Sustainable Bioenergy: A Framework for Decision Makers

UNITED NATIONS

UN-Energy

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Preface

In our first paper, UN-Energy focused on "The Energy Challenge for Achieving the Millennium Development Goals." We pointed out that available energy services fail to meet the needs of the world's poor, with 2.4 billion people relying on traditional biomass for their energy needs and 1.6 billion not having any access to electricity. The basic commitments to poor people cannot be met without a far more focused approach to energy services.

At the same time, awareness has grown across the world of the impact of human energy consumption on our environment, and specifically on our global and regional climate. Whatever the optimal energy mix, it is clear that nations face tough choices in their approach to sources of energy.

It is no surprise, then, that global interest in bioenergy has grown rapidly in recent years. From being merely an interest of marginal innovators, it has become a multibillion dollar business—transforming economies—thanks to rising attention and support from governments and the public. What could be more appealing than home-grown energy, essentially created by sun-and-water-fuelled photosynthesis, with new jobs and development opportunities to be tapped?

Yet, nothing human or ecological is straightforward. And so it is with biofuels, perhaps particularly liquid biofuels. Will biofuels push out food crops, raise food prices, and exacerbate food security? Will biofuels create unexpected negative rather than positive external environmental effects? Could biofuels even exacerbate the impact on climate when the entire production chain is taken into account? How will increased investment in biofuels affect trade patterns? What would a sustainable approach to bioenergy look like? These questions need to be addressed.

In this latest publication, UN-Energy seeks to structure the approach to the current discussion on bioenergy. "Sustainable Bioenergy: A Framework for Decision-Makers" is the contribution of the UN system to the issues that need further attention, analysis, and valuation, so that appropriate trade-offs can be made and both the energy needs of people met and the local and global environment adequately protected. We hope that development partnerships at the country level as well as the management of global issues will be helped by our articulation of the issues.

UN-Energy is a collaborative framework for all UN bodies that contribute to energy solutions. It was born out of the 2002 World Summit on Sustainable Development (WSSD) in Johannesburg, South Africa. Based on the Summit's outcomes and action plan, it brings together the top-level energy managers of the UN system in a modest, collective approach to inform analysis, inspire dialogue, and ultimately promote action by governments, energy stakeholders, and multilateral organizations. We do not replace inter-governmental policy dialogue. Nor can we match the resources of the private sector and civil society.

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However, rooted in the multilateral frameworks of the Millennium Summit, Financing for Development, the WSSD, and the World Summit of 2005, we hope to use the collective strength of the UN system to effect change.

This paper was sponsored by the Food and Agriculture Organization (FAO), drawing on important support from the Worldwatch Institute in creating the document. Many members of UN-Energy have contributed actively. We are grateful to all, and in particular to the Vice Chair of UN-Energy, Gustavo Best of FAO. In the spirit of our chosen method of work, this is a joint product. We hope that you will find it inspirational reading.

Mats Karlsson

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CHAIR, UN-ENERGY
APRIL 2007

Section 1: Purpose of the Paper

This paper on sustainable bioenergy was drafted collectively by UN-Energy members, which include all of the United Nations (UN) agencies, programmes, and organizations working in the area of energy, reflecting their insights and expertise. It is intended to contribute to international discussions on the strategies and policies needed to ensure economic, sustainable, and equitable development of bioenergy in the years ahead.

UN-Energy uses the definition of sustainable development adopted by the UN Commission on Sustainable Development (CSD), i.e., "development that meets the needs of the present without compromising the ability of future generations to meet their own needs."

The paper points to key social, economic, and ecological sustainability issues raised by the rapid development of bioenergy in both small- and large-scale applications. It encompasses the entire bioenergy value chain, from production to use, with the goal of providing a framework for decision-makers who are considering adopting new policies or launching new investments in the bioenergy sector. It is not designed to provide prescriptive measures, but rather to identify areas that require priority attention at the national and international levels.

The paper encompasses all bioenergy systems but focuses in particular on modern bioenergy, which includes liquid biofuels, biogas, and solid biomass for heat and power generation. Traditional use of bioenergy, in the form of inefficient direct combustion, is prevalent in many poor rural regions but is not the primary focus of this document. Because of rapidly increasing attention to liquid biofuels, this paper discusses these in more detail than other forms of modern bioenergy.

