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Expert Consultation on Biofuels
(Co-sponsored by APAARI, IRRI, CIMMYT, ICRISAT)

IRRI, Los Banos, Philippines
27-29 August, 2007

PROCEEDINGS

Asia-Pacific Association of Agricultural Research Institutions (APAARI)
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I. Rationale and Objectives

The debate on biofuels has reached presidential and prime Ministerial offices and the editorial columns of major dailies. Unfortunately, in comparison with other major policy issues, there have been relatively few biofuel studies in developing countries. Thus, NARES leaders and executives have relatively few studies and no long-term experience with the implementation of biofuel policies. Moreover, the pace of technological development is staggering, as public-and private-sector investments in first-and second- generation biofuel technologies are increasing rapidly.

What this all means for food security, land and water use, poverty and rural economic growth is virtually unknown. For this reason, the Third GFAR Conference convened in New Delhi in November 2006 to tackle this topic. To bring inputs to the discussions, CIMMYT and IFPRI with ICRISAT convened a GFAR and APAARI International Workshop on Bioethanol Opportunities and Risks immediately preceding the GFAR Conference. Recommendations were 1) to strengthen relevant crop improvement and crop management research; 2) undertake assessment studies and; 3) create mechanisms for knowledge sharing. Because of the prominence of the bioethanol and biodiesel debates in Asia, APAARI constituents played an active role in the discussions and the framing of the recommendations. This Expert Consultation responded to the spirit of the GFAR recommendations.

Bioefuel production has doubled in the past 5 years and is likely to double in the next 5 years. Nevertheless, only a tiny fraction of transportation energy needs are met from biofuels. So far, the dominant producers are Brazil and the USA, accounting for 90% of bioethanol production from sugarcane and maize grain, respectively. European countries have so far been the leading producers of biodiesel from oilseed, which accounts for about 10% of biofuels produced. International trade in biofuels has been limited. The diversion of maize grain to bioethanol production and the good investment climate have driven up maize prices, which has flowed over to price increases for other cereals and generally food stuffs as well. in many countries. However, the production, consumption, and trade situation could change dramatically in the coming 5 years. In the Asian region, both China and India are gearing up for substantial investments in biofuels. Malaysia and Indonesia are investing heavily in oil palm plantations for biodiesel production. The Philippines has mandated blending of gasoline with 5% biofuel. With this fast evolving, complex situation, some key questions arise:

- How can we design integrated, sustainable food-bioenergy production systems?
- Will there be enough cheap food for the poor?

- Will the expansion of feedstocks threaten the remaining tropical forests?
- Will carbon trading foster more sustainable land management?
- Will the biofuel industry mitigate climate change?
- Will poor farmers in developing countries benefit?
- Will consumers gain or lose?
- Will soils deteriorate because less crop residues are returned to the land?
- What bioenergy technologies are most appropriate for what environment?
- Can second-generation technologies be downscaled to farm and village levels?
- Are there useful genes in the international gene banks for improved feedstocks for biofuel production?

The program (Appendix I) of the meting tried to answer the following questions being the main workshop objectives:

- To discuss how bioenergy production may have an impact on global and regional food security and the sustainability of key agricultural systems in Asia
- To summarize current understanding of bioenergy options for key crops and cropping systems in Asia
- To identify key options and research priorities for designing and evaluating integrated food-bioenergy production systems for Asia
- To develop a framework for research on biofuels in key agricultural systems of Asia and agree on follow-up activities, including meetings with public and private sector partners

In all, 44 participants attend the Expert Consultation (Appendix II).

II. Opening Session

The opening session was chaired by Dr. Raj Paroda, Executive Secretary, APAARI. Welcome statements were made by Drs. Robert Zeigler (IRRI), Rodomiro Ortiz (CIMMYT), William Dar (ICRISAT) and Raghunath Ghodake (APAARI) as co-sponsors of the Expert consultation. Dr. Zeigler was pleased to have an impressive gathering of experts, senior NARS leaders, policy makers and representatives of CSOs. He considered this to be an important event and was pleased that IRRI was hosting it. Dr. Ortiz welcomed on behalf of Dr. Masa Iwanaga, Director General, CIMMYT who at the last minute could not make it. For CIMMYT, this was an important event to deliberate on prospects of biofuel research for development, especially relating to wheat and maize. CIMMYT was pleased to have initiated this dialogue earlier in November last year when in collaboration with APAARI and GFAR, a meeting on this subject was held in New Delhi. Dr. Dar highlighted the importance of this meeting and suggested that a "Biofuel Revolution" will take place soon. We must learn from each other's experiences and ensure that our efforts generate International Public Goods (IPGs) for the benefit to resource poor farmers of the Asia-Pacific Region. How can we make a difference and what R&D efforts are needed through involvement of all stakeholders concerned must be clearly understood. Dr. Ghodake was pleased that based on an earlier recommendation of an APAARI meeting on Regional Research Needs, where biofuels were identified as priority area, this expert consultation was organized in joint partnership of IRRI, CIMMYT, and ICRISAT. He stated that biofuels are the need of the hour and we must harness the opportunity to benefit our small farmers in the region, where maximum poverty still resides. However, a balance between food security and income generation through biofuel options must be maintained. He wished that the outcomes of this important meeting will provide clear directions for the future and he was pleased to welcome the delegates on behalf of APAARI.

Dr. Achim Dobermann (IRRI) outlined the workshop objectives and expected outcome of the meeting. He stated that we need to discuss how bioenergy production would have impact on food security, what our current understanding is and what the key options are for R&D in the area of biofuels.

In a keynote presentation on "Tradeoffs between food-poverty-environment and biofuels in Asia," Dr. Rodomiro Ortiz (CIMMYT) summarized the global biofuel challenges. He reviewed the status of major biofuel developments, possible environmental impacts, options of first and second generation technologies, availability of biomass, and crop options. He outlined CIMMYT's role towards biofuel crop options in the developing world as germplasm provider, trait enhancement efforts and role of a facilitator, honest broker and policy analyst for research on fuel for food, feed, fiber and fuel.

Dr. Alok Adholeya of TERI made a presentation on "Biofuels and climate change". He highlighted the possible impacts on greenhouse gases, biodiversity, water availability and deforestation. Both positive and negative impacts of ethanol and biodiesel were highlighted. Biofuel production may result in high inputs of chemical fertilizers, transportation costs, and increased processing costs. Monoculture of Jatropha could lead to loss of biodiversity, but biofuels are also likely to reduce greenhouse gas emissions. Exploiting the potential of biodiesel using Jatropha would require a well organized supply chain of quality planting material and package of practices. He estimated that biodiesel blending could account for 12% of transport fuel by 2030.

Dr. Adam Liska of the University of Nebraska talked on "Life-cycle performance of biofuels", using the example of corn-ethanol production. He presented an approach for determining the potential energy efficiency of high-performing corn-ethanol systems. Best management cropping practices such as optimal water, nutrient use, good soil preparation, planting time, crop density, weed and insect control could lead to achieving around 80-90% of the maize yield potential and thus greatly enhance net energy yield and energy efficiency of corn ethanol systems. Emphasis was laid on use of the BESS life-cycle analysis model software, which can be used for designing, optimizing and analyzing biofuel systems for varying eco-regions. He concluded that by using a combination of more efficient farming practices and technological improvements in the biofuel conversion process maize-ethanol systems compare well with the best biofuel crops such as oilpalm-biodiesel or sugarcane-ethanol, yielding around 5800 L ha^{-1}, whereas, the current average net energy yield of corn-ethanol is only around 3700 L ha^{-1}. He stressed the need for standardized life cycle analysis approaches, including clearly defined metrics. He also emphasized the technical and economic challenges faced by second generation biofuels such as cellulosic ethanol and offered an optimistic scenario for increasing ethanol production from corn in USA.

III. Technical Sessions

Session 1. Global opportunities and constraints

Technical Session on global opportunities was chaired by Dr. Rodomiro Ortiz in which six papers were presented.

