Bioenergy and Agriculture: Promises and Challenges

Bioenergy in Developing Countries: Experiences and Prospects

Daniel M. Kammen

2020 VISION FOR FOOD, AGRICULTURE, AND THE ENVIRONMENT

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Biomass energy programs offer a wide range of potential benefits for developing countries. Already traditional biomass products like firewood, charcoal, manure, and crop residues provide the main source of household energy use for some 2–3 billion people in the developing world, and this demand is likely to grow in the years ahead. But new technologies for commercial energy production from biomass are emerging that could lead to dramatic new opportunities for agriculture and the rural sector, as well as help developing countries reduce their dependence on expensive oil imports. Both the traditional and the new options for biomass energy pose challenges that will require technology and policy solutions to ensure efficient, healthy, and environmentally sustainable outcomes.

BIOMASS FOR HOUSEHOLD USE

Biomass fuels are vital to basic welfare and economic activity in developing countries, especially in many African countries, where they meet more than 90 percent of household energy needs. For these people, biomass is generally used in open hearths or simple stoves that are inefficient and polluting, with significant impacts on human health. Combustion of biofuels emits pollutants that currently cause more than 1.6 million deaths globally each year (400,000 in Sub-Saharan Africa alone), mostly among children and women. Thus biomass use is directly or indirectly related to multiple Millennium Development Goals (MDGs), including environmental sustainability, reduction of child mortality, and gender equity.

Traditional sources of biomass are also associated with degradation of forest and woodland resources and soil erosion. Charcoal is a good example. This fuel is in high demand in many rapidly growing urban areas, and to meet this demand, charcoal producers often plunder forest and woodland resources. In Kenya, for example, most charcoal is produced in earthen kilns that typically yield only one kilogram (kg) of charcoal for every six kg of wood harvested. To reach Nairobi, charcoal is frequently brought from 200–300 kilometers away. In one year, an urban household cooking exclusively with charcoal uses between 240 and 600 kg of charcoal, produced using between 1.5 and 3.5 tons of wood.

Despite the inefficiency of its production, charcoal remains an affordable fuel for Kenya's urban consumers in part because the national government owns the forests where charcoal production takes place, but does little to control access to them. Charcoal producers pay no stumpage fees, so urban customers pay only for labor, transportation, and handling of the charcoal, plus the middlemen's mark-ups. They do not pay for the feedstock itself. Instead, the costs of replacing the feedstock and coping with the damage caused by the loss of tree cover are borne by the rural population where the trees are harvested.

Prohibiting charcoal, the government concluded, would be extremely unpopular, likely to fail, and harmful to the poor. An alternative to excessively centralized control that could lead to more sustainable charcoal production is to support local community control of forest resources. This approach would channel charcoal revenues into local communities and promote sustainable land management practices rather than the resource mining that is currently taking place in Kenya and elsewhere. Or, if a central administration is deemed best in a given situation, license fees could be collected for charcoal production, ideally "green" tagged to reward sustainable practices, and then returned to local governance groups based on their vigilance and success in ensuring minimally destructive harvests.

During the past decade a series of studies in Kenya examined programs to design and disseminate improved household stoves, as well as efforts to develop and implement sustainable forestry and fuel (often charcoal) production practices in Africa. The studies found that combined attention to both stove and forestry programs can simultaneously lead to dramatic improvements in human health, ecological sustainability, and local economic development. Furthermore, the work in Kenya revealed something exceptional: shifting from burning wood and dung fuels on simple stoves to burning charcoal on improved stoves can reduce the frequency of acute respiratory infections (ARIs) by a full factor of *two*. This is a tremendous impact, for ARIs are the most common illnesses reported in medical exams in Sub-Saharan Africa. Further, comparatively simple materials and design modifications in household stoves are now known to both dramatically improve energy efficiency and reduce particulate and greenhouse gas emissions. As a result, after childhood immunizations, improved stoves may be the single most cost-effective public health intervention.

These benefits can be achieved at exceptionally low cost—a few dollars per life saved—with the added benefit that atmospheric carbon mitigation is possible, also at a few dollars per ton of carbon. In contrast, carbon now trades for roughly US$15–20 per metric ton on the London exchange, a price that reflects greenhouse gas impacts alone. The potential to address both local health and development needs *and* global environmental protection with such economic efficiency makes efforts to support the dissemination and use of improved cookstoves a natural component of any comprehensive development and assistance strategy in Africa or elsewhere.

COMMERCIAL USE OF BIOMASS

New technological innovations in bioenergy, along with dramatically rising international oil prices and extremely volatile natural gas costs, have opened the door to a revolution in commercial bioenergy production. Improvements have been made in ethanol, methanol, and biodiesel production and in the gasification of biofuels. In most countries these developments have important implications for agriculture and may offer new income-earning opportunities for farmers. In some cases, such as Brazil, they dramatically reduce the need for imported oil.