The issues raised by bioenergy development are complex and highly dependent on local circumstances (climatic, agronomic, economic, and social), such that sweeping generalizations about the efficacy of particular approaches are rarely valid. The paper is intended to raise key questions and explain the principal trade-offs involved in bioenergy development, and to contribute to both the international discourse on these issues and the informed decision-making of policy makers.

Growing commitments to bioenergy in recent years are based on studies showing that the diversification of energy supplies can contribute to both economic and environmental goals, including the UN Millennium Development Goals (MDGs), adopted in 2000.

The paper adopts the following outline. Section 2 describes the role of bioenergy in the global energy context, including the potential benefits and trade-offs. Section 3 provides a framework for decision-makers to consider nine key sustainability issues facing bioenergy development:

1. *The ability of modern bioenergy to provide energy services for the poor;*
2. *Implications for agro-industrial development and job creation;*
3. *Health and gender implications;*
4. *Implications for the structure of agriculture;*
5. *Implications for food security;*
6. *Implications for government budget;*
7. *Implications for trade, foreign exchange balances, and energy security;*
8. *Impacts on biodiversity and natural resource management; and*
9. *Implications for climate change.*

Section 4 concludes that bioenergy should continue to be discussed at the national and international levels and offers a brief framework for action. Section 5 provides a list of sources and suggestions for further reading.

Section 2: Bioenergy in the Global Energy Context

Bioenergy, defined as energy produced from organic matter or biomass, has recently become one of the most dynamic and rapidly changing sectors of the global energy economy. Accelerated growth in the production and use of bioenergy in the past few years is attracting interest from policy makers and investors around the globe.

Modern bioenergy technologies[1] that produce heat, electricity, and transport fuels are advancing rapidly, with much of the recent interest focusing on liquid biofuels, in particular ethanol and biodiesel. The United States and Brazil dominate today's liquid biofuels industry, but many other governments are now actively considering the appropriate role for biofuels in their future energy portfolios.

"The gradual move away from oil has begun. Over the next 15 to 20 years we may see biofuels providing a full 25 percent of the world's energy needs." —Alexander M ller, Assistant Director-General for the Sustainable Development Department, FAO

Global production of biofuels alone has doubled in the last five years and will likely double again in the next four. Among countries that have enacted new, pro-biofuel policies in recent years are Argentina, Australia, Canada, China, Colombia, Ecuador, India, Indonesia, Malawi, Malaysia, Mexico, Mozambique, the Philippines, Senegal, South Africa, Thailand, and Zambia.

"[Bioenergy] is an opportunity to add to the world supply of energy to meet the enormous growing demand and hopefully to mitigate some of the price effects. It's an opportunity to do so in an environmentally friendly way and in a way that is carbon-neutral. It's an opportunity to do so in a way that developing countries like Brazil can provide income and employment for their people." —World Bank President Paul Wolfowitz.

Three times in the past three decades, oil-dependent economies have been affected by dramatic oil price increases—in the mid 1970s, the early 1980s, and the current period (2004–07). Oil imports now consume a large and unsustainable share of the meagre foreign exchange earnings of many poor nations, in some cases offsetting any gains from recent foreign debt elimination agreements. In some countries, the foreign exchange drain from recent higher oil prices was five times the gain from recent debt relief.

Unstable and unpredictable oil prices have complicated economic planning around the world, and market analysts expect this pattern to persist. Oil production has already peaked in a long list of major oil producing nations, including Indonesia, Mexico, Norway, the United Kingdom, and the United States. The International Energy Agency projects that oil prices will remain in the $48–$62 range through 2030.[1] In addition to the price level, the dramatically increased volatility of oil prices that began in 2004 is further damaging poor economies.

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Africa's current oil crisis is "an unfolding catastrophe that could set back efforts to reduce poverty and promote economic development for years." —Abdoulaye Wade, President of Senegal

Recent oil price increases have had devastating effects on many of the world's poor countries, some of which now spend as much as six times as much on fuel as they do on health. Others spend twice the money on fuels as on poverty reduction. At a time when energy analysts predict a period of

[1] Modern bioenergy refers to biomass that may be either burned directly, further processed into densified and dried solid fuels, or converted into liquids or gaseous fuels using so-called first- or second-generation technologies, depending on their level of development.