Dr. A. Dobermann of IRRI spoke on "Bioenergy from Rice Systems". The main point brought to the attention of the participants by this speaker was that rice grain should not be used for producing biofuels and that the productive lowland rice areas should not be converted to biofuel crops, either. Dr. Dobermann suggested that options for integrated food-bioenergy systems for rice may such as diversifying selected rice landscapes (e.g. biofuel crops in rainfed upland areas, marginal rainfed or irrigated lowland areas unsuitable for rice) or diversify rice cropping systems by growing biofuel crops in rotation with rice are limited. Instead, bioenergy generation from rice husks and rice straw should be pursued. The need for documenting impacts of the biofuel boom on rice was highlighted. Basic research should consider rice breeding for straw traits, optimized conversion technology for rice biomass, and biomass fractionation technology to obtain fiber and biofuel from the rice straw. Small-scale technology for using rice straw and husks, plus harvest and postharvest technology for handling rice biomass sources were indicated among the main applied research undertakings. Other research topics include life cycle and sustainability analysis of rice-bioenergy systems, and determining how rice farmers may benefit from mitigating greenhouse gas emissions through carbon sequestration in lowland systems, and renewable energy credits from biofuel and biochar.

Dr. J. Dixon of CIMMYT presented his paper on "Biofuels, Maize and Wheat – Global to Local". After providing the general context of the energy economy, Dr. Dixon highlighted the current status of maize and wheat ethanol and the potential impacts of second generation ethanol for enhancing farm incomes. The key points of his talk referred to the substantial impacts of first generation biofuels on global crop prices and human nutrition, noting that they depend on the feedstock choice and country. As expected, both opportunities and risks will be brought by biofuels to the livelihoods of Asian farmers and consumers. The potential for farm income increases, employment generation, energy security and affordable energy source were among the main opportunities, whereas the main risk seems to be associated with increased food prices that could lead to lower consumption and therefore poor nutrition. Likewise, he pointed out the changes in land and water use that crop biofuel shifts may bring to the Asian farming systems, e.g. changes in cropping pattern, water resource depletion for intensive irrigated crops such as sugarcane, or soil degradation through expansion in fragile lands, increased monoculture, and reduced return of crop residues to cover soils (if crop biomass used for 2nd generation biofuels), which brought the researchable issues on how much crop residue can be taken out without threatening the system sustainability.

Dr. Belum Reddy of ICRISAT spoke on "Biofuel Crops for Drylands – Sweet Sorghum, *Jatropha* and *Pongamia"*.. Dr. Reddy introduced the BioPower Strategy of ICRISAT that envisages dryland poor to benefit from the bioenergy revolution. This strategy advocates the use of feedstock that does not compete with food sources. The potential of sweet sorghum as raw material for ethanol production was highlighted during this talk. ICRISAT considers the genetic enhancement of sweet sorghum, the extended use of sorghum genetic resources (e.g. brown midrib mutants) and improved crop management practices among the main researchable issues. To complement this research agenda, ICRISAT engages in public-private-people partnerships to ensure the impacts on livelihoods. After highlighting the advantages of the use of lingo-cellulose feedstocks for 2nd generation biofuels, Reddy provided some examples of ongoing bioenergy public-private-people partnerships in which ICRISAT is actively engaged. His talk ended with a quick overview on the potential of *Jatropha* and *Pongamia* for dryland agriculture in India. Among the main researchable issues, he indicated the need to exploit heterosis and specific adaptation in sweet sorghum, the use of molecular breeding tools and new sorghum genetic resources for enhancing sugar traits as well as second generation biofuel. Similarly, the characterization of Jatropha and Pongamia genetic resources, the standardization of their crop management, and the establishment of their seed systems were also regarded as important research topics.

Dr. L. Carvalho of EMBRAPA made a presentation on “Sugarcane Ethanol – the Brazilian Experience”. This talk shared the successful model used by the sugarcane industry in Brazil. After providing some background information, Dr. Carvalho pointed out the policy impact and setup of the Agroenergy National Plan, which guided government’s actions in the bioenergy chain. He pointed out that the success of the sugarcane industry was due to regional investments in breeding programs (now under the private sector), crop management, harvest practices, precision agriculture, and researching crop energy balances and mitigation of greenhouse gas emissions. In his closing remarks on sugarcane, Carvalho highlighted the social development model that benefited from the tropical location, suitable crop land availability, appropriate water resources for irrigation, natural resources for bioenergy use, scientific and technological capacity coupled with infrastructure, and an attitude towards both a sustainable environment and agribusiness. His talk ended with some information about a new EMBRAPA research breakthrough: sweet cassava, i.e., new sugary cassava clones with sugar content above the best available sugarcane cultivars grown in Brazil, which may provide a new biofuel source worldwide.

Dr. V.K. Gour of J.N. Agricultural. University, India spoke on “Jathropha for Biodiesel”. Dr. Gour provided an overview on the available knowledge about Jatropha in Asia. The status of Jatropha research was highlighted as well as the main factors affecting Jathropa growth and yield. This talk also gave some results from research in India and what institutes are researching on this tree species. He warned about diverting arable land for Jatropha cultivation and indicated some details about the plant growth, plantation systems, plant husbandry, potential use of wasteland for this tree, and the quality of planting material needed. The major researchable activity seems to be breeding for new cultivars with high seed yield per unit area and time with high quantity and quality oil suitable for various agro-ecozones. In this regard, the main idiotype traits were indicated.

Prof. C. Menke, JGSEE, Thailand made his presentation on “Straw – Overall Potential, Possibilities and Challenges on Conversion to Bioenergy”. After introductory remarks that included references to agriculture, straw and climate change, Dr. Menke explained the overall potential of straw residue for bioenergy, drawing examples from rice and wheat. He highlighted energy conversion technologies such as thermal- and bio-conversion, and the remaining challenges in energy conversion. Thermal conversion techniques include combustion, pyrolysis and gasification, whereas biomethanation (or biogas), and acid hydrolysis followed by fermentation were given as examples of bio-conversion. This talk ended with a comparative assessment among technology options for bioenergy conversion. It appears that rice straw could be an important bioenergy source. Rice straw combustion is already being commercialized in countries such as India and China, but many questions remain to be resolved with regards to the logistics of feedstock supply and avoiding common problems such as slagging in the combustion process.

Dr. R. Buresh of IRRI presented his paper on "Implications of Straw Removal on Soil Fertility and Sustainability". The speaker summarized the current knowledge of crop residue management in key cereal systems relevant to Asia: a) wheat and maize (upland crops), b) lowland rice, and c) lowland rice-upland crop rotations. Using information and data provided by Ken Sayre (CIMMYT) from long-term trials held in a rainfed environment in Mexico, he concluded that retention of crop residues is important for sustaining high productivity in rainfed and irrigated upland crop rotations. Furthermore, with zero-till, retention of crop residues is essential, and partial residue removal is feasible with permanent beds. Using data from a long-term conducted by IRRI, Dr. Buresh demonstrated that soil sub-emergence helps maintaining soil fertility in continuous lowland rice cropping with 2 or 3 rice crops per year and only short dry periods (likely through C and N input from biological activity and nitrogen fixation). He warned that incorporation of rice residues in such cropping systems can in fact have detrimental effects because of the initial immobilization of soil N, reduced Zn availability, and increased methane emissions. Hence, retention of rice residues is not essential for sustaining high productivity in continuous rice systems with long periods of flooding, provided fertilizers are applied to balance nutrient off take with residue. His talk ended with an assessment of lowland rice-upland crop rotations using examples from wheat-rice in Jiangsu, China and maize-rice at Los Baños, as well as rice residues before upland crop using data from rice-wheat farming in Punjab, India. Retention of incorporated residues did not prevent loss of soil C when converting continuous rice to rice-maize cropping under full-tillage. However, reduced tillage with retention of rice residue might be merited in such cropping shift. A moderate amount of wheat residue before rice cropping may lead to short-term negative effects due to N. immobilization, but a potential slight net N contribution to rice. Nonetheless, it does not seem to increase rice yield in the short term when fertilization is balanced. Large quantities of maize residues before rice cropping may have negative short-term effects due to N immobilization and reduced seedling vigor. In such rotation systems, there are no short-term savings in N fertilizer, neither does rice yield increase when the fertilization is balanced. Finally, when incorporating rice residues before the wheat planting in the intensive systems of the Indo-Ganges, neither short term saving of N fertilizer nor wheat yield increases under balanced fertilization were observed. However, retaining rice residues in the surface (rather than incorporating them) before the upland crop may be important for sustaining high productivity. The table shown below summarizes in what systems crop residues can be removed without threatening long-term sustainability:

System	Residue	Potential for removal	Portion for removal
Triple rice	Rice	Yes	All
Double rice	Rice	Yes	All
Upland crop before lowland rice	Maize Wheat (China)	Yes Yes	All All

Rice-wheat	Rice (India)	Limited	?
Rice-maize	Rice	Limited	Partial, straw
Sole upland crop	Maize and wheat	Limited	Partial with beds

This technical session provided clear information on the status of bioenergy options for key crops and cropping systems in Asia. Such inputs could assist in further research priority setting and in developing a framework for food-bioenergy systems for Asia.

