic biomass for bioethanol." By 2012, PNOC-AFC aims to achieve the following targets:

- 1,500 hectares of jatropha mega-nurseries cum pilot plantations
- 700,000 hectares of biofuel crop plantations
- 1 million MT biodiesel refineries

6. Key aspects in the implementation of the Act

Based on the above discussion, the following are the key observations and issues in the implementation of the Biofuels Act of the Philippines:

1. Two sets of key players: bioethanol and biodiesel groups

The promotion of the use of biofuels in the Philippines was initially made on two main fronts: bioethanol and coco-biodiesel. Through the efforts of the sugar industry, the Bioethanol Act of 2005, which covered bioethanol blending only, was passed in the Lower House in November 2005. In 2006, the bioethanol group compromised with the coco-biodiesel group to include the biodiesel mandate. The consolidated bills became the Biofuels Act of 2006.

2. Aggressive national policy

One of the objectives of the Philippine Energy Plan (PEP) 2005-2014 is to achieve 60 per cent self-sufficiency by 2010, with attainment through increasing the use of alternative fuels. Concretely, the PEP envisions the following goals:

- 5 per cent CME blend with diesel fuel for vehicles in 2010;
- 5 per cent ethanol blend with gasoline fuel for vehicles by 2007 and to reach 10 per cent in 2010;
- 19.8 MMBFOE (2.9 MTOE) average annual energy savings in ten years through the National Energy Efficiency and Conservation Programme;
    - 17.7 MMBFOE (2.6 MTOE) to come from energy efficiency and conservation programme
    - 2.1 MMBFOE (0.3 MTOE) to come from alternative fuels for transport programme

3. Equally aggressive private sector

As mentioned above, there were two main lobby groups who pushed for the passing of the Biofuels Act. These lobby groups were mainly comprised of industry players (i.e., producers, oil companies, etc.). Further, the availability of commercial brands (e.g., B1 diesel or Envirotek, E10) signifies the strong involvement of the industry players. Likewise, the long list of companies interested in bioethanol production promises a future with locally sourced bioethanol.

4. Conflicting views on the jatropha methyl ester (JME)

The government is pushing for the use of jatropha-based biodiesel because the plant is not a food source, it can be easily planted through seeds or cuttings, is drought-resistant and its seeds can yield 0.75 to 2 tons of biodiesel per hectare in a year (Mendoza, et.al.).

However, there are also groups who caution against planting jatropha saying that it would be "counterproductive" due to the little energy that can be gained from it and the need for clearing forests to make way for the plantation (Burgonio 2008, ibid.).

In this regard, it is always best to take a conservative approach and to await the results of other research currently being undertaken.

5. Pre-mixed biofuels access in provinces

Currently, pre-mixed coco-biodiesel is only primarily available in Metro Manila and several other major cities. In other places, coco-biodiesel is sold by the litre and the necessary blending is done by the vehicle owner or driver. This hampers the widespread use of coco-biodiesel, particularly for long-distance travelers who may find it cumbersome to have to blend proportions of coco-biodiesel for every liter of diesel.

Likewise, the Philippine Fuel Ethanol Alliance cautions of a future scenario wherein oil companies will stop offering bioethanol in the rural areas as soon as they meet their 5 per cent volume compliance in the urban areas (Apañada, n.d.).

6. Monitoring of compliance

A very important provision on the Biofuels Act is the involvement of local government units (LGUs) to monitor the distribution, sale, and use of biofuels and biofuels-blends (Section 21). However, LGUs (and even the DOE) do not have the necessary capacity to do this. There is thus a need to provide technical assistance (in the form of technology and knowledge) to the LGUs so that they will be capable of detecting substandard biofuels.

7. A note on the farmers

Rule 8 of the IRR of the Biofuels Act is the "Development of Social Amelioration and Welfare Programme for Workers in the Production of Biofuels." The objectives of this Programme are the following:

a. Promote gainful livelihood opportunities
b. Facilitate productive employment through effective employment services and regulation; and
c. Ensure the access of workers to productive resources and social protection coverage.

The Programme covers "all rank and file employees of biofuel plants, workers and farmers engaged in the production of crops used as feedstocks in biofuels." It "shall provide basic benefits and assistance that will augment the income and improve the standard of living of workers engaged in the production of biofuels" and may consist of the following components:

d. training and education assistance;
e. livelihood assistance;
f. social protection and welfare benefits; and
g. distribution of financial benefits.

7. A final note: Section 39 on CDM

Section 39 of the IRR of the Biofuels Act is a special clause stating that, "the Act and this IRR shall not be interpreted as prejudicial to the clean development mechanism (CDM) projects that cause carbon dioxide and greenhouse gases emission reductions by means of biofuels use." With the strong participation of the Philippine government in CDM ever since the latter's inception, the Biofuels

Programme is leaving the door open for would-be investors and project developers for biofuels-CDM projects.

Indeed, there have been expressions of interest in engaging in biofuels-CDM projects from biofuels producers. However, one of the main obstacles that stop these projects from taking off is the absence of applicable approved baseline and monitoring methodologies. The lone biofuels methodology (AM0047 – Production of waste cooking oil based biodiesel for use as fuel) does not cover the use of biofuels in the transport sector as promoted by the Biofuels Act. Likewise, a small-scale methodology (AMS III.T Plant oil production and use for transport applications) has been recently approved but this does not cover biodiesel (e.g., coco-biodiesel) as well. It does, however, hold promise for jatropha-based projects.

However, what is being eyed is an ethanol-cogeneration complex such as the one being developed by San Carlos Bioenergy, Inc. Its bagasse-powered cogeneration power plant is already a registered CDM project and they are currently constructing their ethanol distillery. Such combination ethanol-cogeneration increases the return of investment compared to an ethanol plant without the cogeneration component (Diezmos, n.d.).

References

AMS III.T version 1. Available online www.unfccc.intConti, Maria Kristina C. *More perks sought for biofuels ventures, farmers*. Business World 09 January 2008, page 3.

Apañada, Marlon Joseph. No. date. "Using Policy Tools to Maximize Biofuels Opportunity" (A presentation)

Burgonio, TJ. "Rethink biofuel, says Nobel laureate." Philippine Daily Inquirer, 14 January 2008, page 1.

Department Circular No 2005-04-003

Department Circular No 2007-05-0006

Department of Energy. *Philippine Energy Plan 2005-2014: 2006 Update.*

Department of Energy. January 2006. *Results of the Use of 1 per cent CME-Petroleum Diesel Blend for Government Diesel Vehicles* (Executive Summary).

Department of Energy. March 2007. *Biofuels Programme: Key to Energy Independence and Security* (A presentation).

Diezmos, Rafael D. No date. *The Philippine Bioethanol Industry: Status and Prospects*. Available online www.biofuelshub.com

Lotilla, Raphael. 27 March 2007. "Biofuels Initiatives in the Philippines" (A presentation to the California Biomass Collaborative 4th Annual Forum).

Memorandum Circular No. 55

Mendoza, Zamora and Lales. "Jatropha: What the Public Should Know" in Talk of the Town, 08 September 2007. Available online http://opinion.inquirer.net/inquireropinion/talkofthetown/view_article.php?article_id=87461

Philippine National Oil Company-Alternative Fuels Corporation. 2007. *Biofuels Act Primer*.