Section 2: Bioenergy in the Global Energy Context

unpredictable oil markets, with prices dependent on developments in some of the world's least stable regions, fossil fuel dependence has become a major risk for many developing economies. In such national settings, the macroeconomic benefits of channelling fuel revenues into poor, rural economies could be substantial.

With oil production already in decline in many nations, greater biofuel use could help bring the oil market into balance and greatly reduce oil prices. For countries that obtain 50–100 percent of their modern energy from an increasingly unstable world oil market, the arguments for supply diversification are strong. Many of these nations lie in tropical zones where relatively low-cost biofuel crops, such as sugar cane and oil palm, already grow. In this context, 12 African nations joined Senegal in 2006 in forming the Pan-African Non-Petroleum Producers Association, aimed in part at developing a robust biofuels industry in Africa. The idea behind such efforts is to divert a portion of the money now being sent abroad to pay for oil to local agricultural and manufacturing sectors, where it would strengthen economies and generate employment.

Modern bioenergy can also help meet the needs of the 1.6 billion people worldwide who lack access to electricity in their homes, and the 2.4 billion who rely on straw, dung, and other traditional biomass fuels to meet their energy needs. Locally produced bioenergy can provide energy for local agricultural, industrial, and household uses, in some instances at less than the cost of fossil fuels.

The rapid development of modern bioenergy worldwide clearly presents a broad range of opportunities, but it also entails many trade-offs and risks. Experience with the associated economic, environmental, and social impacts is limited, and the types of impacts will depend largely on local conditions and on policy frameworks implemented to support bioenergy development. Agricultural policy, including the availability of rural infrastructure, credit, and land tenure, will determine the scale and distribution of economic benefits. At the international level, efforts to reduce agricultural subsidies in rich countries and to allow free trade in agricultural commodities are inextricably linked to the development of first-generation[2] liquid biofuels which have become the fastest growing segment of the world agriculture market. Trade reform efforts will both have powerful effects on and be subject to sizable impacts from biofuels expansion.

The development of new bioenergy industries could provide clean energy services to millions of people who currently lack them, while generating income and creating jobs in poorer areas of the world. But rapid growth in first-generation liquid biofuels production will raise agricultural commodity prices

MODERN BIOENERGY CAN ALSO HELP MEET THE NEEDS OF THE 1.6 BILLION PEOPLE WORLDWIDE WHO LACK ACCESS TO ELECTRICITY IN THEIR HOMES, AND THE 2.4 BILLION WHO RELY ON STRAW, DUNG, AND OTHER TRADITIONAL BIOMASS FUELS TO MEET THEIR ENERGY NEEDS.

and could have negative economic and social effects, particularly on the poor who spend a large share of their income on food. In many countries, the current structure of agricultural markets means that the bulk of the profits go to a small portion of the population. Unless ownership is shared more equitably, this divide could become as true for energy commodities as it is for food commodities today. For instance, two companies, Cargill and Archer Daniels Midland, control more than half of the world's grain trade.

Thus, the economic, environmental, and social impacts of bioenergy development must be assessed carefully before deciding if and how rapidly to de-

[2] "First-generation" fuels refer to biofuels made from sugar, starch, vegetable oil, or animal fats using conventional technology. "Second-generation" fuels are made from lignocellulosic biomass feedstock using advanced technical processes.

velop the industry and what technologies, policies, and investment strategies to pursue. Rapid growth in liquid biofuel production will make substantial demands on the world's land and water resources at a time when demand for both food and forest products is also rising rapidly. Liquid biofuel growth has already begun to raise the prices of the world's two leading agricultural feedstock—maize and sugar—and soaring palm oil demand may be leading industrialists in Southeast Asia to clear tropical forests for new plantations.

The ability of various bioenergy types to reduce greenhouse gas emissions varies widely, and where forests are cleared to make way for new energy crops, the emissions can be even higher than those from fossil fuels. Unless new policies are enacted to protect threatened lands, secure socially acceptable land use, and steer bioenergy development in a sustainable direction overall, the environmental and social damage could in some cases outweigh the benefits.

The rapid advance of new crops, farming practices, and conversion technologies now under development may mitigate some of the social, environmental, and economic costs associated with large-scale production of liquid biofuels and increase their potential environmental and economic benefits. The bioenergy field is experiencing an unprecedented wave of research and development, flowing from both the public and private sectors. The timing of commercialization is uncertain, but those countries that have begun to develop bioenergy industries may be the most likely to attract investment and benefit from the resulting technology transfer.