Session II. Country status reports

This Session was Chaired by Dr. Achim Dobermann in which three country status reports were presented. Dr. Murari Shyam of ICAR, India began his overview by summarizing recent policy decision on bioenergy and biofuels in India. He reported that a National biofuels policy may be declared shortly, targeting petrol replacements of 5% by 2012, 10% by 2017, and 20% beyond 2017. The Government of India may make E5 mandatory with immediate effect in 2007 and is also considering raising this level to 10% from October 2008. Current ethanol production is about 1.5 billion L, but the installed production capacity is already at more than 3.2 billion L.
Key components of the current GOI strategy for bioethanol include:

- Declare National Biofuel Policy up to 2020: set blending targets in phases; GOI/State Govts. define tax incentives; Use of feed material is made flexible; Blending ratio may vary depending upon availability of raw material
- Minimum price for bioethanol be declared along with the price of sugarcane every year.
- Lift inter-state ban on movement of feed & bioethanol
- Provision of incentives for setting up modern economic size distilleries
- Incentives for bagasse cogeneration (616 MW; Pot. 5000 MW) & biomethanation of effluent
- Integration of distilleries with sugar mills: more than 35% distilleries are stand alone
- Provision of incentive for modern economic size distillery
- Flexibility in use of raw material

Dr. Shyam highlighted that the widespread burning of crop residues in India represent both great concerns and a great opportunity. Hence, second generation biofuel technologies are seen as an important invest area, but it will take at least 10 years until commercially viable solutions may be available. He then summarized the status of R&D on biodiesel crops. Many investigations have been carried out during last 2 decades. Aspects being investigated are production and byproduct utilization of the available plant oils and operation of stationary & automobile engines using blends. Pilot projects for biodiesel are under operation and a major program for promotion of biodiesel has been finalized and shall be launched shortly. A national network on Jatropha has been set up and numerous demo projects for promotion of Jatropha cultivation in forest & non-forest wastelands has been implemented. It is hoped that 13 MT of biodiesel may be produced by 2013, including the cultivation of Jatropha and Pongamia on upt o 11 MHa of unsued land. Dr. Shyam listed numerous examples of commercial biodiesel project that have been established recently. He concluded by suggesting that these activities may help the rural poor and lead to a greening of degraded land that may not affect food/ feed availability in the country, but substantial research on all aspects involved is needed.

Dr.Cheng Xu, China Agricultural University, Beijing presented his country report on China. In 2006, the total volume of modern renewable energy in China reached 180 million tons of coal equivalent, accounting for 7.5% of the nation's consumption of primary energy. Among the different forms of bioenergy, biogas, ethanol and biopower from combustion of biomass are the most widely used forms in China. However, only 0.06% of the tapable bioenergy sources are currently used, indicating large potential for further development of the bioenergy industry in China. In 2004 and for the first time, biomass-based energy from Chinese agriculture became part of the long- and medium-term national programs for science and technology. Major reasons for this included: (1) the importance of increasing peasants' income and revitalizing rural economies through development of bio-energy feedstuff and primary processing *in situ*, (2) providing hundreds of millions peasants' households with clean energy, (3) decreasing the reliance on imported oil and (4) the need to reduce GHG emissions in China. A *Renewable Energy Law* was passed in January 2006. Targets of "Agro-forestry Biomass Engineering" until 2020 inlcude:

1) To process 250 million tons of crop residues, 50m million tons of forestry wastes, and 350 million tons of livestock excrements into non-harmful energy resources.
1. To develop 4.5 million hectares of low quality land into energy crops and establish demonstration enterprises of agro-forestry biomass
2. To reach an annual capacity of biogas-electricity generation of 140 million kwh, and 50 million tons of solid lumped lignin-cellulose materials, so as to improve the energy supply for 40 million peasant households
3. To increase peasants' income by 4 million yuan RMB annually and create 10 million new jobs in agro-forestry biomass enterprises
4. To substitute degradable bio-film for petroleum-based plastic film on about 1.4 million hectares of arable land.
5. To realize annual capacities of 12 million MT equivalent of ethanol, biodiesel, and bio-plastics so as to substitute for 48 million MT of petroleum, and reduce 160 million MT of the discharged CO_2

After providing this background information, Professor Cheng Xu went on to address four critical issues: (1) Bioenergy as a sensitive issue in relation to food security in China; (2) Expanding production of energy crops and the full use of organic residues, (3) Environmental impacts due to the development of bioenergy, and (4) Opportunities for bioenergy in China. He indicated that sound guidelines for bioenergy have not been worked out yet and there is still no broad consensus on the benefits and potential risks associated with developing a large bioenergy industry. He made clear that food security remains the highest priority for Chinese agriculture.

Sweet sorghum in the north of China and cassava (including sweet potato) in the south have shown very promising as practical energy crops, but many technological issues such as prevention of soil erosion, cultivation and pretreatment after harvest are still unsolved. Combustion of rice and wheat is being commercialized already, but technical and logistics problems have not been addressed yet. The central government has allocated several billion yuan RMB to subsidize farmers to build some 50 million biogas ponds by the year of 2030, which would equip one fifth of all peasant's households with their own bioenergy source. Central supply system of biogas through medium and big sized biogas engineering is also promoted.

Prof. Cheng Xu concluded by suggesting that bioenergy is expanding the scope of traditional agronomy and agriculture. To tackle the challenge, agronomists should learn and adopt an inter-disciplinary approach and promote a new field, i.e. biomass engineering.

Mr. H. Layaoen, MMSU, made his presentation on Philippines. Dr. Layaoen summarized recent developments in the Philippines, with an emphasis on sweet sorghum. The Philippine Biofuels Act was signed into law in January 2007, mandating the use of biofuels in engines sold in the Philippines. The immediate target is to reach 5% blending of gasoline with ethanol within 2 years, but some companies are already marketing E10 and E20 fuel. Sweet sorghum work in the Philippines was established with help from ICRISAT in 2004. DOST-PCARRD funds for studying the use of sweet sorghum for ethanol production have been allocated in June 2007. Three ICRISAT cultivars with high juice yield, sugar content and grain yield are now ready for large scale production. Some local varieties with high juice sugar content have also been collected. Collaboration with the private sector on conversion technologies and commercial solutions has started. A seed production and distribution system is being built up. Among the target areas for sweet sorghum are about 1.1 million ha of rainfed rice. In these environments sweet sorghum may be grown after wet season rice, utilizing residual moisture and remaining rainfalls and thus allowing an intensification of these cropping systems. Crop management practices for such rice-sweet sorghum systems are under investigation. First cost assessments in sweet sorghum systems show that about 60-65% of the total production cost is labor. Net income of about $1000 per ha can be realized. Dr. Layaoen concluded that the Philippines is blessed with a climate in which sweet sorghum can be grown throughout the year and planting operations could be staggered to ensure an almost continuous feedstock supply to mills and distillers, thus providing new income and employment opportunities.

