AGRICULTURE & RURAL DEVELOPMENT
NOTES

Bioenergy Development:
Issues and impacts for poverty and natural resource management

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EXECUTIVE SUMMARY

The Food and Agriculture Organization of the United Nations (FAO) defines bioenergy as all energy derived from biofuels (FAO, 2004). Biofuels are, in turn, defined as fuels derived from biomass (i.e., matter of a biological origin). Biofuels can be further sub-divided by type (solid, liquid or gas) and by origin (forest, agriculture or municipal waste). Biofuels from forests and agriculture (woodfuel and agrofuel) can come from a wide range of sources (e.g., forests, farms, specially grown energy crops and waste after harvesting or processing of wood or food crops).

The last five to ten years have seen a strong resurgence of interest in bioenergy along with the gradual development of more modern and efficient bioenergy production systems. This has been driven by several factors including instability in oil producing regions, financial market shift of investments in 2007-2008 to commodities and oil, extreme weather events, and surging energy demand from developing countries. High oil prices were directly related to the establishment of biofuel mandates and rising biofuel production directly tracks rising oil prices from around 2004-2008. Other drivers for biofuel production may include domestic agricultural support programs, demand for self-supply of energy commodities, mitigation of climate change, and the belief that such fuels are cheaper. In response to these various factors, many countries have begun to explore bioenergy alternatives. Most countries encouraging bioenergy development have at least one of the following policy objectives: to increase energy security; stimulate rural development; reduce the impact of energy use on climate change; and improve the environment more generally. Bioenergy systems present opportunities for countries with land resources suitable for energy crop cultivation to develop a national source of renewable energy (and possibly provide additional export revenues).

Bioenergy developments present both opportunities and challenges for socioeconomic development and the environment and have a number of potential impacts on forests and the rural poor who depend on forests for their livelihoods. In developing countries, the impact of bioenergy on poverty alleviation will depend on the opportunities that are presented for agricultural development, including income and employment generation and the potential to increase poor peoples' access to improved types of bioenergy. There are significant concerns surrounding the efficiency of different bioenergy options to combat climate change, the impact on agriculture, food security and sustainable forest management and the social impacts of bioenergy development, particularly related to land use changes, land tenure, and land rights. Food insecurity may result if staple crops are used for energy production or land conflicts and if production displaces local communities or restricts access to land. The environmental impacts of these developments are uncertain and will vary considerably from case to case. The development of bioenergy is likely to have significant impacts on the forest sector directly, through the use of wood for energy production, and indirectly, as a result of land use changes. It is expected that energy production from solid biomass will have both direct and indirect impacts on the sector, whereas liquid biofuels will mainly have indirect effects.

Photo: © Curt Carnemark / World Bank

MAIN FINDINGS

Finding 1: Solid biomass will continue to provide a principle source of energy and should not be overlooked.

At the global level in 2005, primary solid biomass accounted for 95 percent of Total primary energy supply (TPES) from bioenergy, while biogas and bioethanol accounted for about two percent each

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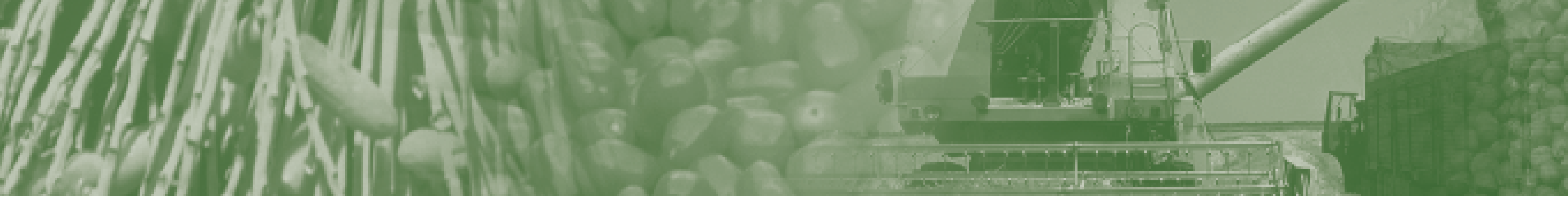


and biodiesel the remaining one percent. At the regional level, biogas and liquid biofuels are relatively more important in North America, the European Union (EU) and Latin America, (with shares of about 15 percent, 10 percent, and 5 percent respectively), but these sources of bioenergy are extremely small outside these three regions.