Accelerated interest in bioenergy in the coming years will place great demands on decision-makers to evaluate and guide the development of these new industries. They will need to address chronic structural problems in agriculture, forestry, and the economy so that the economic benefits to the poor outweigh the losses. Brazil, the European Union, and the United States have already demonstrated that government regulations and tax incentives are essential to the development of modern bioenergy. The structure of these and other policies will shape the direction of the new industries in a powerful way.

Section 3: Key Sustainability Issues

Bioenergy is being used all over the world. In some instances it is truly sustainable, and in others it is highly destructive. A wide range of bioenergy types currently exists, as well as a variety of production and utilization systems that have very different social, economic, and environmental impacts. The following eight sections discuss the key issues related to the sustainability of bioenergy and raise critical questions for decision-makers to consider as they evaluate various bioenergy options.

Issue 1 — Ability of Modern Bioenergy to Provide Energy Services for the Poor

INTRODUCTION

No country in modern times has substantially reduced poverty in the absence of massive increases in energy use, and countries with higher incomes and higher human development indexes also tend to be those with higher energy consumption. For the world's poorest households, basic energy services for cooking and heating, lighting, communication, water pumping, and food processing are particularly important. Shifting these basic energy uses from traditional bioenergy (when used in unsustainable and health-damaging forms) to modern fuels and electricity is probably one of the most important and long-lasting challenges.

National and international efforts have focused on this issue for decades, and many lessons have been learned, hopefully pointing to possible solutions. Some of these efforts include the introduction of liquid petroleum gas (LPG), which in many instances, and when backed with technical and financial support mechanisms, offers an excellent manner to reduce pressure on wood demand and reduces heavy human work and smoke-related problems. Although this path does not resolve long-term sustainability worries, it establishes a context for transitioning to more sustainable and renewable resource bases in the future. Solar systems such as cookers and water heaters have had some success and will probably continue to enter poor rural societies mainly in the form of subsidised programmes. Modern bioenergy as a solution to lack of energy services by the poor fits in a context that includes many more such solutions—LPG and solar systems as well as microhydro and wind energy, to name a few.

The situation with modern bioenergy systems is more complex to assess due to the variety of options as well as trade-offs among various social, environmental, and economic sustainability goals. Some, such as more efficient cook stoves, may contribute to reduced biomass demand in many countries. Work continues to enhance efficiency, reduce costs, and better understand acceptability. Biofermentation (biogas) systems can be a first-rate solution when the necessary feedstock, water inputs, and knowledge converge. Other systems, such as small-scale biomass gasification, torrification, and charring, are still under development and demonstration, with outstanding examples in some countries. Liquid biofuels such as vegetable oils and biodiesel offer opportunities for power production at relatively small scales and, in particular, for small and medium-size electricity grids at village or community levels. The adaptation of the many existing diesel engines to use these biofuels has enormous potential. The challenge remains to break the cost and other barriers for expanded use of modern bioenergy systems, as these systems are far from reaching the levels of conversion efficiency of power plants and generators based on the combustion of solid biofuels or biogas.

ISSUES THAT NEED TO BE ADDRESSED IN THE LOCAL CONTEXT

A. Resource Availability and Competing Uses

Key issues with any energy source are physical availability and access (mainly location of demand and supply, and purchasing power versus cost). A key concern in poor rural areas is the competition of biomass energy systems with present use of biomass resources (such as agricultural residues) in applications such as animal feed and bedding, fertiliser, and construction materials. These may be of higher priority to rural populations, as alternatives might not exist. Thus, a very detailed and participatory resource assessment must be done before initiating action on bioenergy systems using existing resources.

B. Economic Access, Reliability, & Accessibility

Economic access by poor rural societies to different bioenergy options is a key matter. In many cases, it is precisely their low economic level that prohibits these populations from purchasing modern energy services and makes them rely on wood fuels and residues from their own land, or on other non-commercial fuels acquired from public or open-access lands or traded informally (in the case of solid fuelwood and some agricultural residues). In the case of bioenergy for cooking, the cost and efficiency of a stove or other systems such as biogas or small gasifiers is often a greater barrier to uptake by consumers than the actual cost of fuel, which is still practically zero in many areas.