Republic Act 9367

Yap, Arthur. No date. "Biofuels: Situation in the Philippines" (A presentation)

No author. "At least P12B in bioethanol projects lined up" Available online http://www.alternat1ve.com/biofuel/2007/09/15/philippines-has-p12-billion-worth-of-biofuel-investments/

No author. 2007. "Carbon credits prove elusive or biofuels." Available online www.bioenergy-business.com/index.cfm?setion=features&action=view&id=10396

MUNICIPAL ORGANIC WASTE AS AN ALTERNATIVE URBAN BIOENERGY SOURCE

WANG, Jing-Yuan

Environmental Engineering Research Centre
Nanyang Technological University

School of Civil & Environmental Engineering, Nanyang Technological University, 50 Nanyang Ave, Singapore 639798
Tel: 65-67904100; Fax: 65-67927319; Email: jywang@ntu.edu.sg

Executive Summary

To increase the use of bioenergy from current 4 per cent to higher percentage, reduce the emission of particulate matters from direct burning of biomass, and help alleviate solid waste management problems, converting municipal organic solid waste into biofuels in both developing and developed countries can be considered as an alternative bioenergy source. Using Singapore as an example, about 75 per cent of the total solid waste collected for disposal is available to be used as "urban biomass" for bioenergy recovery. Converting urban biomass, i.e. municipal organic solid waste, can not only resolve waste management problems, but also provide alternative bioenergy for urban human activities. Although there are available bioenergy technologies, there is still a need to develop approaches that would address related global issues while acting locally. Home grown technologies are necessary to address domestic and possibly cultural concerns in Singapore. Such developments can eventually be modified and eventually exported to other countries/societies which share cultural and economic commonalities. Three emerging bioenergy technologies, including a novel three-phase anaerobic digestion system for co-production of bio-hydrogen and bio-methane, bioconversion of green waste into sugars for ethanol production, and biodiesel production from algae using photo-bioreactors, were introduced.

1. Introduction

About 85 per cent of global energy usage in 2004 was covered by oil, coal, and gas (Wikipedia, 2007). This high energy demand will eventually lead to the depletion of fossil fuel resources. For instance, it is estimated that coal may run out in 200 years, while the current oil deposit may only last for another 60 years (Evers, 2006). Another serious concern from the use of fossil fuels is the increase in CO_2 concentration in the atmosphere; it may cause climate change due to global warming. Therefore, finding renewable and clean alternative energy sources has been a pressing need to sustain human activities on earth, especially when the price of oil is high. The reliance on fossil fuels may drop to 80 per cent if oil prices remain high. The use of alternative energy such as solar energy, wind energy, and bioenergy is expected to be considerably encouraged.

Bioenergy, including direct burning of biomass and use of biofuels, is a renewable energy option and can be considered as a sustainable alternative to conventional fossil fuels. Biofuels, converted from biomass or organic waste, are generally CO_2-neutral and contribute less to global warming. Also, depending on their compositions, the application of biofuels may diminish emission of particulate matters, CO_2, and NOx. Hence, biofuels are considered as a clean energy source. Furthermore, as biomass is abundant in the region, especially in South-East Asia, biofuels can be developed into a key alternative energy source as important as solar energy. Currently, the use of solar energy is only 0.5 – 0.6 per cent of total world energy consumption (15 trillion watts), while the use of biomass and biofuel is about 4 per cent. Energy supply by direct burning of biomass (96 per cent of total bioenergy used), is mainly used in under-developing and developing countries. Due to imperfect burning and the lack of emission control, direct biomass burning may emit particulate matter into the atmosphere, together with other air pollutants, and hence directly or indirectly produce aerosols that may eventually cause climate change.

To (1) increase the use of bioenergy from current 4 per cent to a higher percentage, (2) reduce the emission of particulate matters from direct burning of biomass, and (3) help alleviate solid waste management problems, converting municipal organic solid waste into biofuels in both developing and developed countries can be considered as an alternative bioenergy source to supply urban human activities. In this paper, the opportunities and challenges for converting municipal organic solid waste (MOSW) into biofuels as an alternative energy source in Singapore is discussed.

2. Municipal Organic Waste Management in Singapore

2.1 Solid Waste Management

Over the last three decades, Singapore has spent billions of dollars building incineration plants and sanitary landfills. The four incineration plants have significantly reduced the volume and weight of waste for final disposal and recovered energy and scrap metals, while landfills have been used to dispose of non-incinerable waste and incineration ash. The offshore Semakau Landfill that commenced operation on 1 April 1999 is the only landfill existing in Singapore. The solid waste disposed of in Singapore has increased 6 fold, from 1,200 tonnes/ day in 1970 to 7,024 tonnes/ day in 2006. Of the total solid waste generated, domestic waste increased by approximately 3-fold, while the non-domestic component increased 8-fold. The rise in non-domestic waste is mainly due to high growth in the manufacturing and service sectors. With the rapid growth rate in solid waste, Singapore would need to build a new incineration plant every 5 to 7 years and a new landfill the size of Semakau offshore landfill every 30 to 40 years to cope with the need.

Building more waste disposal facilities based on current state-of-the-art to meet increasing amounts of waste does not conform to sustainable development. Moreover, it is costly to build and operate new disposal facilities. The sustainable waste management approach is to minimise waste while maximising recycling to help defer construction of new disposal facilities, reduce the demand for land to build these facilities, and possibly reduce the cost of waste disposal. Singapore Green Plan (SGP) 2012 has set a target to achieve at least 60 per cent of recycling rate by 2012. To help reach the goal, the Singapore government has encouraged universities and research institutes to conduct research and development work on waste minimization and conversion of waste residues into resources (e.g. materials and energy) through appropriate management of dewatered sewage sludge; incineration ash; municipal solid waste; and commercial, industrial and horticultural waste. The ultimate goal is to develop technologies that will help to increase the recycling rate to 60 per cent by 2012.

2.2 Municipal Organic Solid Waste as "Urban Biomass"

Table 1 presents Singapore's solid waste statistics and recycling rate in 2006. It shows that the recycling rate has reached 51 per cent, which is 9 per cent shy of the targeted 60 per cent by 2012. Food waste is about 19.5 per cent of the total waste to be disposed of, while there is only 8 per cent of recycling, mainly used as animal feed. According to SGP2012, the food waste recycling rate is expected to be 30 per cent by 2012. Paper/cardboard is currently recycled for 51 per cent, which is a bit lower than the expected 55 per cent by 2012. Plastics waste is currently recycled at 12 per cent, which is far lower than the expected 35 per cent, though Singapore government has been cutting the use of plastic bags in the major shopping centres and grocery stores. It is surprising to find that a considerable amount of construction debris has been recycled. Currently, only 0.59 per cent of construction debris went to the Pulau Semakau Landfill for disposal. Wood/timber and horticultural waste are another two recyclable wastes. With the current recycling rates, more recycling effort is needed by 2012; they are expected to be recycled for 40 per cent and 70 per cent by 2012, respectively.

Generally, the above-mentioned solid wastes are organic wastes and can be considered as "urban biomass" for bioenergy recovery. These urban biomasses included:

- Food waste: 498,000 tonnes (19.4 per cent)
- Paper/Cardboard waste: 544,900 tonnes (21.3 per cent)
- Plastic waste: 579,000 tonnes (22.6 per cent)
- Wood/Timber waste: 142,000 tonnes (5.5 per cent)

- Horticultural waste: 144,000 tonnes (5.6 per cent)
- Total organic waste available as Resources = 1.91 M tonnes (74.4 per cent)

Table 1 Singapore's waste statistics and recycling rate for 2006 (Singapore NEA, 2007)

Waste Statistics and Recycling Rate for 2006				
Waste Type	**Waste Disposed of (tonne)**	**Total Waste Recycled (tonne)**	**Total Waste Output (tonne)**	**Recycling Rate (per cent)**
Food waste	498,000	44,700	542,700	8
Paper/Cardboard	544,900	571,400	1,116,300	51
Plastics	579,000	77,800	656,800	12
Construction Debris	15,000	604,000	619,000	98
Wood/Timber	142,000	81,700	223,700	37
Horticultural Waste	144,000	87,000	231,000	38
Ferrous Metals	68,500	657,400	725,900	91
Non-ferrous Metals	16,000	70,700	86,700	82
Used Slag	53,600	417,000	470,600	89
Sludge	126,800	0	126,800	0
Glass	56,600	6,400	63,000	10
Textile/Leather	87,700	4,100	91,800	4
Scrap Tyres	4,500	19,400	23,900	81
Others (stones, ceramics & rubber	227,000	15,300	242,300	6
Total:	2,563,600	2,656,900	5,220,500	51

Depending on the types of businesses/activities and environmental infrastructure, the MOSW of a municipality could be even higher than the estimated 75 per cent for Singapore. Furthermore, on top of the MOSW mentioned, 270,000 tonnes of dewatered sewage sludge and 128,000 tonnes of industrial sludge (mixed chemical and biological sludge) were collected for disposal in 2006. These sludges can be used as urban biomass for energy recovery, bioenergy, if properly managed.