Solid biomass has various uses. Traditional biomass energy (wood, charcoal, dung, and crop residues) is used primarily by the poor for heating and cooking and artisanal purposes, whereas modern uses (co-firing, heat and power installations or pellets) of wood biomass are generally used at an industrial scale for heat and power generation, although there are applications for small-scale use.

Globally, traditional uses of biomass are expected to decline slightly. This decline is mostly driven by large shifts in energy consumption patterns in East Asia and the Pacific toward other fuel sources, including electricity. In other regions, traditional biomass use is likely to grow, particularly in Latin America and Africa.

However, modern uses of primary solid biomass for heat and energy production are expected to increase significantly. Thus, the share of primary solid biomass in total bioenergy production will remain high.

Finding 2: There will be major land use implications resulting from bioenergy developments.

The impact of bioenergy production on land and other resources is determined by the demand for biomass and the efficiency of land use (i.e., energy yield per hectare). An important question is whether the biomass crop can be grown on unused or degraded land or will take land out of agriculture and/or forests. In order to meet ambitious global targets, the total area of land that is used for bioenergy production is likely to increase. Although some bioenergy developments are planned for, and likely to occur on, degraded or unused lands, this is not likely to meet the overall requirements. Therefore, land will need to be converted from other uses—namely agriculture/rangelands or forests/grasslands.

This analysis suggests that large changes in land-use may occur as a result of solid biomass and liquid biofuel feedstock production in order to meet current government targets. Most of the changes are likely to result from agricultural crops to produce ethanol and biodiesel since these make up the largest percentage of all government targets. Solid biomass is likely to account for a smaller, but still significant amount of land conversion.

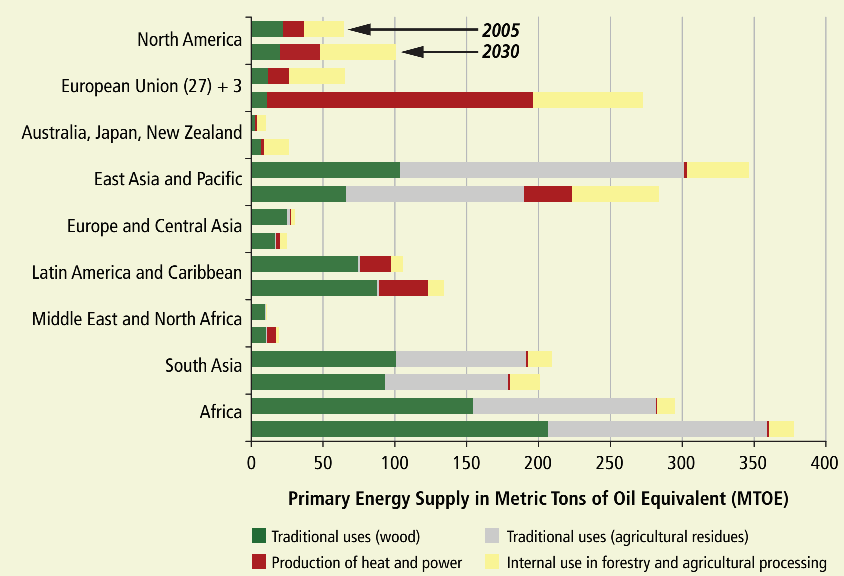
Finding 3: It is critical to consider tradeoffs, including those related to poverty, equity, and the environment, when choosing a bioenergy system.

In most countries, current bioenergy policies have a number of (often conflicting) objectives that require careful decisions to reach desired outcomes. For example, between energy security and rural development on one hand versus food price implications and natural resource impacts on the other. Increased consumption of bioenergy is likely to result in increased competition for land that has potential to impact agriculture and forestry and could negatively affect the poor in other ways, such as through changes in access to resources and overall environmental quality. Another consideration is whether bioenergy provides climate reduction benefits. Furthermore, there are many measures and instruments that can be used as part of policy implementation and these may have different impacts on different objectives.

In choosing a bioenergy system, it is important to identify the expected outcomes and to choose a system based on the stated program goals for a particular location while minimizing negative impacts. For example, a country may choose different systems based on employment benefits versus maximization of fuel production. Also, cost considerations are likely to play a role in making these decisions. It is critical to keep in mind the land use and environmental implications of each system in the locale in which they are implemented, since production of a particular feedstock may have minimal impacts in one location and very severe impacts in another. The chart below presents an example matrix view of some of the tradeoffs that can be considered for liquid biofuels.