The level of trade in fuelwood (and in some areas, agricultural residues) is on the increase, and the poorest of the poor are struggling increasingly to meet even their minimum requirements. Liquid biofuels, where feedstock cost sometimes represents 75–90 percent of the cost of the fuel, can be an interesting option for rural areas where local availability and reliability of supply are high, if overall production costs are competitive with alternative energy sources. (The share of the cost from feedstock depends on the scale of production as well as the type of biofuel: it tends to be higher for smaller-scale production, and higher for alcohol-based ethanol than for methyl-ester biodiesel.) In remote rural areas or on islands, where fossil fuel prices are usually high due to transport costs, bioenergy systems may prove to be the most economical option.

Bioenergy options such as small- and medium-scale biogas or gasifiers and power generators operating with locally available biomass sources such as vegetable oils, biogas from manure, and agricultural and forestry by-products can become in some areas the most economical and reliable providers of energy services for the poor. Reliability, local maintenance and monitoring capacity, and accessibility of the technologies needed to make use of these resources are in many cases the key barriers.

Section 3: Key Sustainability Issues

BOX 1.

FOSTERING JATROPHA BIOENERGY IN MALIAN VILLAGES

Since 1999, a local NGO in Mali called the Mali-Folkecenter Nyetaa (MFC Nyetaa) has been working on the promotion of jatropha, an oilseed plant, as a source of local bioenergy. MFC Nyetaa represents Denmark's Folkecenter for Renewable Energy and is supported by global partners including UNEP, UNDP, and the Global Village Energy Partnership (GVEP).

MFC Nyetaa's interest in jatropha stems from two main observations. First, because the plant is resilient enough to grow in the fragile and arid Malian environment, it can be cultivated on substandard land and help restore eroded areas, effectively generating clean energy while helping to reduce carbon dioxide emissions and revitalise local ecosystems. Second, Mali depends heavily on fossil fuel imports to meet its modern energy needs. Jatropha provides a viable energy alternative and has vast potential for building a vibrant and dynamic local economy in remote villages, adding value locally and generating employment and income through the sale of seeds and sub-products.

MFC Nyetaa's projects focus on several aspects of jatropha production and use, including plantation, use as a living hedge, soap making, use as a diesel substitute for transportation, and power generation for rural electrification. In the village of Tiécourabougou, the group launched the idea of "energy service centres" built around jatropha. Some 20 hectares of plantations grow seeds for producing jatropha oil, which is used as fuel to power activities like millet grinding and battery charging. Villages within a 20-kilometer radius also benefit from these services.

In collaboration with its partners, MFC Nyetaa has embarked on a large-scale, 15-year jatropha-fueled rural electrification project in the village of Garalo in southern Mali. The project will set up 1,000 hectares of jatropha plantations to provide oil for a 300-kilowatt power plant. The facility aims to provide electricity and other modern energy services to more than 10,000 residents, potentially transforming the local economy.

IMPLEMENTATION ISSUES

A. Financing

Financing has a unique connotation when focusing on the poorest sectors of rural populations. In these cases, the main objective should be to provide the means (including the minimum levels of energy services) to allow these populations to move out of extreme poverty. "Financing development" is an approach that has been applied widely in many countries, with subsidies being granted for electricity and in many cases liquid fuels for operating water pumps and other devices. The key issues are level, timescale, and conditions. For example, with regard to conditions, subsidized finance could tie policy support specifically to least-cost energy options.

A commonly accepted concept is that subsidies for energy sources and/or services should be transparent and linked to the economic development they are supposed to promote. Subsidies should "accompany" development and, if successful, ultimately become unnecessary. To date, consumption of domestically produced liquid biofuels has always depended on government support, but additional measures may be necessary for small-scale farmers if they are to be included in medium- or large-scale biofuel crop production. This support can be in the form of policies supporting decentralised production, local use of the energy produced, and organization of cooperatives or other forms of participation.

Financial development instruments vary greatly, in some cases targeting the price (price support measures), the consumer (bank loans for purchasing end-use equipment), or the producer (helping entrepreneurs invest in production facilities, tax breaks, etc.). The universe of prospective beneficiaries includes instances where pro-poor energy services are economically viable, competitive, and/or affordable without subsidies, but do not get off the ground due to lack of access to upfront finance. It also includes beneficiaries that are never competitive or affordable, but that justify subsidies due to their dramatic public benefits.