Residues are an especially important potential biomass energy source in densely populated regions, where much of the land is used for food production. In fact, biomass residues play important roles in such regions precisely because the regions produce so much food; crop production can generate large quantities of by-product residues. For example, in 1996 China generated crop residues in the field (mostly maize stover, rice straw, and wheat straw) plus agricultural processing residues (mostly rice husks, maize cobs, and bagasse) totaling about 790 million metric tons, with a corresponding energy content of about 11 exajoules (EJ). To put this in perspective, if half of this resource were to be used for generating electricity at an efficiency of 25 percent (achievable at small scales today), the resulting electricity generation would be about half of the total electricity generated from coal in China in 1996. Of course, most of China's residue consumption is in traditional combustion devices. Residues yield about 35 percent of the rural population's total household energy consumption and 20 percent of the national total.

There is also significant potential for providing biomass for energy by growing crops specifically for that purpose. In one scenario from the Intergovernmental Panel on Climate Change (IPCC), 385 million hectares globally are planted with biomass energy plantations in 2050 (equivalent to about one-quarter of the present planted agricultural area), with three-quarters of this area in developing countries. Using so much land for bioenergy raises the issue of intensified competition with other important land uses, especially food production. Competition between land use for agriculture and for energy production can be minimized, however, if degraded land and surplus agricultural land are targeted for energy crops. Though these lands are less productive, targeting them for bioenergy plantations can have secondary benefits, including restoration of degraded land and carbon sequestration. In developing countries in aggregate, about 2 billion hectares of land have been classified as degraded, though this land is certainly not entirely unoccupied. Although there are many technical, socioeconomic, political, and other challenges involved in growing energy crops on degraded lands, successful plantations have already been established on such lands in some developing countries.

Biomass-based industries are also a significant source of jobs in rural areas, where high unemployment often drives people to take jobs in towns and cities, dividing families and exacerbating problems of urban decay. Compared with other fossil-fuel and renewable energy production, biomass is relatively labor intensive, even in industrialized countries with highly mechanized industries. Traditional bioenergy provision also creates a significant source of employment. One study reported that 33 percent of randomly selected respondents in one charcoal-producing area claimed charcoal production as a source of income. It should not be assumed, however, that all rural areas in developing countries are characterized by surplus unskilled labor and that labor-intensive bioenergy projects will automatically have a pool of workers from which to select. Employment in rural areas is primarily agricultural and hence, highly seasonal. It also moves in longer cycles coinciding with good and bad harvests, which can have ripple effects extending into the formal economy.

CONCLUSIONS

Biomass energy programs offer a wide range of benefits, but achieving them requires significant public policy guidance. In the household fuel and health sector, tremendous gains in fuel reduction and health improvement are possible through the design and dissemination of improved stoves. At the same time, significant benefits to forest sustainability and biomass production are achievable by enforcing sustainable forest and agricultural waste management strategies.

The dramatic gains, however, exist where an effort is made to integrate both programs: a technically feasible but often politically challenging goal. To make integrated end-use and forest and field production programs the norm, integrated planning is needed across the forestry, public health, and transport sectors.

Commercial energy production from biofuels has also undergone a technological and economic revolution in the past decade. These changes open the door for both advanced, low-carbon electricity production and for dramatic reductions in gasoline use (such as the 40–50 percent decline achieved in Brazil). Developing countries may be particularly interested in this nexus because of biofuels' significant employment benefits compared with fossil-fuel energy systems. Expanded attention to ethanol, biodiesel, and biofuel gasification programs is warranted. Local and international support for research and development is recommended, along with careful attention to developing useful distribution systems for biofuels blended with gasoline. Some of the greatest gains are likely when traditional biomass practices are integrated into ethanol bioenergy schemes in ways that both support local farmers (by providing local solid biomass for cooking) and produce ethanol or biodiesel for local consumption and regional sale. ■

For further reading see M. Ezzati and D. M. Kammen, "Evaluating the Health Benefits of Transitions in Household Energy Technologies in Kenya," *Energy Policy* (2001) 30: 815–826; M. Ezzati and D. M. Kammen, "Indoor Air Pollution from Biomass Combustion and Acute Respiratory Infections in Kenya: An Exposure-Response Study," *The Lancet* (2001), 358: 619– 24; R. Bailis, M. Ezzati, and D. M. Kammen, "Mortality and Greenhouse Gas Impacts of Biomass and Petroleum Energy Futures in Africa," *Science* 308 (2005): 98–103; E. Kituyi et al., "Biofuel Availability and Domestic Fuel Use Patterns in Kenya," *Biomass and Bioenergy* 20 (2001): 71-82; E. Kituyi et al., "Biofuel Consumption Rates and Patterns in Kenya," *Biomass and Bioenergy* 20 (2001): 83–99; and A. E. Farrell et al., "Ethanol Can Contribute to Energy and Environmental Goals," *Science* 311 (2006): 506–508.

Daniel M. Kammen (kammen@berkeley.edu) is the Class of 1935 Distinguished Professor of Energy and co-director of the Berkeley Institute of the Environment at the University of California, Berkeley, U.S.A. Kammen is also a professor in the Energy and Resources Group and in the Goldman School of Public Policy at the University of California, Berkeley, U.S.A.

International Food Policy Research Institute
2033 K Street, N.W. • Washington, D.C. 20006-1002 • U.S.A.
Phone: +1-202-862-5600 • Fax: +1-202-467-4439 • Email: ifpri@cgiar.org
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