Session II1. Food security versus biofuels in Asia

A Panel Discussion on Food Security vs Biofuels in Asia was chaired by Dr. William Dar, Director General, ICRISAT. The keynote paper was presented by Dr. Siwa Msangi of IFRI giving macro level analysis results on “Linkages between agricultural and energy markets: implication for food security”. His key conclusions were:

1. The linkages between agricultural and energy markets are complex. Biofuel trade is small compared to oil and natural grass trade. The value of energy trade is larger than that of agriculture. Use of agricultural crops for biofuels production results in a short term increases in food prices. However, the developing countries may come up with policy adjustments to neutralize the price increase of food commodities. The factors that need to be considered are type of farming, food and energy system, land and water availability, economic growth and energy demands including transport and livestock feedstock needs, blending policies, etc.
2. Using the IMPACT model, various scenarios depending upon the production capacity, main drivers (population and GDP), policy driven blending requirements, etc. were outlined. Depending on the scenario, the percent price changes by 2020 estimated for corn range from +3 to + 20% and for oil seeds from +8 to + 26%. Available calories changes (%) ranged from -8% to (East Asia Pacific Region) to -1.3% (in Latin American countries) for bioethanol and -1.6% (East Africa Pacific Region) to -2.7% (Sub-Saharan Africa) for biodiesel expansion. Thus, biofuel expansion will lead to increased pressure on agriculture, which calls for greater investment in crop breeding and crop management R&D for higher productivity.

3. Impacts of global biofuel development on the rural poor are likely to be mixed. There is room for synergies and there are common sets of conditions for enhancing rural growth and biofuel capacity. However, the core business should stay focused on rural development.

Five panel members also provided their views in this important session. Dr. Nawab Ali (ICAR, India) emphasized that food security should be given priority. However crops such as sweet sorghum which has fuel, food and feed uses should receive major attention for research and commercialization of its ethanol based technology. Further, after meeting the livestock feed needs, crop residues may be diverted to biofuel production. Varietal development and crop management practices should be given priority before investing in Jatropha and Pongamia plantations on large scale. Dr. M. E. Tusneem (PARC, Pakistan) indicated that, to meet the biofuels needs, research on productivity increases including water and the soil either through genetic enhancement and/or crop management is required to produce enough feed stocks in an affordable manner. He emphasized further to take advantage of cellulosic technology. International centers should provide the platform to enable NARS to have access to various processes, enzymes and microorganisms that are locked-up at present in private sector hands because of patents. Dr. Kenji Iiyama (JIRCAS, Japan) emphasized the need to exploit the biomass of low-lignin plants such as seaweed and high biomass producing species such as napier grass and silver grass to produce bioethanol. He outlined the steps involved in cellulosic technology. Mr Jan Poulisse (FAO) emphasized the need to go for large scale operations in biofuel production as it has edge over small scale production. He said further biofuel production accelerates commercialization and the intensification of agriculture. Therefore; greater attention needs to be paid to the research on biofuel crops. The impact on food security, he said can also be minimized by adjusting diets in many developed countries. Dr. Ajit Maru (GFAR) called for caution on reporting the results of biofuel crops research and their impacts on livelihood and incomes. Considering food security he suggested that food crops grain should not be diverted to biofuel production. Biomass cellulosic technology should be exploited for biofuel purpose.

Following the panel member's presentation, Drs. Raghunath Ghodake, Rodomiro Ortiz, Alok Adholeya, Raj Paroda, and Adam Liska participated in the general discussion. Points made were: 1. Since the globalization of trade is effective, one need not think locally about ill effects, if any of the food crops utilization in biofuel production. (2) However, there is need to look at the type of feedstock, biofuel, and technology, and the scale of operation based on individual country needs; and Brazil should be taken as the model in formulating international policies. (3) The biofuel production is the need of the hour and it's revolution offers challenges and opportunities for the betterment of the people and national economies. (4) Research on increasing crop yields through genetic enhancement and improved management is vital for increasing the productivity of agricultural systems to meet newly emerging demands. (5) Research should not only address liquid biofuels, but also bioenergy technologies such as combustion (6) The research strategy should aim at exploiting synergies and complementarities of the traits related to bioenergy and food/field aspects.

The chairperson, Dr. William Dar summed up the proceedings of the sessions as follows: For the Asia-Pacific Region it is essential for us to be part of the bioenergy revolution and work together united in a way that helps enhance the incomes of smallholder farmers and the poor while contributing food and nutritional security and enabling better environmental protection; otherwise the poor and smallholder farmers will be further marginalized and cannot share the benefits of this bioenergy revolution. Further he stressed that the pro-poor bioenergy research, development and the technology access and dissemination strategy should draw upon the strengths of local agro climatic conditions, drivers of the nation`s economy and the government policies and if required, the strategy should include efforts to influence policy environment in favor of this pro-poor bioenergy strategy.

IV. Plenary Session on General Recommendations

The Plenary Session was chaired by Dr. Raghunath Ghodake, Chairman, APAARI.

Three workgroups discussed different bioenergy technologies in more detail, and their analysis on various issues are given in Annex III. Recommendations emerging from the group discussions were:

Group I: Bioenergy from thermal conversion of biomass

- Thermal conversion technologies that focus on straw and other unutilized biomass that can be safely removed have less impact on food security and the environment than many other bioenergy technologies.
- The principles of thermal conversion technologies are well understood, but these technologies have not been optimized yet for utilizing straw available in smallholder agriculture, particularly rice straw.
- The technical problems at the boiler or gasifier level are small relative to the managerial and logistics problems associated with the feedstock supply chain.
- Big scale production of bioenergy: concentrate R&D on optimizing systems for straw combustion.
- Small scale production of bioenergy: concentrate R&D on optimizing pyrolysis solutions for decentralized production of charcoal and/or bio-oil that minimize transport and pre-processing of straw as the primary feedstock.
- Asian countries should become leaders in these technologies.

Group II: Ethanol from sugar, starch or cellulose biomass

- Sweet sorghum has great potential to produce ethanol at a village scale, but needs further research and development for harvesting, storage, processing, including crop productivity and soil fertility/carbon balance in different regions. China will lead the large-scale implementation of this crop in the near future.
- Standardized life-cycle assessment methods need to be developed to compare all ethanol feedstocks (sweet sorghum, maize grain ethanol, sugarcane, cassava, lignocellulosic biomass) using the same criteria to determine (1) energy balance, and (2) greenhouse gas balance. International organizations need to oversee standardized analysis. This methodology will allow to evaluate and fine-tune existing and potential systems.

- Lignocellulosic ethanol technology is developing in the private sector. Profitable conversion technologies are 10-15 yrs away, and international mechanisms are needed to transfer this technology to the public sector.
- Country-level meetings should be held to develop action plans suited for individual agro-climatic conditions, including supporting policy environment for the industry.

Group III: Biodiesel from oil crops

- Countries need to prioritize research investments for particular crops and align research with national agendas and priorities for better use of research findings
- Share available knowledge and resources in the region, with APAARI and international centers/organizations playing a key role in bring different players together.
- Provide better, unbiased information on the potential and constraints for developing biodiesel systems to policy makers, including analysis of their sustainability and environmental and socioeconomic impact – and including the uncertainties, where information is simply not known, related to different feedstocks
- APAARI should commission a detailed review of Jatropha by a group of experts to come up with R & D issues, potentials and also the uncertainties.
- Experiences on biodiesel from coconut oil in the Pacific region should be summarized with the help of APAARI.

General Recommendations:

1. The Bioenergy Revolution is fast approaching. Biofuels will play a major role in the global economy of the future. Many countries are exploring different strategies and policies on alternative energy sources; and the Asia-Pacific region, in particular, is expected to play a significant role in development and promotion of biofuels.
2. Poverty is still widespread in Asia. It is not clear to what extent poor farmers will benefit from the Bioenergy Revolution. What is clear is that the introduction and/or expansion of biofuel crops will cause major land use changes, and that many feedstocks (although originally targeted at marginal lands) will compete with food crops in productive eco-regions. The challenge is to ensure a balance between food and biofuel production.
3. Policy makers need to protect the poor from rising commodity prices likely to be triggered by diversion of crop produce or area expansion of biofuel crops. Therefore, there is an urgent need to strengthen policy research in order to avoid decisions that may lead to competition between food and bioenergy; and identify a complementary approach that benefits both sectors.
4. International organizations and the International Agricultural Research Centers (IARCs) must accelerate their biofuel-related research in order to generate much needed International Public Goods (IPGs) that will benefit resource-poor farmers. They also need to enhance regional coordination of R&D efforts on bioenergy in the Asia-Pacific region; encourage regional information sharing; and facilitate research networking and capacity building of NARS.
5. Public sector research needs to ensure that technology advances made in the private sector ultimately benefit the poor in the developing world. This is particularly important for many second generation biofuel technologies, which for want of proper policies and IPR regime, may not be accessible to poor farmers in Asia. Public-private partnerships, being the key factor, will have to be established and promoted.