In many developing countries, small-scale bioenergy projects could face challenges obtaining finance from traditional financing institutions, as such initiatives generally have a less favourable risk rating compared to more well-established energy technologies. Although these projects could be critical in providing modern energy services to populations currently lacking access, they will likely require an effective microcredit or other alternative credit delivery mechanism to assist at all stages—plantation, oil extraction (in the case of oil seeds), conversion, distribution, and end-use. Financial institutions with a network of branches and expertise in microcredit (e.g., Grameen Banks) are best qualified to fulfil this requirement; however, they may perceive a high risk given the current absence of strong market and other linkages in bioenergy development. As mentioned before, this risk perception may need to be addressed through policy and technical support measures in the initial stages.

IN MANY DEVELOPING COUNTRIES, SMALL-SCALE BIOENERGY PROJECTS COULD FACE CHALLENGES OBTAINING FINANCE FROM TRADITIONAL FINANCING INSTITUTIONS...

BOX 2.

PUBLIC-PRIVATE INVESTMENT FUND TO REDUCE GHG EMISSIONS IN ECONOMIES IN TRANSITION

Since 1991, the Energy Efficiency 21 Project (EE21) has worked to achieve sustainable development in the energy sector at a regional level. EE21's main objective is to assist Southeast European (SEE) and Eastern European, Caucasus, and Central Asian (EECCA) countries to enhance their energy efficiency, diminish fuel poverty, and meet international environmental treaty obligations under the UN Framework Convention on Climate Change and the UN Economic Commission for Europe (UNECE). EE21 focuses on developing the skills of private and public sector experts at the local level for energy efficiency and renewable energy investments.

A new phase of the project will provide for a Public-Private Partnership Fund dedicated to financing energy efficiency and renewable energy investments in selected UNECE transition economies. The objective is to form an energy-efficiency market in SEE and EECCA countries so that cost-effective investments can provide a self-financing method for reducing global greenhouse gas emissions. The project is intended to complement other financing schemes and initiatives and to help participating countries address the financial, technical, and policy barriers to energy efficiency and renewable energy investments, including bioenergy investments.

In cases where bioenergy development requires considerable investments, such as large-scale ethanol or pellet production, appropriate financing mechanisms will be important. Businesses, companies, and communities investing in the new technologies will need access to finance, risk guarantees, and/or innovative mechanisms such as microcredit or cooperative investing platforms.

More broadly, there are different roles to be played by private banks (in physically providing the actual loans or credits) and public banks (in hedging the risk or giving guarantees). In the case of foreign direct investment, export credit agencies or multilateral banks could provide the guarantees, while in the case of domestic investments, banks with a national scope may be better poised to play a role.

BOX 3.

FINANCING SMALL-SCALE BIOENERGY PRODUCTION AND USE IN INDIA[ii]

Experience in biofuel crop financing is very limited in India. Apart from technological inhibitions, financiers are concerned about oilseed supply risks and return on investments, since productivity is currently inconsistent. Land productivity and oil yield are major concerns of bankers providing microcredit to small farmers. Therefore, research and development examining technical options to increase the yield and reduce production volatility is needed.

The perceived risk of crop failure means financiers need appropriate mitigation measures—for example, crop insurance, strong technical assurances through availability and use of best crop varieties and practices, and assured market linkages (such as linkages through contract farming for big buyers).

Issue 2 — Implications for Agro-Industrial Development and Job Creation

INTRODUCTION

Traditional bioenergy provision is labour intensive and thus a significant source of formal and informal employment in developing countries. Modern bioenergy provision can also be labour intensive, particularly compared with producing energy from fossil fuels and other renewable sources. Bioenergy is powering new small- and large-scale agro-industrial development and spawning new industries in industrialised and developing countries alike.

ISSUES THAT NEED TO BE ADDRESSED IN THE LOCAL CONTEXT

A. Types of Agro-Industry to Be Developed: Short- and Long-Term

In the agro-industrial context, it is important to distinguish between "raw" versus "processed" bioenergy sources—e.g., the raw bagasse (sugarcane pulp) generated in sugar mills, which can be used to generate heat and power, versus the processed sugar that becomes a fuel in the form of ethanol. Biomass can be used for industrial applications in solid, liquid, or gaseous form (for heat, mechanical power, electricity, and transport fuels) and combusted in either pure form or integrated energy systems. Common integrated practices include co-firing biomass with coal, co-firing biogas or biofuels with natural gas or diesel (respectively) for heat and power generation, and blending biofuels with transport fuels.