3. Bioenergy Technology Development

3. 1 Biomass Conversion

Biomass can be converted into various biofuel products, such as biogas, biodiesel, bioethanol, and methanol, through a range of technologies like direct combustion, gasification, pyrolysis, anaerobic digestion, biodiesel production, bioethanol production, and methanol production (Oregon Department of Energy, 2007). Converting urban biomass, i.e. municipal organic solid waste, can not only resolve waste management problems, but also provide alternative bioenergy for urban human activities.

3.2 Challenges and Issues of Current Bioenergy Technology Development

Current bioenergy technology development mainly concentrates on overcoming recalcitrance of cellulosic biomass. The trend is to develop biotechnologies for converting cellulosic biomass into reactive intermediates that can subsequently be converted into energy, fuel, heat, and by-products. The following summarizes the challenges and issues of current bioenergy technology research and development, while Table 2 identifies key challenges and opportunities on commercial aspects (Goodfellow, 2006).

Biogas: The research in biogas (mainly hydrogen and methane) generation through anaerobic digestion centres on monitoring and controlling the digestion processes and on cleaning the methane and hydrogen produced. Different approaches and substrates are being attempted to enhance biogas production. In addition, characterization and usage of the spent digestate is of concern. The research in biohydrogen production is mainly on a lab-scale level using pure substrate/culture, while methane has been commonly generated using various biomass including food waste and animal waste.

Bioethanol: Bioethanol is one of the most common renewable biofuels and can be derived from corn grain (starch) and sugar cane (sucrose). Limits to the supply of these common raw materials in the near future and their high value as a food crop makes lignocellulosic biomass an attractive feedstock for future supplies of ethanol. Cellulosic feedstock, including forest residues, horticultural waste and aquatic biomass, is attractive because of its low cost and widespread availability. Cost-effective production of bioethanol from lignocellulose is being researched.

Biodiesel: Conversion of low cost oils and fats, such as restaurant waste oils and animal fats, or natural oil-rich seeds (e.g. jatropha), into biodiesel is also under current biofuel research focus areas.

3.3 Current Bioenergy Technology Development in Singapore

Although there are available bioenergy technologies, there is still a need to develop approaches that would address related global issues while acting locally. Home grown technologies are necessary to address domestic and possibly cultural concerns in Singapore. Such developments can eventually be modified and eventually exported to other countries/societies which share cultural and economic commonalities. This is especially true for those numerous fast developing economies and populous countries with significant rural to urban migration patterns, e.g. China, India, ASEAN, and the Middle East. These countries are witnessing unprecedented market growth. The following summarizes some selected bioenergy technologies being developed in Singapore:

Technology 1: Co-production of biohydrogen and biomethane using a novel three-phase anaerobic digestion system

Over the last 6 years, NTU has been very successful in the waste to biogas research including the conversion of wastewater, sludge, and food waste into biogas using innovative anaerobic digestion technologies. The hybrid anaerobic solid-liquid (HASL) digestion system, which was developed to convert food waste into biogas, has been a successful home-grown technology (Wang et al., 2002, 2005a). The HASL system includes an acidogenic reactor to hydrolyze and acidify solid food waste and a modified upflow anaerobic sludge blanket (UASB) methanogenic reactor for the conversion of volatile fatty acid from the acidogenic reactor into biogas. Part of the effluent from the methanogenic reactor is used for the dilution of the acid effluent from the acidogenic reactor to maintain optimal pH for methanogenesis, and the other stream of the effluent from the methanogenic reactor is recycled into the acidogenic reactor to avoid addition of water for food waste hydrolysis.

NTU's waste to energy group has been using the HASL system to study bioconversion of food waste into biogas since 2001. The investigated research topics included comparative study on operation of batch and semi-continuous digestion of food waste using lab-scale and pilot-scale HASL systems (Wang et al., 2003a; 2005b), enhancement of food waste anaerobic digestion in HASL system by removal of ammonia in an aerated submerged biofilter (Wang et al., 2003b),

Table 2 Key Challenges and Opportunities of Biofuels (Goodfellow, 2006)

Output	**Feedstock**	**Preparation**	**Key transformation**	**Refining**	**Distribution / Usage**	**Co-products**
Transportation						
Ethanol (starch)	Designer crop	De-watering	Continuous flow Microbials	Mostly resolved	Sediment	**Market for DDG**
Ethanol (cellulose)	Beyond clean straws to waste cellulose	**Acid and enzyme Pre-treatment De-watering**	Right-sizing / business model	Mostly resolved	Sediment	**What to do with C5 sugars**
Biodiesel	**Beyond food crops** **Blue-green algae?**	Purity/consistency of non-virgin oils De-watering	Higher efficiency catalyst Containment of catalyst	Product consistency Standards	Water contamination	**Glycerine quality / markets**
Heat and Electricity						
Biogas (Anaerobic Digestion)	Beyond manure SRM Recipes	**Particle size** **De-watering**	Well understood Microbial efficiency and nutrition	Gas clean-up Gas compression	Generator efficiency and robustness	**Markets for spent digestate**
Syn Gas (Gasification)	Beyond homogeneous feedstock	**Sorting technology** **Moisture removal** **De-watering**	Heat transfer Material handling	Gas clean-up Gas compression	Generator efficiency and robustness	Market development for CO_2
Bio Oil (Pyrolysis)	Beyond homogeneous feedstock	Particle size De-watering	Mostly worked through	**Chemical characterization and extraction**	**Generator efficiency and robustness**	Use of fuel is the co-product

the use of HASL system for the treatment of lipid-containing food waste (Stabnikova et al., 2005a), and batch digestion of thermally pre-treated food waste in HASL system (Wang et al., 2006). With a research grant of S$1.67 million from Singapore government and industry, a HASL pilot plant having a treatment capacity of 3-tonne/day has been established on the NTU campus to test and study its commercial viability.

The main objective of the study is to develop a novel three-phase anaerobic digestion system (3PADS) that can optimize a high rate co-production of biohydrogen and biomethane.

Technology 2: Bioconversion of green waste to sugars for bio-ethanol production

Compared to oil, the application of bioethanol would not affect the amount of carbon dioxide in the atmosphere. The emission and toxicity of bioethanol are lower than those of petroleum. All automobile manufacturers produce vehicles that can readily use 10 per cent ethanol or 85 per cent ethanol blends for fuel, and ethanol can replace diesel in heavy vehicles. The main objective of the research is to isolate some effective microbes from (1) the guts of tropical animals, such as termite, caterpillar, cockroach, etc. and (2) the process of natural degradation of green waste (leaves, tree bark and grass etc.) in aerobic and anaerobic conditions. These microbes can convert green wastes to simple sugars, which can then be further converted to bio-ethanol by fermentation.

Technology 3: Biodiesel production in photobioreactors

Microalgae are sunlight driven cell factories capable of producing a wide range of products of economical values including biodiesels. Biodiesels derived from algal photosynthesis include methane, which is indirectly produced by anaerobic digestion of algal biomass, and metabolic hydrogen of hydrocarbon production. A recent study has shown that microalgae, because of their high metabolic rates, are the only biodiesel producer potentially able to meet the global demand for transport fuel (Chisti, 2007). Algal biodiesel production is also a CO_2-neutral process as anaerobic digestion of algal biomass residues can provide the mechanical energy needed to operate the process. Algal growth can also be simultaneously used for nutrient recycle and pollution control such as during wastewater treatment in aerobic ponds, or gas treatment for the removal of CO_2, NOx and SOx pollutants (Muñoz and Guieysse, 2006). Although the idea of producing biodiesel from algae is not new, it has regained a recent worldwide interest due to the rising oil price and CO_2-policies.

The main objective of the project is to develop a robust and economically viable algal-based bioprocess for biodiesel production by (1) improving the biocatalyst by screening of new species, metabolic or genetic engineering, oriented selection and "training"; (2) improving the design, operation, modelling and hydrodynamic understanding of photobioreactors; and (3) improving product recovery.