6. It is critical that scientists examine and share unbiased information on the life cycle performance and economics of bioenergy technologies, and their impact on food security and poverty. The social and environmental impacts of these technologies will also have to be assessed. This requires a standardized typology of food-feed-fiber-energy producing agricultural systems as well as standardized methodologies for their integrated assessment.
7. Asian countries should consider utilization of crop residues, especially rice and wheat straw, which are largely being burnt in most countries. This is a priority area for R&D, particularly with regard to thermal conversion technologies for different scales and the level of residue retention which may be needed for sustainable land use under different cropping systems.
8. Potential biofuel producing countries in Asia should conduct their own national assessments critically and devise appropriate strategies to meet long-term bioenergy goals. APAARI and other regional/global organizations should devise strategies for the Bioenergy Revolution, and sensitize policy makers so that countries in the Asia-Pacific can reap the expected benefits.
9. The donor community should fund new R&D efforts on bioenergy, since the long-run benefits will lead to both poverty alleviation and protection of environment – thus meeting the two of the major Millennium Development Goals.

APPENDICES

1. Program
2. List of Participants
3. Workgroup outputs

APPENDIX I: PROGRAM

August 27, 2007 (Monday)

Opening Session *(Chaiperson: Dr. Raj Paroda)*

08:00-08:30	Registration	
08:30-08:50	Welcome statements	
	IRRI	Dr. Robert S. Zeigler
	CIMMYT	Dr. Rodomiro Ortiz
	ICRISAT	Dr. William Dar
	APAARI	Dr. Raghunath Ghodake
08:50-09:00	Workshop objectives and logistics	Dr. Achim Dobermann
09:00-09:45	Should energy be a product of 21st century agriculture in developing countries	Dr. Rodomiro Ortiz
09:45-10:15	Coffee break and photo session	
10:15-11:00	Biofuels and global climate change	Dr. Alok Adholeya, TERI
11:00-11:45	Life-cycle performance of biofuels	Dr. Adam Liska University of Nebraska
11:45-12:00	General discussion	
12:00-13:00	Lunch	

Technical Session I: **Global opportunities and constraints** (*Chairperson: Dr. Rodomiro Ortiz)*

13:00-13:30	Rice	Dr. Achim Dobermann, IRRI
13:30-14:00	Wheat and maize	Dr. John Dixon, CIMMYT
14:00-14:30	Biofuel crops for dry lands: Sweet sorghum, jatropha and pongamia	Dr. Belum Reddy, ICRISAT
14:30-15:00	Sugarcane for ethanol	Dr. Luiz Carvalho, EMBRAPA
15:00-15:30	Jatropha for biodiesel	Dr. V.K. Gour, J.N. Agricultural University
15:30-16:00	Coffee break	
16:00-16:30	Straw conversion to bioenergy	Dr. Christoph Menke, GTZ/JGSEE

16:30-17:00	Implications of straw removal on soil fertility and sustainability	Dr. Roland Buresh, IRRI
17:00-17:30	General discussion	
19:00	Dinner reception	IRRI Guesthouse

August 28, 2007 (Tuesday)

Technical Session II: Country status reports (*Chairperson: Dr. Achim Dobermann)*

08:00-08:30	India	Dr. Murari Shyam, CIAE, ICAR
08:30-09:00	China	Prof. Cheng Xu, CAU
09:00-09:30	Philippines	Dr. Heraldo Layaoen, MMSU
09:30-10:00	General discussion	
10:00-10:15	Coffee break	

Technical Session III: Food security vs biofuels in Asia (*Chairperson: Dr. William D. Dar)*

10:15-11:00	Linkages between agricultural and energy markets: implication for food security	Dr. Siwa Msangi, IFPRI
11:00-12:00	Panel discussion (four panelists):	Dr. Nawab Ali, ICAR Dr. M.E. Tusneem, PARC Dr. Kenji Iiyama, JIRCAS Mr. Jan Poulisse, FAO
12:00-13:00	Lunch	

Technical Session IV: Group discussions on thematic issues

13:00-17:00	Group I:	Thermal conversion of biomass
	Group II:	Ethanol
	Group III:	Biodiesel

August 29, 2007 (Wednesday)

08:00 – 11:30 Field visit

IRRI long-term trials
Sweet sorghum demonstration plot, UPLB
Jatropha demonstration plot, Freshwind Farm, Pila, Laguna

Plenary Session *(Chairperson: Dr. Raghunath Ghodake)*

13:30-14:00	Presentation of Recommendations of Group I
14:00-14:30	Presentation of Recommendations of Group II
14:30-15:00	Presentation of Recommendations of Group III
15:00-15:30	Coffee break
15:30-16:30	Discussion on "Way Forward"
16:30-17:00	Wrap Up and Concluding Remarks

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APPENDIX III: GROUP DISCUSSION OUTPUTS

Group I: Bioenergy from thermal conversion of biomass

K. Iiyama, O. Koyama, J. Poulisse, M. Shyam, C. Menke, Cheng Xu, R. Buresh, S. Haefele, A. Dobermann (chair)

- Combustion of biomass
- Gasification of biomass
- Pyrolysis of biomass
- BTL: Gasification/pyrolysis + liquefaction technologies (not discussed)
- Biogas (not discussed)

Combustion (C), gasification (G), or pyrolysis (P) of biomass

Major target environments in Asia	
Primary target areas	**All:** primarily rural and semi-rural areas of the semi-humid and humid tropics/subtropics integrated industrial facilities with heat/power demand
Key integrated production systems providing feedstock and other products (food-feed-fiber-fuel)	**All:** Rice and/or wheat straw, particularly from intensive systems (double or triple cropping) Maize and/or wheat straw in maize-based systems (single or double cropping) Cassava residues (stems, leaves) Sugarcane leaves, Cotton stems Organic waste in integrated processing facilities (sugar mills – bagasse; oil palm refineries – shells, kernel, bunches; rice mills – husks; coconut shells - charcoal)
Major bioenergy forms produced and their uses	**C:** Heat → electricity **G:** Gas → electricity **P:** Charcoal and bio-oil
Major (sellable) other products for food, feed, fiber, industrial uses	**C:** Fly ash **G:** Fly ash and residual ash **P:** none
Countries in the Asia-Pacific region with major interest and ongoing activities	**C:** Many, including larger plants (India, China) **G and P:** Few
Current national policies in the Asia-Pacific in support of R&D and adoption	**C:** Various types of incentives, tax breaks, investment subsidies; but: lack of support policies for enabling co-firing to improve efficiency (China) **G and P:** not clear, but currently few incentives

Technical issues	
Current status of development, including any recent major breakthroughs	**C and G:** Well known for selected feedstocks (wood, rice husks, etc), but insufficient R&D on adaptation to using crop residues as feedstock in Asia. Problems with those. **P:** Well known for selected feedstocks with emphasis on producing charcoal, but insufficient R&D for straw as feedstock and bio-oil as additional product.
Known applications: centralized (medium to large) or decentralized (small) operations	**C:** Small - large, some straw-powered plants targeting up to 25 MW **G:** Small - medium, up to 1 MW, decentralized **P:** Small but scalable: decentralized, including doing it in the field for charcoal Producing bio-oil may require larger units
Critical constraints and research needs: Feedstock: physical/chemical requirements, potential for breeding, crop management practices, harvest technologies and logistics, handling, pre-processing, storage	**All:** Detailed understanding of feedstock (straw) availability (spatial, temporal) in relation to cropping systems, harvest techniques. Production systems that could provide combinable feedstocks for co-firing(e.g., woody materials+straw) Locally adapted technologies for collecting, chopping, baling/compressing, transporting, drying (moisture content of rice straw), storing of straw (little work so far in Asia); Solutions that are cheap, labor-efficient, don't add burden and negatively affect human health (women and children) Solutions must be integrated with needs of animal operations Logistics issues depend on scale of technology, but generally decrease in the order **C > G > P**. **C:** needs depend on combustion system used and size of plant; fluidized beds can use whole bales of unchopped straw; blow-in systems require chopped straw **C and G:** Breeding: "brittle straw" and/or reduce mineral content (Si, Cl, K) without compromising other traits/crop production goals – explore existing genotypic variation; trade-off agronomy vs. engineering demands