In the short-to-medium term, bioenergy use will depend heavily on feedstock costs and reliability of supply, the cost and availability of competing energy sources, and government policy decisions. Established technologies with solid track records—such as ethanol and biodiesel production and biomass combustion—will predominate, while up-and-coming technologies, such as modern biogas utilization, will gain market share. New, smaller-scale industries can be expected to arise in feedstock pre-processing and biofuel post-processing—e.g., fuel densification and drying, biogas cleanup and compression. Supportive industries (e.g., maintenance of bioenergy hardware, feedstock and biofuel logistics) will grow in parallel to the development of bioenergy markets.

In the long term, the relative economics of bioenergy will likely improve as agricultural productivity and agro-industrial efficiency improve, as more-supportive agricultural and energy policies are adopted, as carbon markets mature and expand, and as new methodologies for carbon sequestration accounting are developed. At the same time, technological advancement will reduce costs and foster the emergence of a variety of new products, including advanced biofuels like cellulosic ethanol (ethanol made from cellulose rather than sugar or starch) and bio-based synthetic diesel fuel, as well as an array of co-products. Advanced biofuels, also called "second-generation" biofuels, are fuels made from inedible plant material (i.e., lignocellulosic biomass) using advanced technical processes.

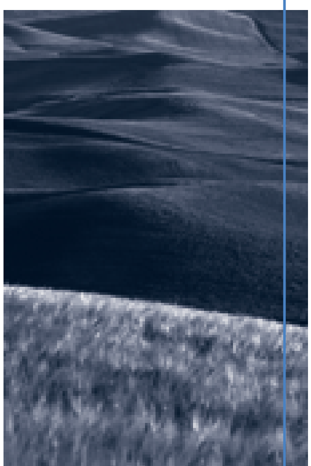
There are two basic pathways for converting cellulosic biomass into liquid transport fuels: (1) using enzyme-enhanced fermentation to convert crop residues, perennial grasses, and other cellulosic material into ethanol, and (2) using gasification and Fischer-Tropsch synthesis (also called FT diesel, or biomass-to-liquids, BtL) to convert woody biomass into synthetic biodiesel (and potentially other products). Demonstration plants exist for lignocellulosic ethanol in Canada and BtL in Germany, and pilot-scale pre-commercial plants are currently being built. Both routes can make use of non-edible crops, reducing potential competition between food and fuel, and convert the whole plant material into useable energy, making their efficiency far higher than today's plant oil or starch-based first-generation biofuels. These technologies are expected to become commercially available before 2015.

Other pathways to advanced biofuels are also being researched, for example HTU (Hydro Thermal Upgrading) diesel, which makes use of moist biomass, and biomethane from biogas and gasified wood. Other research is investigating the production of biofuels from algae, which could be grown in ponds or photoreactors. If and when second-generation biofuels become competitive with petroleum-based fuels—some estimate that this could happen in the next 10–15 years—liquid biofuels will have a good chance of achieving low carbon dioxide abatement costs while providing a host of other environmental and social benefits.

B. Scale of Bioenergy Agro-Industrial Chains

The appropriate scale of a bioenergy facility will be determined by a variety of factors, including: the feedstock chosen, proximity to markets, project goals and company objectives (e.g., local energy provision vs. production for export), type of bioenergy, and access to finance. Scalable projects will be desirable in some instances, where it is best to start with modular, experimental, and/or demonstration projects that can be enlarged or replicated as markets grow and as appropriate infrastructure, human management capacity, and awareness are developed.

IN THE LONG TERM, THE RELATIVE ECONOMICS OF BIOENERGY WILL LIKELY IMPROVE AS AGRICULTURAL PRODUCTIVITY AND AGRO-INDUSTRIAL EFFICIENCY IMPROVE, AS MORE-SUPPORTIVE AGRICULTURAL AND ENERGY POLICIES ARE ADOPTED, AS CARBON MARKETS MATURE AND EXPAND, AND AS NEW METHODOLOGIES FOR CARBON SEQUESTRATION ACCOUNTING ARE DEVELOPED.