4. Conclusions or Recommendations

- To (1) increase the use of bioenergy from current 4 per cent to higher percentage, (2) reduce the emission of particulate matters from direct burning of biomass, and (3) help alleviate solid waste management problems, converting municipal organic solid waste into biofuels in both developing and developed countries can be considered as an alternative bioenergy source to supply urban human activities.

- Using Singapore as an example, about 75 per cent of the total solid waste collected for disposal is available to be used as "urban biomass" for bioenergy recovery. This does not include 270,000 tonnes of dewatered sewage sludge and 128,000 tonnes of industrial sludge (mixed chemical and biological sludge) collected for disposal. These sludges can be used as urban biomass for energy recovery, bioenergy, if properly managed. Converting urban biomass, i.e. municipal organic solid waste, can not only resolve waste management problems, but also provide alternative bioenergy for urban human activities.

- Current bioenergy technology development mainly concentrates on overcoming recalcitrance of cellulosic biomass. The trend is to develop biotechnologies for converting cellulosic biomass into reactive intermediates that can subsequently be converted into energy, fuel, heat, and by-products. Although there are available bioenergy technologies, there is still a need to develop approaches that would address related global issues while acting locally. Home grown technologies are necessary to address domestic and possibly cultural concerns in Singapore. Such developments can eventually be modified and eventually exported to other countries/societies which share cultural and economic commonalities.

- Three emerging bioenergy technologies, including a novel three-phase anaerobic digestion system (3PADS), bioconversion of green waste into sugars for ethanol production, and biodiesel production from algae using photobioreactors, were introduced.

References

Chisti Y. 2007. Biodiesel from Microalgae. Biotechnol. Adv. 25(3):294-306.
Evers J.R. 2006. Biofuel – A Fiji Perspective. Workshop on Biofuel, 24 – 28 April, 2006, Nadi, Fiji.

Goodfellow, R. (2006). Bio-based Energy and Products: Opportunities for Collaboration. Presentation at ICES, Singapore, 16 June, 2006.

Muñoz R. and Guieysse B. 2006. Algal-bacterial processes for the treatment of hazardous contaminants: a review. Water Research. 40(15), 2799-2815.

Oregon Department of Energy 2007. http://oregon.gov/ENERGY.

Singapore NEA (National Environment Agency) 2007. http://www.nea.gov.sg.

Stabnikova O., Ang S.S., Liu X.Y., Ivanov V., Tay J.H., Wang J.Y. 2005a. The use of hybrid anaerobic solid-liquid (HASL) system for the treatment of lipid-containing food waste. Journal of Chem. Technol. Biotechnol., 80 (4), 455 – 461.

Sahajwalla, V., Narendra Saha-Chaudhury, Lan Hong. Waste Plastics - A Resource for EAF Steelmaking, AIST, 2006.

Wang J.Y., Xu H.L., Tay J.H. 2002. A hybrid two-phase system for anaerobic digestion of food waste. Wat. Sci. Technol., 45 (12), 159-165.

Wang J.Y., Xu H.L., Zhang H., Tay J.H. 2003a. Semi-continuous anaerobic digestion of food waste using a hybrid anaerobic solid-liquid (HASL) bioreactor. Wat. Sci. Technol., 48 (4), 169–174.

Wang J.Y., Zhang H., Stabnikova O., Tay J.H. 2003b. Removal of ammonia in a modified two-phase food waste anaerobic digestion system coupled with an aerated submerged biofilters. Waste Management and Research, 21 (6), 527–534.

Wang J.Y., Zhang H., Stabnikova O., Ang S.S., Tay J.H. 2005a. A hybrid anaerobic solid-liquid (HASL) system for food waste digestion. Wat. Sci. Technol., 52 (1-2), 223–228.

Wang J.-Y., Zhang H., Stabnikova O., Tay J.-H. 2005b. Comparison of lab-scale and pilot-scale hybrid anaerobic solid-liquid systems operated in batch and semi-continuous modes. Process Biochem.y, 40 (11), 3580–3586.

Wang J.Y., Liu X.Y., Kao J.C.M., Stabnikova O. 2006. Digestion of pre-treated food waste in hybrid anaerobic solid-liquid (HASL) system. J. Chem. Technol. Biotechnol., 83 (3), 345 – 351.

Wikipedia 2007. http://wikipedia.org.

Sector Development for Domestic Biodigesters: Experiences of SNV, Dutch Development Organisation

Bastiaan Teune
SNV Advisor Biogas/Renewable Energy

R. 104, 2G Bldg., Van Phuc Diplomatic Compound
298 Kim Ma, Ba Dinh, Hanoi, Viet-Nam
Tel. (84.4) 726.1771, Mob. 09 1332 7915
Email: bteune@snvworld.org
http://www.biogas.org.vn

"Sum all the gifts that man is endowed with, and we give our greatest share of admiration to his energy. And today, if I were a heathen, I would rear a statue to Energy and fall down and worship it!" Mark Twain

Abstract

This paper kicks of by analysing the current status of renewable energy programmes in developing countries in relation to its dissemination and durability. Sadly, the conclusion may be drawn that many programmes providing households with renewable energy services, have gone out like a candle in the night. By focussing on sector development of domestic biodigesters, the SNV approach has been a success, although certainly not unique and with some limitations. Concrete examples from the Biogas Programme in Viet-Nam explain the meaning of sector development. Finally some concluding remarks are made that may give a direction to the way forward.

1. Renewable energy: ready to take off

During the World Summit on Sustainable Development in Johannesburg, September 2002, it was stressed that in order to meet the Millennium Development Goals, affordable access to reliable energy services should be perceived as an important catalyst towards development. With the quantitative targets for poverty reduction in mind, not only the appropriateness of technologies, but far more the actual dissemination of these technologies is, and still is, considered the great challenge for 2015.

From the green side, carbon compensation schemes like Clean Development Mechanism, and its voluntary variants, have put renewable energy in developing countries even higher on the agenda. Though it should be noted that when fuel costs and emissions are considered, the household energy choices of developing countries need not be limited by economic, climate-change or energy-security concerns (EIA, 2006), it does open an opportunity of substantial financial revenues.

With the push from a targeted poverty reduction strategy and growing awareness on environmental issues, a paradigm shift from 'small is beautiful', pilots and researches towards impact, large scale dissemination and public private partnerships entered the realm of renewable energy and development assistance.

Having the same intentions in mind, policy makers and practitioners are faced with a reality that obviously demands a lot of energy to change. The next paragraph will illustrate this when looking at the overview of the status of renewable energy dissemination in the developing world.

Status of renewable energy dissemination
In 2007, the Global Network on Energy for Sustainable Development conducted a study on nine different renewable energy technologies and its accessibility for the poor in 10 developing countries throughout the world. It stated that: "... there is a huge potential for development of renewable resources of every type in developing countries, but that renewable energy technologies have a somewhat chequered history. Although many developing countries have considerable experience with some of the technologies, projects have typically been fragmented efforts with a research focus and have been carried out in isolation ..."; And "... in spite of their obvious capacity to provide attainable solutions in a variety of situations, dissemination of renewable energy technologies in most countries has still not reached a satisfactory momentum".

The report links this status to a number of barriers like poor institutional frameworks, lack of finance, bad quality of products, poor hands-on capacities and little awareness among end-users and potential retailers.

These findings are in line with various evaluations with regard to initiatives in the implementation of biogas technologies. An evaluation in Cambodia in 2005 was conducted under up-to-two year old plastic biogas digesters, on its operation and functioning. The rate of operation went down in time; in the first year this rate is high, however only two years late this rate seemed to dwindle to almost zero. "In total, 26 of the 55 digesters surveyed were broken. Without regular maintenance or repair, others will stop functioning soon." But, "(...) most of the other institutions have finished their programmes and have no more funds to visit the installed digesters."

"It seems that having a plastic biogas digester is for most farmers about the same as having a motorbike or car: they know how to use it but need an expert for repair and maintenance."