Critical constraints and research needs: Conversion technology: major constraints for more efficient practical applications	**C and G:** Slagging, high-T corrosion, Diversified feedstocks, co-firing solutions Solutions that include additional fuel may be required Emissions – optimal gas cleaning solutions depending of feedstock combinations **C:** Smaller plants: need for chopping to feed into boiler – dust problems **G:** Tar removal – depending on flow type; requires good gas cleaning **P:** Few problems in small units targeting charcoal production, but little work on designing medium size units targeting charcoal and bio-oil (or gas); bio-oil recovery, storage and processing needs much more R&D
Critical constraints and research needs: Bioenergy products: use, storage, opportunities for further processing	**C:** Demand for the heat produced Producing electricity is less efficient in small plants (cost depends on emission standards required) **G:** Demand gas/electricity. Producing electricity is less efficient in small gasifiers
Critical milestones and realistic time framework for making progress	**C:** Design and thoroughly assess integrated prototype systems for new feedstocks such as rice straw (whole crop production to energy chain); thorough conduct research before promoting further expansion through subsidies/tax incentives, 5 years Models for determining optimal solutions: plant size vs. logistics of feedstock supply and type **G and P:** Need a whole R&D program for straw materials.

Socioeconomic and environmental impact	
Expected impact on national and local energy supply and energy mix	**C:** Locally and nationally important. Economical potential at national level is unknown: need better data from commercial scale plants. Technical potential for using straw in some countries may be 2- 5% of total electricity demand. **G and P:** Locally important energy sources (community impact)
Impact on land use and food security – potential conflicts	**All:** Small because the emphasis is on currently unutilized biomass;
Impact on rural economy: benefits/potential threats for farmers and landless rural poor	**All:** Extra income for farmers, depending on market price, extra cost, and support mechanisms; ideally: farmers should become co-owners of bioenergy plants Employment opportunities still unknown Health impact: reduced smoke from burning of straw
Status of Life Cycle Assessment: energy efficiency, energy yield, net reduction in GHG	**All:** LCA done for combustion plants that use other biomass; need to do LCA ("eco-footprint") for complete crop production – bioenergy chain, also to qualify for extra income potential from CDM (GHG trading)
Observed and potential impact on natural resources (air quality, water, soils, biodiversity)	**All:** impact depends on size: C > G > P Better air quality through reduced emissions from open field burning - plant emissions can be controlled Reduced CH_4 emissions in rice paddies SOM decline in certain systems (depending on cropping systems and harvest methods); Nutrient removal: not much difference compared to current practice of burning in the field; and fly-ash could be returned to the field as fertilizer **G:** Waste water problems (hydrocarbons)

Building partnerships for mutual gains	
Public – private sector partnerships: existing successful models and key needs	Agriculturists need to work closer with energy engineers to design integrated solutions Improve linkages between research and ongoing private sector investment in biomass combustion plants Straw supply chain –intermediaries between plants and farmers?
Different roles of stakeholders - what should national and international agricultural research organizations focus on?	To make this work, all stakeholders need to be included from the beginning, first through carefully designed pilot plants led by research institutions: financing sector, farmers, cooperatives, public sector researchers, private sector Public sector: sustainability issues, equity, impact assessment, crop production component; (germplasm), framework for designing optimal local solutions
Suitable research and information exchange platform: specific partnerships and	International centers and organizations should facilitate information exchange (e.g., on rice straw characterization and processing)
Suggestions for specific follow up activities	Assess current combustion plants/projects in Asia (China, India) – what can be learned from those for designing new solutions? Develop plan for integrated pilot studies that includes key institutions – explore funding opportunities. Assess breeding opportunities for improving combustion or gasification.

Group II: Sugarcane - Ethanol

Major target environments in Asia	
Key integrated production systems envisioned (food-feed-fiber-fuel)	Stalk juice for ethanol or sugar; tops as animal feed
Major bioenergy forms produced and their uses	Ethanol; co-generation of electricity from stillage/bagasse; thermal energy for distillation
Major (sellable) other products for food, feed, fiber, industrial uses	Molasses, syrup, vinegar, wine, paper pulp, animal feed
Potential for semi-arid tropics, semi-humid tropics/subtropics, humid tropics in Asia	Irrigated and high rainfall tropics/humid- 60-75 tons/ha (per cropping season) (all @70 liters/ton, 70% juice extraction)
Countries in the Asia-Pacific region with major interest and ongoing activities	India, Philippines, China, Thailand, Indonesia, Vietnam, Myanmar
Current national policies in the Asia-Pacific in support of R&D and adoption	Favorable generally

Technical issues	
Current status of development, including any recent major breakthroughs	1. Commercialization is going on; 2. large areas in India and other countries in the region; micro propagation/tissue culture in the Philippines and India of HYV
Known applications: centralized (medium to large) or decentralized (small) operations	Medium to large distillery – 100-500klpd; Decentralized – crushing and syrup-making
Critical constraints and research needs: Feedstock: physical/chemical requirements, potential for breeding, crop management practices, harvest technologies and logistics, handling, pre-processing, storage	Genetic upgradation of the stalks – earliness and high yield, pest and disease tolerance; Adaptation trials; best management practices; seed systems; nutrient removal and carbon balance in the system
Critical constraints and research needs: Conversion technology: major constraints for more efficient practical applications	Juice quality assessment; storage or shelf-life prolongation of the juice; harvesting and post-harvesting technology
Critical constraints and research needs: Bioenergy products: use, storage, opportunities for further processing	Molasses used as animal feed ingredient
Critical milestones and realistic time framework for making progress	Adaptation trials (2yrs); best management practices (2yrs); seed systems – production system to be implemented (5yrs); soil nutrient removal and carbon balance in the system (3yrs)

Socioeconomic and environmental impact	
Expected impact on national and local energy supply and energy mix	Ethanol – E20; augment the petrol supply at national level; reduce CO2 emissions; possible electricity production
Impact on land use and food security – potential conflicts	Alternative to other irrigated/dry crops; large effect on food production
Impact on rural economy: benefits/potential threats for farmers and landless rural poor	Employment generation; rural economy rejuvenation
Status of Life Cycle Assessment: energy efficiency, energy yield, net reduction in GHG	Studies of the life cycle greenhouse gas and energy balance needed in a standardized framework in comparison to other crop-based biofuels
Observed and potential impact on natural resources (air quality, water, soils, biodiversity)	Significant soil degradation; more long-term studies are required
Critical research needs	Long-term field trials on sugarcane to assess the soil fertility and crop productivity; legume intercropping/relay cropping; water use efficiency
Economics of sweet sorghum/ethanol enterprise and the social impacts	Studies on marketing systems/arrangements/channels and the economic feasibility and the social and the livelihood issues

Building partnerships for mutual gains	
Public – private sector partnerships: existing successful models and key needs	Several public-private partnerships ; successful sugar cooperative models: need to allow diversified juice-based products
Different roles of stakeholders - what should national and international agricultural research organizations focus on?	National: review of policy issues International: global market surveys, international environmental regulations, networking
Suitable research and information exchange platform: specific partnerships and	Consortiums, APAARI, CGIAR, FAO-GFAR
Suggestions for specific follow up activities	Mechanisms to sensitize the farmers, NGOs, government departments, and the private industry to facilitate adoption and upscaling

Group II: Sweet sorghum - ethanol

Major target environments in Asia	
Key integrated production systems envisioned (food-feed-fiber-fuel)	Grain for food; stillage/bagasse for feed; stalk juice for ethanol
Major bioenergy forms produced and their uses	Ethanol; co-generation of electricity from stillage/bagasse; thermal energy for distillation
Major (sellable) other products for food, feed, fiber, industrial uses	Syrup, grain, vinegar, wine, flour, paper pulp, animal feed
Potential for semi-arid tropics, semi-humid tropics/subtropics, humid tropics in Asia	Semi-arid tropics- 50 tons/ha (per cropping season); semi-humid- 65 tons/ha; humid- not recommended; (all @45 liters/ton, 50% juice extraction)
Countries in the Asia-Pacific region with major interest and ongoing activities	India, Philippines, China, Taiwan, Thailand, Indonesia
Current national policies in the Asia-Pacific in support of R&D and adoption	Favorable generally- example: China- government aims to produce 4.8billion liters from sweet sorghum, more tax rebates