The matrices below are broad generalizations of potential impacts, which will vary widely depending on specific site conditions and land uses currently in place. There is more need for technical analysis

Total Primary Energy Supply from Primary Solid Biomass by Region and Type in 2005 and 2030



Source: Based on IEA (2006) and Broadhead et al (2001).

and evaluation of options, measures, and instruments in many countries with respect to bioenergy development. Thorough environmental and social impact evaluations (including strategic evaluations) should be undertaken in advance of making large-scale investments into bioenergy, which can help to identify and mitigate potential impacts.

Finding 4: There is considerable potential for greater use of forestry and timber waste as a bio-energy feedstock.

Although there is considerable variation (depending on local market conditions and average transport distances), the least expensive source of biomass is recovered wood (i.e., post-consumer waste) and forest processing waste (residues from timber mill or timber processing). Agricultural and forest residues (those left over from harvesting operations) are the next most inexpensive source of waste. Crops specifically managed for biomass production (e.g., energy crops such as switchgrass, miscanthus, and short-rotation coppice) are generally more expensive than these wastes, as are forest thinnings produced using traditional forest harvesting systems. In the developed regions of the world, traditional wood energy is already supplied mostly by forest thinnings, harvesting residues, and trees outside forests, whereas biomass for heat, power, and internal use is mostly supplied from industry waste and recovered wood products.

There are opportunities for the private sector, and organizations which invest in private sector development, to develop processing facilities serving more than one purpose. In some developing countries (particularly in East Asia and the Pacific), forestry thinnings are underutilized and the cost of biomass can be quite low. In addition, in some situations, biomass waste presents a disposal problem (i.e., where disposal in a landfill is costly) and producers may be willing to have this material removed. Some timber and biofuel operations are already energy self-sufficient due to co-firing (using forestry residues and bagasse) and the availability of logging and milling wastes from traditional timber operations provide additional opportunities for heat and power generation (particularly in developing countries where waste products are not fully utilized).

Finding 5: The climate benefits of bioenergy development are uncertain, and highly location- and feedstock-specific.

Climate change impacts of bioenergy have the potential to be both positive and negative. The major liquid biofuel crops in the future are expected to be sugarcane, maize, and oil palm. Ethanol production from sugar cane will account for a major share of bioethanol production and, so long as this does not result in forest clearance, this production system has a fairly low energy intensity and good potential to reduce net greenhouse gas emissions because ethanol processing facilities often utilize sugarcane bagasse for heat generation. Biofuel production from corn requires fossil fuel inputs through every stage of the process, including conversion into corn ethanol. Corn ethanol has minimal carbon savings versus conventional gasoline and may actually increase emissions. Biodiesel from oil palm can have lower emissions than fossil fuels, but is highly dependent on the type of land on which it is planted.

Trade-off Matrix for Liquid Biofuels

	Corn	Sugarcane	Sweet Sorghum	Cassava	Nypa Palm	Soy	Oil Palm	Rapeseed	Jatropha	Jojoba	Pongamia
Employment potential	Low	Medium	Medium	Medium	High	Low	High	Low	High	High	High
Potential for smallholders	Low	Medium	High	High	Medium	Low	Medium	Low	High	Variable	High
Improvement of degraded land	Low	Low	High	High	High	Low	Low	Low	High	High	High
Impact on natural forests	Variable	Variable	Low	Low	Low	High	High	Medium	Low	Low	Low
Impact on agriculture	High	Low	Low	Low	Low	High	Low	High	Low	Low	Low
Resource competition	High	Low	Low	High	Low	High	High	High	Low	Low	Low
Impact on water resources	High	Medium	Medium	Low	Low	Medium	High	High	Low	Low	Low
Impact on soil resources	High	High	Low	Low	Low	Low	High	High	Low	Low	Low
Impact on biodiversity	Variable	Variable	Variable	Variable	Low	High	High	Variable	Medium	Medium	Medium
Invasiveness	Low	Low	High	Low	High	Low	High	High	High	Low	Medium

Note: Impacts are evaluated based on the minimum necessary inputs and the type of land uses targeted by decision makers. It does not take into account planting on land areas aside from what are targeted or additional inputs, such as irrigation. These changes would be likely to change the suitability of the above-mentioned crops.

Source: Based on Cushion et al (2009).

The impacts of increased bioenergy production from primary solid biomass are similarly complicated. Increased traditional uses of biomass are likely to result in some forest degradation and possibly increased greenhouse gas emissions (where woodfuel is not collected sustainably), but the increased production of heat and power using industry residues could have a positive impact on climate change.