In 2004, an extensive evaluation on biodigesters in India revealed that in time, half of the biodigesters under the national programme did not function anymore. Due to various reasons training, maintenance and after sales services failed and the private sector had no role to play in it. As these cases show, indeed the dissemination of renewable energy technologies in most countries has still not reached a satisfactory momentum.

2. SNV's biogas practice[9]

The main objective of the biogas practice of SNV is to support the long-term development of a sustainable domestic biogas sector in a number of developing countries by providing advisory services for capacity development. A first screening of countries is made on the basis of pre-conditions for large-scale dissemination of biogas plants. If the major pre-conditions are met, SNV will undertake fact finding missions and feasibility studies in order to make a well founded "go/no go" decision for intervention. These missions and studies do include comprehensive context and multi-stakeholder analyses. In case of a "go" decision, a detailed proposal for a national programme including output

[9] The next four sections heavily rely on Van Nes 2007.

targets, estimated expenditures and proposed financing is formulated in cooperation with the different (potential) partners.

SNV aims to involve a maximum of organisational and institutional capacities already available in the country and to strengthen these capacities through local capacity building organisations rather than keep the implementation of activities in its own hands. National programmes require multiple actors to conduct distinguished functions in a coordinated manner (see Figure 1).

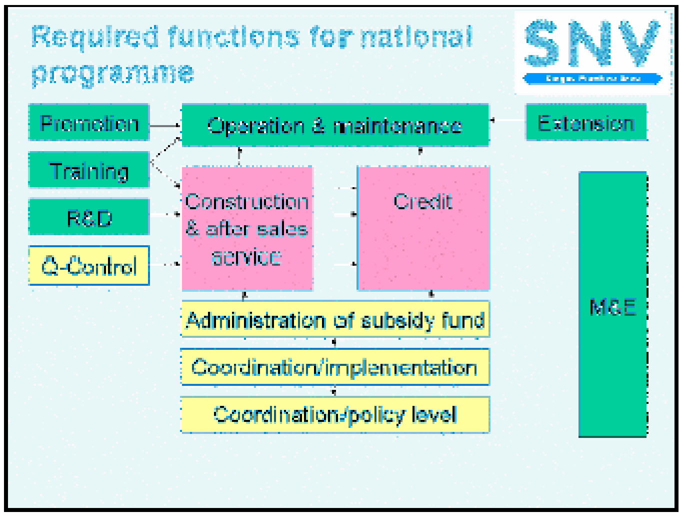


Fig. 1. Different functions required for a national domestic biogas programme

SNV aims to support the development of the biogas sector as a whole, and therefore all actors in the sector are potential partners. The focus of support might shift, depending on the needs of the programme and the capacity of the involved organisations at a certain moment in time.

In the end, SNV hopes to see a fully developed sector in which livestock farmers purchase biogas plants and acquire micro-credit to finance the installation of biogas plants on a commercial basis. Producers of biogas plants and credit institutions compete with each other on a level playing field with an agreed set of quality standards with regard to construction, training and after sales.

Business development and commercialisation by the private sector alone

Business development encompasses a number of techniques designed to grow an economic enterprise. Such techniques include, but are not limited to, assessments of marketing opportunities and target markets, intelligence gathering on customers and competitors, generating leads for possible sales, follow-up sales activity, formal proposal writing and business model design. Business development involves evaluating a business and then realizing its full potential, using such tools as marketing, sales, information management and customer service[10].

Commercialisation can be defined as the introduction of a product or service into the market, for profit. The term usually refers to new processes, products and inventions making their debut on the market[11].

[10] http://en.wikipedia.org/wiki/business_development).

[11] www.promitheas.com/glossary.php

Business development and commercialisation in the domestic biogas sector basically relate to construction and maintenance of biogas plants by producers and to provision of credit by (micro) finance institutes. Figure 2 provides a general overview of the product/market combinations. So far, as evidenced in PR China, India, Nepal, Viet-Nam and Bangladesh, the private sector alone has not been able to disseminate biogas units at a large-scale. It seems the domestic biogas market is not an attractive market for the private sector.

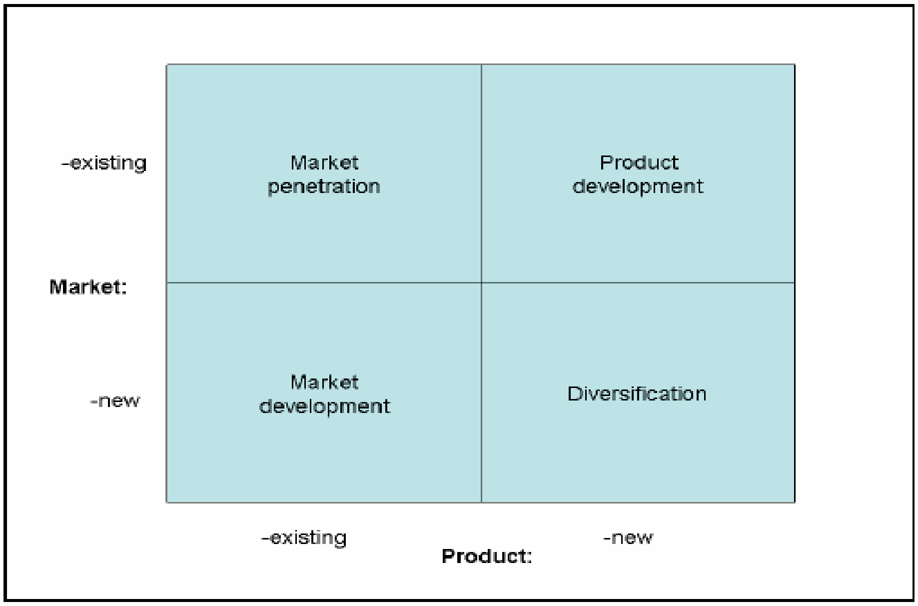


Fig. 2. Product/market combinations for domestic biogas from the perspective of the private sector[12]

There may be different reasons for this phenomenon. In some countries, the functions of construction, maintenance and financing were executed for a long time by government institutions, excluding the private sector. In more recent years, however, the role of the private sector has been appreciated more and more. In countries with a more favourable business climate, the investments for market development to be made by the private sector usually are often beyond their financial capabilities. A third important reason is related to the rather high investment costs of the biogas plants ranging from USD 200 to 400 in Asia, depending on size, country and location. These costs are rather prohibitive from the perspective of the customer in the rural areas who is still able to collect traditional fuels by labour (almost) free of cost. The private sector failed to mobilise sufficient budgets for the reduction of investment costs through product development.

Business development and commercialisation facilitated by the public sector

There are quite a number of benefits of the biogas unit that are not accruing to the customer, but to the society like the benefits related to gender, health and the environment. These socio-economic benefits have been calling for policy and financial support by the public sector. The most evident examples are the biogas programmes set-up and implemented in PR China and India. In these programmes, the role of the private sector – at least in the past - has been quite modest, as most of the functions were executed by government institutions. The SNV approach aims to maximise the role of the private sector in national programmes and to support business development and commercialisation through

[12] Modified Ansoff's matrix

capacity building. In addition, a choice is made on the development of markets rather than of products, see Figure 3.