Technical issues	
Current status of development, including any recent major breakthroughs	1. Proof of the concept of commercialization demonstrated; 2. 1000 hectares planted in India, more than 100hectares in the Philippines; 500 hectares in China; 3. Hybrid technology developed to provide continuous feedstock supply
Known applications: centralized (medium to large) or decentralized (small) operations	Medium to large distillery – 100-500klpd; Decentralized – crushing and syrup-making
Critical constraints and research needs: Feedstock: physical/chemical requirements, potential for breeding, crop management practices, harvest technologies and logistics, handling, pre-processing, storage	Genetic upgradation of the stalks – cold tolerance, and pest and disease tolerance; Adaptation trials; best management practices; seed systems; nutrient removal and carbon balance in the system
Critical constraints and research needs: Conversion technology: major constraints for more efficient practical applications	Juice quality assessment; storage or shelf-life prolongation of the juice; harvesting and post-harvesting technology
Critical constraints and research needs: Bioenergy products: use, storage, opportunities for further processing	Animal feed quality assessment; Making animal feed bricks
Critical milestones and realistic time framework for making progress	Adaptation trials (2yrs); best management practices (2yrs); seed systems – production system to be implemented (5yrs); soil nutrient removal and carbon balance in the system (3yrs)

Socioeconomic and environmental impact	
Expected impact on national and local energy supply and energy mix	Ethanol – E20; augment the petrol supply at national level; reduce CO_2 emissions; possible electricity production
Impact on land use and food security – potential conflicts	Alternative to other dry land crops; little effect on food supply; positive economic effect on food security
Impact on rural economy: benefits/potential threats for farmers and landless rural poor	Increase small farmer income; employment generation; rural economy rejuvenation
Status of Life Cycle Assessment: energy efficiency, energy yield, net reduction in GHG	Studies of the life cycle greenhouse gas and energy balance needed
Observed and potential impact on natural resources (air quality, water, soils, biodiversity)	No known evidence on soil degradation in systems where legumes intercrop are rotated and all biomass are taken out from sweet sorghum system; more long-term studies are required
Critical research needs	Long-term field trials on sweet sorghum to assess the soil fertility and crop productivity
Economics of sweet sorghum/ethanol enterprise and the social impacts	Studies on marketing systems/arrangements/channels and the economic feasibility and the social and the livelihood issues

Building partnerships for mutual gains	
Public – private sector partnerships: existing successful models and key needs	Joint research activities; existing: Government of the Phils. and Seaoil/Philippine Ethanol Corp. in the Philippines; ICRISAT and the Rusni Distilleries Ltd in India; and ICRISAT and JADE in Mexico; China?
Different roles of stakeholders - what should national and international agricultural research organizations focus on?	National: adaptation trials, best management practices, seeds systems; market and farmer integration. International: feedstock improvement, partnership development, conversion technology up-gradation
Suitable research and information exchange platform: specific partnerships and	Consortiums, APAARI, CGIAR, FAO-GFAR
Suggestions for specific follow up activities	Mechanisms to sensitize the farmers, NGOs, government departments, and the private industry to facilitate adoption and upscaling

Group II: Cassava – Ethanol

Major target environments in Asia	
Key integrated production systems envisioned (food-feed-fuel)	Roots/leaves for food; roots for ethanol and animal feed
Major bioenergy forms produced and their uses	Ethanol
Major (sellable) other products for food, feed, industrial uses	Syrup, chips, vinegar, wine, flour, paper pulp, animal feed, starch
Potential for semi-arid tropics, semi-humid tropics/subtropics, humid tropics in Asia	Semi-arid tropics- 30 tons/ha (per cropping season); semi-humid- 55 tons/ha; humid- not recommended; (all @ 137-190 liters/ton)
Countries in the Asia-Pacific region with major interest and ongoing activities	India, Philippines, China, Taiwan, Thailand, Indonesia, Vietnam, Myanmar
Current national policies in the Asia-Pacific in support of R&D and adoption	Favorable generally- more tax rebates are needed

Technical issues	
Current status of development, including any recent major breakthroughs	1. Proof of the concept of commercialization demonstrated; 2. Sugary cassava area negligible
Known applications: centralized (medium to large) or decentralized (small) operations	Medium to large distillery – 100-500klpd; Decentralized – chip-making and drying
Critical constraints and research needs: Feedstock: physical/chemical requirements, potential for breeding, crop management practices, harvest technologies and logistics, handling, pre-processing, storage	Introduction of sugary cassava mutants; Genetic upgradation of the stalks –pest and disease tolerance; Adaptation trials; best management practices; seed systems; nutrient removal and carbon balance in the system
Critical constraints and research needs: Conversion technology: major constraints for more efficient practical applications	Juice quality assessment; storage or shelf-life prolongation of the starch; harvesting and post-harvesting technology; aflatoxin problems
Critical constraints and research needs: Bioenergy products: use, storage, opportunities for further processing	Animal feed quality assessment; Making animal feed bricks; biodegradable plastics
Critical milestones and realistic time framework for making progress	Introduction of sugary cassava (2yrs); Adaptation trials (2yrs); best management practices (2yrs); seed systems – production system to be implemented (5yrs); soil nutrient removal and carbon balance in the system (3yrs)

Socioeconomic and environmental impact	
Expected impact on national and local energy supply and energy mix	Ethanol – E20; augment the petrol supply at national level; reduce CO2 emissions;
Impact on land use and food security – potential conflicts	Alternative to other dry land crops; some possible effect on food supply; positive economic effect on food security
Impact on rural economy: benefits/potential threats for farmers and landless rural poor	Increase small farmer income; employment generation; rural economy rejuvenation
Status of Life Cycle Assessment: energy efficiency, energy yield, net reduction in GHG	Studies of the life cycle greenhouse gas and energy balance needed
Observed and potential impact on natural resources (air quality, water, soils, biodiversity)	No known evidence on soil degradation in systems where legumes intercrop are rotated and all biomass are taken out from sweet sorghum system; more long-term studies are required
Critical research needs	Long-term field trials on sugary cassava to assess the soil fertility and crop productivity
Economics of sweet sorghum/ethanol enterprise and the social impacts	Studies on marketing systems/arrangements/channels and the economic feasibility and the social and the livelihood issues

Building partnerships for mutual gains	
Public – private sector partnerships: existing successful models and key needs	Joint research activities; existing: San Miguel Corporation and Philippine government in Philippines; Embrapa, Brazil and other national programs; Thailand and China?
Different roles of stakeholders - what should national and international agricultural research organizations focus on?	National: adaptation trials, best management practices, seeds systems; market and farmer integration; Embrapa, Brazil – supply of sugary mutants International: feedstock improvement, partnership development, conversion technology up-gradation
Suitable research and information exchange platform: specific partnerships and	Consortiums, APAARI, CGIAR, FAO-GFAR
Suggestions for specific follow up activities	Mechanisms to sensitize the farmers, NGOs, government departments, and the private industry to facilitate adoption and upscaling

Group II: Cellulosic Ethanol

Major target environments in Asia	
Key integrated production systems envisioned (food-feed-fiber-fuel)	Crop residues- rice, wheat, maize, sugarcane and sweet sorghum; biomass crops – silver grass, switch grass, napier grass, etc.; fast-growing agro-forestry crops and residues
Major bioenergy forms produced and their uses	Ethanol; co-generation of electricity from residues; lignin for thermal energy for distillation
Major (sellable) other products for food, feed, fiber, industrial uses	Bio-refinery chemicals and animal feed, compost/organic fertilizer
Potential for semi-arid tropics, semi-humid tropics/subtropics, humid tropics in Asia	All agro-ecosystems in the country – 3-30 tons/ha, depending on the rainfall
Countries in the Asia-Pacific region with major interest and ongoing activities	India, Philippines, China, Taiwan, Thailand, Indonesia, Malaysia, Myanmar, Pakistan, and others
Current national policies in the Asia-Pacific in support of R&D and adoption	None