If agricultural or forested land is converted for bioenergy production, the carbon emissions may actually increase over fossil fuel emissions (especially if the land converted is forested peatlands). Land conversions, nitrous oxide emissions from degradation of crop residues during biological nitrogen fixation (common with soy and rapeseed), or emissions from nitrogen fertilizer should be factored into the analysis. For this reason, life cycle analyses are the best predictors of total carbon reductions for a fuel source. For example, a 2008 study presented how converting rainforests, peatlands, savannas, or grasslands to produce food crop-based biofuels in Brazil, Southeast Asia, and the United States could create a "biofuel carbon debt" by releasing 17 to 420 times more CO2 than the annual greenhouse gas (GHG) reductions that these biofuels would provide. While there are uncertainties regarding the estimated amount of carbon emissions, the important message is that changes in land use could significantly outweigh any carbon benefits that may result from planting biofuels.

POLICY IMPLICATIONS

It is important for consumer countries to consider the upstream impacts of their bioenergy mandates and targets, including social and environmental effects. For example, the EU has already begun discussions regarding the potential environmental implications that their standards will have in producer countries and what this means for the targets. Consumer countries can help drive the development of biofuel production standards (such as the roundtable on sustainable biofuels). Consumer countries can also purchase biodiesel only from producers who already meet previously established standards (such as the roundtables on sustainable soy or sustainable palm oil). With respect to solid biomass, wood pellet use is expected to increase in developed and some developing countries. This growth in demand will not be met without imports, including from the tropics. This could, in turn, increase pressures on land and for local populations if it is not under sustainable production schemes.

In producer countries, it is important to balance production targets with environmental and social concerns, including food security. The tradeoffs of bioenergy production should be carefully considered in order to determine the correct feedstock for a particular location and balance this choice with production costs and rural development. Some regional criteria within countries that have established national biofuels promotion policies may also need to be applied, since some areas may have very low environmental risks of expanding biofuels, while other regions have very high risks.

There is also a role for investors and development organizations, including helping to drive investments into feedstocks that meet best practices for environmental, social, and climate change considerations.

CHALLENGES AND OPPORTUNITIES

As a result of various initiatives that are being developed to reduce carbon emissions and environmental degradation, (including payments for environmental services, carbon markets and bioenergy developments) new demands are being placed on environmental goods and services, and lands (including forests) are being assigned a monetary value. While these initiatives may provide new opportunities for income generation and job creation, they are also likely to become more attractive to investors. This can result in insecure rights for the poor, including reduced access to the land or reduced ability to secure products. Therefore, these new opportunities, including bioenergy, should ensure the participation and land rights of the people already present in the areas targeted for new initiatives.

Bioenergy solutions should strive to be environmentally sensitive and have a positive social impact. There appear to be more opportunities for this with regard to solid biomass than liquid biofuels (based on current feedstocks and production methods), which tend to have larger environmental risks and mixed benefits for the poor.

In addition to opportunities for the poor resulting from production of conventional bioenergy development (at both large- and small-scales), there are other options that should be studied more closely, including biochar, which when produced at a small scale, may provide climate change mitigation potential and opportunities to increase rural production (which would have nutritional and financial benefits). Biochar is made as a by-product from the pyrolysis of solid biomass and, when added to the soil on degraded lands, can help to improve fertility. Other opportunities mentioned in this document include black liquor and the use of modern stoves.

References:

1) FAO, 2004, UBET, Rome, Italy, available at: http://www.fao.org/DOCREP/007/j4504E/j4504E00.HTM
2) Fargione, Joseph, Jason Hill, David Tilman, Stephen Polasky and Peter Hawthorne, 2008, Land Clearing and the Biofuel Carbon Debt, *Science*, Vol 319, No 5867, pp 1235 – 1238.
3) Broadhead, J S, J Bahdon, and A Whiteman, 2001, Past trends and future prospects for the utilisation of wood for energy, Food and Agricultural Organization of the United Nations, Rome, Italy.

   IEA, 2006, World Energy Outlook 2006, International Energy Agency, Paris, available at: http://www.iea.org.
4) Cushion, E., Whiteman, A. and G. Dieterle. 2009. Agriculture and Rural Development Series: Bioenergy Development: Issues and Impacts for Poverty and Natural Natural Resource Management. Agriculture and Rural Development, World Bank, Washington, D.C. (to be published in November).

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