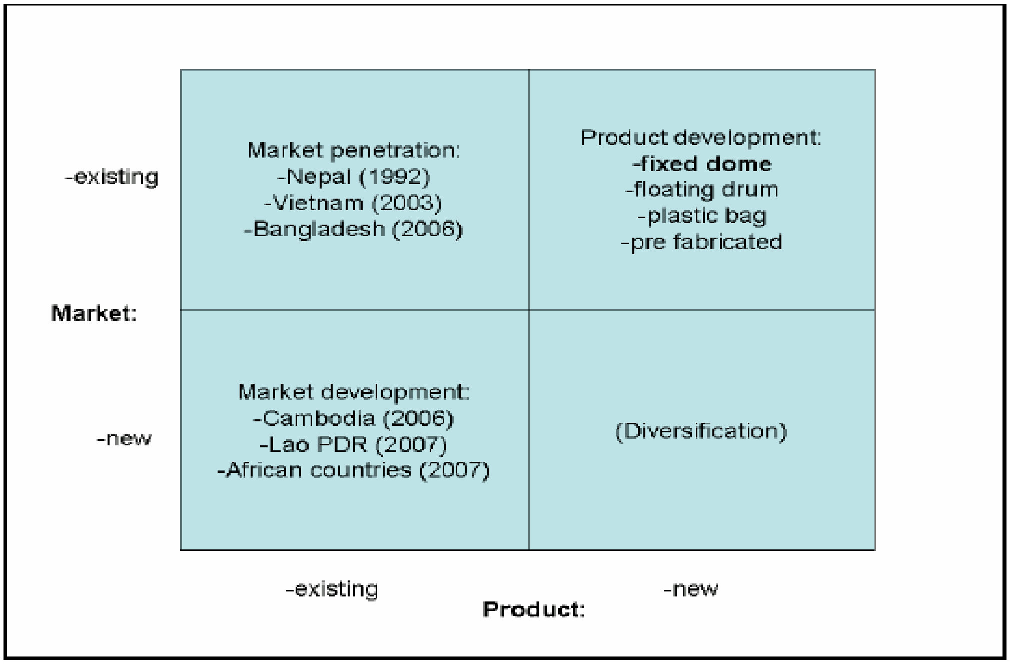


Fig. 3. Product/market combinations for domestic biogas in national programmes facilitated by SNV

For the product to disseminate, the fixed dome model has been selected, providing a better quality/price ratio compared to floating drum and plastic bag digesters. The rather high investment costs of this model are more or less taken as a fact, allocating only very modest budgets for applied R&D. The main efforts are put in development of the market such as in Cambodia, Lao PDR and in African countries or in penetration of the market like in Nepal, Viet-Nam and Bangladesh. The costs of market development and penetration, including investment subsidies, are covered by public budgets including Official Development Assistance (ODA). The private sector is invited to execute the functions of construction and maintenance and finance under strict quality standards. This approach allows many companies and (micro-) finance institutes to enter the market, as the overall promotional costs are being paid by the programme.

The results of this approach in Nepal and Viet-Nam are very encouraging. In Nepal, about 60 private companies and over 100 MFIs are involved in the Biogas Support Programme (BSP). The companies are the drivers behind the successful dissemination of domestic biogas throughout the country.

In Viet-Nam, about 300 Biogas Construction Teams (BCTs) have been established in 12 provinces covered by the 1st phase of the programme. Besides construction and maintenance, these teams play also an important role in the collection of demand. They have been operating so far on an informal basis, but are to be transformed in legal entities during the 2nd phase of the programme.

3. Sector development: the Biogas Programme in Viet-Nam

The overall objective of the Biogas Programme in Viet-Nam is to further develop the commercial and structural deployment of biogas, establish a robust framework for domestic biogas dissemination at national as well as provincial level.

The biogas programme in Viet-Nam takes place in a country where the technology already existed, and a "scattered" market was established. Different domestic biogas digester programmes have been implemented in Viet-Nam over the past 50 years, but none have aimed at large scale dissemination or long term operational success, despite the fact that conditions in Viet-Nam are favourable for biogas and that people are interested in the technology because of the obvious benefits that biogas can provide.

Against this background, the Vietnamese and Netherlands Governments agreed on the implementation of a domestic biogas dissemination project in January 2003. The first phase was successfully completed in January 2006 with 18,000 plants. In 2006, the programme expanded from 12 to 20 provinces and increased the number of installations with another 9,000; by December 2007, the programme took place in 25 provinces, and in total more than 41,000 plants were constructed.

The planning up to 2011 is to cover virtually all provinces and facilitate the construction of 150,000 plants, which will provide 800,000 people (on average 5 to 6 persons per household) with improved energy services.

Table 1 Outputs Biogas Programme Viet-Nam period 2003 to December 2007

Constructed biogas plants	41,000
Number of Provinces	25
Savings on workload household	1 to 1.5 hours per day
Savings of fuel household	5 Euro per month
Rural job creation for masons	450,000 labour days
Income masons	2,5 Euro per day
Turnover biodigester market	9 mln Euro
Sanitation	40% of toilets attached to digester

Ambitious targets and the need for sector development

Even though the current results in Viet-Nam may sound impressive and successful, the actual goal is to establish a biogas sector in which all services, as reflected in Figure 1, are self perpetuated by incentives from the public and private sector. Those services sustain the continuation of construction, quality management, promotion, extension and finance for the costumers, constructors and the programme. In other words, the programme aims at laying the foundation with a focus from 150,000 to 1,000,000[13] biogas digesters on the longer run.

Increasing numbers of construction and widening of geographical scope have, in practise, much more consequences than just multiplying the business as usual by a certain factor. At central level, control decreases drastically, routine work, management and coordination demands are stressed far beyond the available human capacities. This situation asks for solution which can be sought in costly increase of staff members, and/or extreme overwork, denying weekends and holidays. Or solutions can be sought

[13] It is estimated that the potential market for domestic biodigesters in Vietnam is 1,000,000.

in the framework of decentralisation and outsourcing of services. Considering the limits of the programme's budget and physical endurance it does little convincing to agree that the only way forward is to create partnerships and arrangements with other actors. And in doing so, the programme heads for a sector approach.

With reference to the services and functions of Figure 1 and the barriers as described in the GNESD report, the developments that take place in Viet-Nam to create the fundaments for a sector are described in the next sections.

Training

Take the training component for instance. In past years the programme on central level managed to provide high quality training to different actors. However, In the coming three years many more dozens of civil servants, hundreds of masons and tens of thousands of households, living throughout the country, need to be trained each year. In total, 6,500 training programmes need to be provided for more than 200,000 people. To meet these training needs in a nation that stretches 2,000 km, the programme has signed an agreement with vocational training schools in the North, Central and the South, to take over these services. Even though capacitating these institutes requires even more efforts on the short term, in the future it will prove to be vital in meeting the goals of the programme. Especially when schools integrate biogas trainings in their regular curriculum, this will secure vocational training capacities after the programme will end.

Construction and sales

The core of the primary process is in the commercial transaction between the (prospective) biogas household and the Biogas Construction Enterprise, in which both parties aim to maximize their returns. The first party by demanding the best possible service level at the lowest possible costs, the latter aiming for high profit and future market penetration. In this process, the importance of the quality of domestic biogas cannot be overstated. Particularly in a rural setting, a household that is satisfied with the benefits of a biogas plant is by far the most powerful promotional tool for the technology (SNV/Winrock, 2007).

During the SNV Biogas Practise conference on market development in Phnom Penh, November 2007, lessons from various countries showed that biodigester is not a typical product for the free market that can be led by the 'invisible hand'. The private sector alone has failed to disseminate domestic biogas at a large-scale; it seems that this market is too difficult and risky to develop. Reasons for this are the nature of the product itself that does not inhibit potential advantages of economy of scale, nor would rural households be able, nor willing to pay for higher margins. Another consideration is that after having reaped the 'low hanging fruits', meaning households that can easily afford a biodigester, constructors have to operate in lower market segments for which a 200 Euro investment is considerable, and moreover that is found in difficult and remote terrains.

The conclusions of an ADB-financed national biogas market study in 2007 are that constructors indeed have more difficulty finding new clients. Therefore the programme is going to facilitate trainings on business skills and marketing to increase awareness and capacities. So far these activities are still in the hands of the programme but will increasingly fall on the shoulders of the constructors. The purpose of this is to secure a lasting supply of high quality domestic biodigesters.

Micro credit

Another response by the programme to facilitate the market is to link up with existing micro-finance organisations to make the investment of biodigesters affordable for a bigger number of (poorer) households. A Dutch development finance institution (FMO)-financed survey in 2006 showed that there is an abundance of micro-finance facilities in rural Viet-Nam, however to get access seems not easy. Partnerships are explored with preferable market oriented MFIs that can help to ease access to finance and increase the market for biodigesters.

Governmental roles and contributions
As mentioned before, the use of biodigesters serves both private and public purposes, so it is both a private and a public good. Therefore, support by the government is justified, not only in providing a conducive environment but also to commit itself to in-kind and financial contributions.