Technical issues	
Current status of development, including any recent major breakthroughs	Proof of the concept on small-scale demonstrated
Known applications: centralized (medium to large) or decentralized (small) operations	Centralized: Wheat straw being used in Iogen, Canada
Critical constraints and research needs: Feedstock: physical/chemical requirements, potential for breeding, crop management practices, harvest technologies and logistics, handling, pre-processing, storage	Feedstock collection, densification, and transport systems
Critical constraints and research needs: Conversion technology: major constraints for more efficient practical applications	Accessibility to the steps in feedstock conversion, IPR issues overcoming for technology, microorganisms and enzymes, process engineering technology accessibility
Critical constraints and research needs: Bioenergy products: use, storage, opportunities for further processing	High-value bio-refinery chemicals such as adhesives, dyes, active chemical ingredients, etc.
Critical milestones and realistic time framework for making progress	Feedstock collection, densification, and transport systems (2-3yrs); Accessibility to the steps in feedstock conversion, IPR issues overcoming for technology, microorganisms and enzymes, process engineering technology accessibility (10-15yrs)

Socioeconomic and environmental impact	
Expected impact on national and local energy supply and energy mix	Ethanol – E20; augment the petrol supply at national level; reduce CO2 emissions; possible electricity production
Impact on land use and food security – potential conflicts	No effect on food supply; positive economic effect on food security
Impact on rural economy: benefits/potential threats for farmers and landless rural poor	Increase small farmer income; employment generation; rural economy rejuvenation
Status of Life Cycle Assessment: energy efficiency, energy yield, net reduction in GHG	Studies of the life cycle greenhouse gas and energy balance needed in a consistent format compared to existing biofuels studies
Observed and potential impact on natural resources (air quality, water, soils, biodiversity)	No known evidence on soil degradation in systems where legumes and cereals intercropped or rotated and all biomass are taken out; more long-term studies are required
<u>Critical</u> research needs	Long-term field trials to assess the soil fertility and biomass productivity
Economics of biomass/ethanol enterprise and the social impacts	Studies on marketing systems/arrangements/channels and the economic feasibility and the social and the livelihood issues

Building partnerships for mutual gains	
Public – private sector partnerships: existing successful models and key needs	Joint research activities: Iogen in Canada; Abengoa in Spain, USA and Brazil; BP-UC Berkeley (EBI)
Different roles of stakeholders - what should national and international agricultural research organizations focus on?	International: feedstock improvement, partnership development, conversion technology research and its exchange with the National programs
Suitable research and information exchange platform: specific partnerships and	Consortiums, APAARI, CGIAR, FAO-GFAR
Suggestions for specific follow up activities	Timely mechanisms to sensitize the farmers, NGOs, government departments, and the private industry to facilitate adoption and upscaling

Group III: Biodiesel from Oil palm (O), Jatropha (J), Pongamia (P), Coconut (C), Castor bean (B), Rubber seed (R)

Major target environments in Asia	Pongamia follows same analysis as Jatropha – hence not need to fill remaining boxes Coconut very similar to Oil Palm status –main issue the high price of oil as per today's international market, which may preclude its use as biodiesel. However in the pacific region this is already in use..
Key integrated production systems envisioned (food-feed-fiber-fuel)	Jatropha monoculture, Jatropha based system, Oil palm monoculture Castor bean as monoculture Rubber plantation
Major bioenergy forms produced and their uses	**J, P:** Biodiesel, biogas and cogeneration **O:** Oil for biodiesel,cake for energy **B:** Oil for industrial applications, could get in to biofuel route **R:** Oil seeds with potential for biodiesel
Major (sellable) other products for food, feed, fiber, industrial uses	**J, P:** Cake for fertilizer, bark for paper, branches for board **O:** Cooking oil, other food & cosmetics products **R:** Old source for pneumatic tires and rubber bands (until Dupont et al. brought synthetic sources); latex for enzymes (peroxidases), also as raw material for building
Potential for semi-arid tropics, semi-humid tropics/subtropics, humid tropics in Asia	**J, P:** Semi arid, minimum 500 mm rainfall **O:** At least 2000 mm rainfall and within tropical rainforest (±10^0 latitude) **R:** Rainforest at least 1000 mm rainfall
Countries in the Asia-Pacific region with major interest and ongoing activities	**J, P:** India, China, Philippines, Indonesia, Thailand, Myanmar, PNG **O:** Malaysia, Indonesia, Thailand, PNG, Philippines, India, China, Sri Lanka **R:** Thailand, Malaysia, Indonesia, India, PNG, Vietnam, Lao, Cambodia, Sri Lanka, Myanmar, Philippines, China
Current national policies in the Asia-Pacific in support of R&D and adoption	**J, P:** There is promotion on R&D in most of the countries in Asia **O:** Strong R&D platforms especially in Malaysia and Indonesia **R:** Quite good R&D platforms but not for biodiesel

Technical issues	
Current status of development, including any recent major breakthroughs	**J, P:** There is one variety developed and released from India **O:** Perhaps under proprietary domain **R:** In its infancy for biodiesel – hence a need for developing a holistic bionergy agenda for this crop
Known applications: centralized (medium to large) or decentralized (small) operations	**J, P:** Decentralized **O:** Centralized
Critical constraints and research needs: Feedstock: physical/chemical requirements, potential for breeding, crop management practices, harvest technologies and logistics, handling, pre-processing, storage	**J, P:** Elite germplasm conservation, Development of cultivars and package of practices, Plantation management to achieve optimum yields **O:** already a lot of knowledge and technology available but productivity gains still needed
Critical constraints and research needs: Conversion technology: major constraints for more efficient practical applications	**J, P:** Small scale efficient technology **O:** Already known for large scale but not for smallholders?
Critical constraints and research needs: Bioenergy products: use, storage, opportunities for further processing	**J, P:** Short-shelf life of seed and oil **O:** Enzymatic treatments: new tech needed
Critical milestones and realistic time framework for making progress	**J, P:** Five to ten years **O:** Already happening

Socioeconomic and environmental impact	
Expected impact on national and local energy supply and energy mix	**J, P:** Oil and other resources at village level are needed for local energy needs and employment generation **O:** Well known in Malaysia and Indonesia economy, and others following example of both of above
Impact on land use and food security – potential conflicts	**J, P:** Should be restricted to marginal lands and asses socio-environmental impacts, No conflicts with food security **O:** Competing with rainforest land, e.g. in Indonesia or Thailand; Displacement of small farmers and land tenure issues; e.g. in The Philippines
Impact on rural economy: benefits/potential threats for farmers and landless rural poor	**J, P:** Income generation and employement,cheaper energy resource **O:** Employment
Status of Life Cycle Assessment: energy efficiency, energy yield, net reduction in GHG	**J, P:** Yet to be done **O:** Self-sustaining system
Observed and potential impact on natural	**J, P:** Yet to be done

resources (air quality, water, soils, biodiversity)	**<u>O:</u>** Soil degradation and deforestation, thereby threatening biodiversity
<u>Critical</u> research needs	**<u>J, P:</u>** Socio economic research ,Risk mitigation mechanisms,Minimum support price **<u>O:</u>** Small and medium size farmers, resettlemnt of displaced rural population(s)

Building partnerships for mutual gains	
Public – private sector partnerships: existing successful models and key needs	**<u>J, P:</u>** Contract farming is in progress and sucessful models are emerging **<u>O:</u>** Some models are ongoing
Different roles of stakeholders - what should national and international agricultural research organizations focus on?	**<u>J, P:</u>** Region specific germplasm well worked through intensive research and development processes at National level **<u>O:</u>** Brokering proprietary technology exchanges and knowledge sharing
Suitable research and information exchange platform: specific partnerships and	**<u>J, P:</u>** Development of regional network for knowledge and material exchange **<u>O:</u>** Link with ongoing international platforms for the crop
Suggestions for specific follow up activities	**<u>J, P:</u>** Sharing knowledge through ground level case studies in Asia-Pacific region **<u>O:</u>** Impacts of pricing on oil palm uses: food or biodiesel?