The biogas programme in Viet-Nam has been initially financed by Overseas Development Assistance (ODA) from the government of the Netherlands, however the government of Viet-Nam accounts for an increasing share of the costs. Helped by a successful implementation record of previous years, the winning of the Energy Globe Award in 2006 and the obvious benefits the programme delivers, provincial governments are already contributing to half of the implementation costs.

Another positive development is that biodigester technology is increasingly mentioned in various policy documents as most feasible renewable energy source in Viet-Nam.

The way forward
Commercialisation and development of businesses on domestic biogas has proved to be successful in Nepal and Viet-Nam, and emerges as well in Bangladesh and Cambodia, whereas in Laos progress is still modest. The combination of investment subsidy for the customer coupled with strict enforcement of quality control is required to establish product reliability being indispensable for market penetration. At the other side, it may take away the incentive for individual private companies to increase their market share through market and/or product development.

Furthermore, sector development requires a long-term engagement and can not be achieved through quick wins. This requires that external financial support has to be mobilised for a period of five to ten years, depending on the capability of the private sector in the respective country. Such support is well justified based on the social benefits of the biogas programmes, but may not always be easy to realise.

The lack of financial sustainability at the end of the programme period may be the most challenging risk. Therefore, it is imperative to gradually decrease the dependency on ODA and search for alternative sources like higher contribution of the costumer, heavier involvement of the host country's national and sub-national government or via the opportunities that the Clean Development Mechanism and voluntary carbon markets may provide.

References

Geres 2005, Survey of Plastic Biogas Biodigesters in Cambodia Are Inexpensive Plastic Biodigesters a Reliable Alternative for Concrete Digesters?

GNESD 2007, Renewable Energy Technologies and Poverty Alleviation: Overcoming Barriers and Unlocking Potentials, GNESD 2007

Ho Thi Lan Huong and Le Thi Thoa 2006, Master Plan – Training Component Biogas Project for the Animal Husbandry in Viet-Nam 2007-2011

IEA 2006, Energy Outlook 2006, Chapter 15 Energy for Cooking in Developing Countries

Nes, van W 2006 Asia Hits the Gas, Biogas From Anaerobic Digestion Rolls Out Across Asia, Renewable Energy World ,Jan/Feb 2006

Nes, van W 2007, Commercialisation and business development in the framework of the Asia Biogas Programme, paper Seminar on Policy options for expansion of community-driven energy service provision, Beijing, China, 2007

Programme Evaluation Organisation Planning Commission Government of India 2002, Evaluation Study On National Project on Biogas Development.

SNV/Winrock 2007, Contours of a national domestic biogas programme for Pakistan.

REGIONAL FORUM ON BIOENERGY: CONCLUSIONS AND RECOMMENDATIONS

Agriculture and rural development strategies are a critical component of an inclusive growth strategy for Asia and the Pacific region. In particular, the production and use of bioenergy in its modern forms can have a major and positive impact on agricultural development and the environment. It could have a profound influence in many rural areas of developing countries.

The world biofuels production is on a sharp rise since 2000. However, the impact of producing biofuels on food security due to potential change in land use and switch in plantation of agricultural crops should be carefully assessed by policy-makers. Furthermore, the processing and conversion technology of bioenergy production is another important aspect to be considered. Future bioenergy technologies may have to rely on dedicated energy crops and agricultural and timber wastes instead of food crops. Second generation technologies of bioenergy production and processing could potentially make a higher contribution to energy security and climate change mitigation.

Bioenergy development must therefore take into account the full spectrum of agricultural, ecological, and socio-economic issues, such as food and energy security, impacts on environmental and ecological systems, and overall improvements in the well-being of the farmers and other stakeholders.

Conclusions Presented by the Expert Participants

In view of the forecasted shortages and surging prices of fossil fuels, climate change and global warming, and the need for income and employment opportunities in rural areas, bioenergy has become an important priority for the Asia and the Pacific (AP) region. The production and use of bioenergy (bioethanol, biodiesel, biogas, and biomass) have entered a new era of green growth areas, with both the scale of the industry and the number of countries involved reaching unprecedented levels. Underlying the growing commitment of governments to bioenergy development is the desire to find new markets for farmers and their products and to reduce emissions of carbon dioxide and other gases that contribute to global warming. The major conclusions of the Regional Forum are summarized as follows:

Production and application potential of bioenergy

- Many countries in the AP region are endowed with rich agricultural and forest resources that are generating wastes and residues. These could be transformed into bioenergy production for industrial, household or community use and consumption.

- Many countries in the AP region have high potential for production of biofuels from feedstock such as corn, sugarcane, cassava, physic nut (*jatropha carcus*), coconut, oil palm, etc. However, there are issues and concerns that make the future production of biofuels difficult to ascertain. These issues include:

- Uncertainty of the market for biofuels;
- Pricing of biofuels in the domestic and global market;
- Security of feedstock supply;
- Cost of production;
- Environmental concerns;
- Food shortage leading to ag-inflation (i.e. food price inflation);
- Competition with other uses of biomass;
- Long-term climate impact (e.g., on resource-base and water supply).

- Although the estimates of the potential of biofuel production from existing feedstocks vary along with different studies and sources, there is a general acceptance that a substantial portion of the transportation fuel demand of the world could be substituted by biofuels if the trend for biofuel production is maintained. For instance, it was reported in the Forum that if all unused arable lands are cultivated for biofuel feedstock, a significant portion of the fuel transportation demand of the world could be covered.

- South Asia can provide a considerable amount of biofuels demanded by North Asia or EU at low costs, while North-East Asia or EU can offer advanced technologies and finances to improve the economics of biofuels in South and South-East Asia.

- Rapid increases of investments in the plantations in Southeast Asian countries have been observed. Recently, many companies from EU, China, ROK, Japan, etc. began to invest in the production of Jatropha, oil palm, coconut, cassava, etc.

- Owing to food security issues, the existing biofuel programmes have focused on non-edible tree based oilseeds – Jatropha, Pongamia, etc. Concerted research efforts should be directed to producing ethanol from ligno-cellulosic materials such as bagasse, rice straw, etc., as the next generation biomass feedstocks.

Expansion of support policy scope

- The lack of a comprehensive legal framework for the production and use of bioenergy has led to a slower response in the large-scale market of bioenergy technologies. For smooth implementation of the bioenergy programme, policies should be supported by legal enactments that promote, sustain and cover all aspects of bioenergy production and consumption.

- Adequate polices to promote bioenergy and encourage potential project developers to implement them should cover provisions such as:
    - Fiscal incentives, such as tax holidays, reduction in import tariff rates, etc.;
    - Adequate regulations on access and pricing for sales of electricity to the grid;
    - Targets that are reflected in the Power Development Plans;
    - Bioenergy or renewable energy quotas for utilities.

- Current subsidies for bioenergy production are related to time-bound projects or programmes.

In order to give medium- and long-term investment guarantees, specific actions that governments can take to expedite the transition include:

- Provision of various incentives and support: Preferential tax revenue policy, low-interest, long-term loans and risk guarantees.
- Enactment of mandates, such as blending mandate. Mandates should also be tied to environmental and social standards.
- Support to farmers: Access to information, crop and equipment assistance, market access.
- Funding of R&D and demonstration projects: Sustainable/next-generation feedstocks, flexible-fuel vehicle (FFV) technology.

- Cases of monetary incentives:
  - The most general incentive mechanism in the EU and the USA is the exemption of excise tax, investment tax, income tax, fuel tax, or environmental (carbon) tax.
  - Agricultural subsidy on the farmers who cultivate feedstocks for biofuels is common in EU.
  - ROK has started to offer agricultural subsidy in 2007, referred to as landscape conservation subsidy, to the production of rapeseed for biodiesel.

Strengthening national/regional R&D and demonstration activities

- Research is needed to develop feedstocks and sustainable management practices that reduce pressure on farmland and on food security, as well as technologies for harvesting, processing, transporting, and storing of feedstock and fuels. Future R&D should be aimed at appropriate sizing of the technology according to the required application, cost reduction and improving overall efficiencies.

- In order to achieve the development goal of the bioenergy sector, there is a need to strengthen technology R&D in the following aspects:
  - Improvement of conventional feedstock: Selection and cultivation of new species of energy crops with optimized yield and high adaptability.
  - Highly efficient processing and conversion technologies and equipment for different resource species: Use of biomass in low carbon technologies.
  - Development of next-generation feedstock: Introduction of biofuels from micro/macro algae and BTL (Biomass to Liquid), which can relieve concerns over the tradeoffs on agricultural market, food security, biodiversity, and GHG emissions from deforestation.
  - Exploration of various biofuel crops such as non-edible oil seed crops and root crops through regional research and development cooperation.

- Demonstration and field trials should be extended towards the entire process chain from the cultivation of various energy crops and biomass to the production of biofuels, in order to develop biofuel production on a large scale:

  - Establish biofuel demonstration bases using different raw materials in different regions, including harvest, transportation and storage facilities.

- Biofuels for agricultural machinery and vehicles; Rural community-based biofuel production and consumption can enhance rural economy and environment. It can also lower the production cost of biofuels by reducing delivery cost of biofuels and feedstock.
  - Biofuels for boilers and power plants do not require high standards compared to biofuels for transportation. North-East Asian countries have restrictions on the use of tropical feedstocks as biofuels, since the cold filter plug point (CFPP) of tropical feedstock does not satisfy the requirement for transportation fuel standards in those countries.

Bioenergy market development

- A market-oriented approach should be adopted to promote widespread dissemination and implementation of bioenergy through actions such as more accessible financing, public-private partnerships, improvement of infrastructure and logistics related to transport and supply of biomass residues, and other relevant support policies.

- Successful application and operation of industrial and domestic biogas technologies exist in some countries of Asia and the Pacific. Programmes on domestic biogas development have shown positive social and economic impacts in China, Nepal, and Viet Nam. The issues and challenges that should be addressed for a successful sector development and further utilization in other countries include: Training of local participants, creation of a workable business model between the technology providers and users, linking up with existing micro-finance institutions, and public sector role and contributions.

- The most efficient way to hasten a rapid expansion of bioenergy production is for governments to encourage and support private sector investment in bioenergy sector development. Policy-makers should focus on creating a predictable and growing market for bioenergy. Policy actions that governments can pursue to help develop the market include:
  - Enact tax incentives: Tax incentives have been used effectively in Brazil, Germany, the United States and other countries to spur bioenergy production and reduce bioenergy prices, to encourage certain types of bioenergy development (i.e. small-scale, community-based), and to speed up the adoption of biofuel-compatible vehicles and other infrastructure.
  - Use government purchasing power: Government purchasing of vehicles and fuels that are certified under sustainability schemes could provide a powerful market driver. Local governments can switch entire fleets to vehicles run by biofuels.
  - Collaborate to set international fuel quality standards: In order to develop a significant international biofuel market, the quality standards of biofuels need to be agreed upon and enforced at the international level. This is necessary for the expansion of international trade in biofuels.
  - Facilitate Public-Private Partnerships (PPP): PPPs have resulted in important technological breakthroughs that have led to dramatic cost reductions and will continue to have an important role in advancing next-generation technologies.

Cooperation in the international know-how exchange

- Cooperation with developed countries and companies that have successful experience in bioenergy production will speed up the development of the bioenergy sector in Asia and the Pacific.

- Introduce advanced technologies in bioenergy production, especially in biogas and biofuels through clean technology transfer among countries in Asia and between Asia and EU (SNV, GTZ). For example, the biodiesel technology developed by the Malaysian Palm Oil Board (MPOB) and has been successfully tested using palm oil in Malaysia could be adopted by countries like Thailand and Indonesia. Similarly, the food waste treatment facility developed by Nanyang Technological University (NUS) of Singapore could be introduced to other Asian countries.
- ERU (Emission Reduction Unit) from JI (Joint Implementation): Developed countries producing biofuels using domestic feedstocks may apply for JI.
- CER (Certified Emissions Reduction) from CDM (Clean Development Mechanism): Developing countries producing biofuels using domestic feedstocks may apply for CDM projects.

- The following are some opportunities for Asia-Pacific Regional Cooperation:
    - Biofuel resources and technology management, and strategy development;
    - Biomass resource assessment and management;
    - Biomass stoves for diverse applications in rural areas, e.g. households, restaurants, schools;
    - Service company management and training;
    - South-South technology transfer;
    - Carbon financing and regional programmes on CDM.

Possible negative impacts of biofuels production

- Threat to biodiversity: Burning tropical forest to clear lands for planting biofuel feedstock (e.g., plantation) can lead to serious damage to the habitat of endangered species such as Orang-utan. Monotonous cultivation and genetically modified crops can cause significant distortion to biodiversity.

- Unsustainable biofuel production: Use of peat and deforestation in order to extend arable land for biofuels will magnify GHG emissions significantly rather than reduce them.

- Water shortage: Expansion of arable land areas will require more irrigation. Water depletion might occur in the countries producing feedstocks for biofuels.

- Ag-flation (rising costs of agricultural products) and food security: More requirement of land due to the increase in biofuel production leads to shortage of food and inflation in the food market. Exploration of new and unused arable land may overcome the ag-flation phenomenon and food security tradeoff.

- There are risks that there will not be enough biomass residues available as fuel for the lifetime of the biomass energy plants.

Recommendations for the Way Forward

Based on the views presented during the Regional Forum, the following recommendations are put forth with respect to bioenergy sector development:

Sustainable economic development is the right of all countries. The Asia-Pacific region, however, does not need to repeat the pollution practices of other industrializing countries, and must take the path of sustainable development because of the pressures of scarce energy resources and fragile environment. The Asia-Pacific region should look for appropriate policy, strategy, framework, and the way forward for the bioenergy sector development in the region, especially in the aftermath of the United Nations Conference on Climate Change in Bali, December 2007 and in the context of the post-Kyoto framework.

Supportive government policies are essential to the development of bioenergy. Blending mandate, tax incentives, government purchasing policies, electricity feed-in tariffs, and support for infrastructure and technologies have been the most successful in fostering bioenergy production and use. Countries seeking to develop domestic biofuel industries will be able to draw important lessons – both positive and negative – from the leading pioneers of the world: Brazil, the United States, and the European Union.

Financial incentives should be devised for bioenergy to become an alternative source of energy for fossil fuels in the short term. However, due to factors such as the costs of biofuel production, level of fossil fuel taxes, etc., the incentives to be applied should be carefully considered and analyzed.

Outreach/extension: UNESCAP-APCAEM could play a significant role in outreach/extension of information and in closing institutional gaps among countries in the region:

- On the national level, findings need to be disseminated to producers through demonstration projects, extension services, and other farmer education mechanisms, including feedstock demonstration projects. In addition, farmers will need the appropriate know-how, capital, and incentives to risk planting new energy crops and to follow best and innovative practices.
- On the international and regional level, a clearing house is needed to gather and make available to the global community, information regarding relevant findings and successful experiences with bioenergy research and policies.

Strengthening R&D and demonstration: R&D investment in the next generation technologies and clean technology transfer from advanced countries to developing countries should be encouraged, in the following aspects:

- Selection and cultivation of new species of energy crops with optimized yield and high adaptability;
- Highly efficient processing and conversion technology;
- Development of micro/macro algae, BTL (biomass to liquid), and FFV (fuel flex vehicle).

Cooperation in international know-how exchange: Cooperation with countries that have experience in bioenergy, and regional South-South cooperation in terms of technology sharing, best practices and innovative approachs to bioenergy development are necessary to speed up the bioenergy development in the Asia-Pacific region. It is recommended to establish an Asian-Pacific Bioenergy Network (APBN) to facilitate and promote the regional cooperation.

Change of economic development paradigm: For countries, industries and individuals to adopt the Green Growth approach, which emphasizes on achieving rapid economic growth without compromising the environment. This principle is a departure from the conventional idea of purely environmental protection, to a more responsible environmental sustainability. It is a win-win synergy, which allows the economy to grow while promoting environmental sustainability.

* * * * *