BOX 4.

A MULTIPLYING MODEL IN BIOGAS DEVELOPMENT[iii]

Over the last 13 years, the Dutch-Nepalese Biogas Support Programme has installed more than 120,000 biogas plants in Nepal, providing approximately 3 percent of Nepalese homes with the benefits of fuel for lighting and cooking as well as reduced levels of indoor air pollution. The programme is an excellent example of how to scale up bioenergy applications. Moreover, because roughly 72 percent of the biogas plants connect to latrines, human health risks have been reduced and sanitation improved on a large scale.

This biogas programme was the first of its type to be recognised under the Kyoto Protocol's Clean Development Mechanism and has since traded certified emission reductions. Each of the 120,000 operational biogas plants is worth funds equivalent to 4.6 tons of carbon dioxide per year, or over US$18 a year based on a mid-range rate of US$4 per ton in current carbon finance markets.

Since 2003, Dutch-Vietnamese cooperation has built on the famous Nepalese experience by implementing a Biogas Programme for Vietnam's animal husbandry sector. The programme, which won an Energy Globe Award in 2006, has built approximately 25,000 biogas plants benefiting more than 100,000 people in 20 provinces. The cooperation aims to establish a commercially viable domestic biogas sector and focuses on quality assurance and the training of end users, biogas construction teams, and technicians.

Vietnamese households use the biogas for cooking and use the bio-slurry residues as crop fertilisers and fish feed. Health improvements include reduced indoor air pollution and odour as well as improved latrines, sanitation, and stable facilities. In addition, the use of biogas has freed women and children from burdens related to housework and firewood collection while also reducing deforestation.

C. Large vs. Small Companies

There is no doubt that bioenergy production will bring huge opportunities. The question is, for whom and under what conditions? Opportunities exist in feedstock production, handling, and processing; distribution and marketing; and many other facets of these new industries. Many independent entrepreneurs and small-scale farmers see the promise of bioenergy and are innovating and investing time and resources in its development.

Meanwhile, many large companies from both developing and industrialised countries are studying biofuels markets and increasingly making substantial investments. Small- and medium-sized enterprises (SMEs) might also play a major role in pioneering these markets, particularly with first-generation biofuels and in rural settings. While large players have advantages associated with economies of scale and vertically integrated agro-industrial chains, efficient clusters of SMEs could participate in different stages of those chains. In later stages, the "aggregation" of SMEs into larger firms could become attractive; this is already happening in markets where smaller producers are trying to compete in the face of increased competition.

D. Type, Quality, and Distribution of Employment

Successful bioenergy industries bring significant job-creation potential, with positions that include highly skilled science, engineering, and business-related employment; medium-level technical staff; low-skill industrial plant jobs; and unskilled agricultural labour. Because the vast majority of bioenergy employment occurs in farming, transportation, and processing, most of these jobs would be created in rural communities where underemployment is a common problem. The construction and operation of these facilities generates additional rural economic activity, since the weight and volume of most biomass crops usually makes it necessary to locate collection and conversion facilities close to where the feedstock is grown. Jobs are being created in bioenergy agro-industries in rich and poor countries alike.

However, in some cases, large-scale, mechanised farming may displace workers and poor labour conditions are associated with some large-scale agricultural plantations. The shift to biomass production for bioenergy will make it necessary to address these issues.

E. Infrastructure Considerations

Bioenergy's infrastructure requirements depend on the energy type, the distribution of feedstock sources and conversion sites, and the target end-use application. While existing roads can often support additional freight movements for feedstock in places where plant material is already transported from fields or forests, in some areas new roads will need to be constructed. Second-generation feedstock material (lignocellulosic feedstock; densified bales of switchgrass, wheat, or maize; and chips of short-rotation coppice) can be shipped long distance via waterways and railroads to centralised processing plants, although decentralised densification or chipping equipment is required.

With regard to distribution, both conventional biofuels (such as first-generation biodiesel and ethanol) and next-generation synthetic diesel and cellulosic ethanol can be mixed directly with fossil diesel and gasoline, respectively (to different levels depending on vehicle specifications). Thus, at least at low blending levels, they may pose no significant additional infrastructure needs. This is also the case for upgraded biogas or bio-based

SNG (substitute natural gas from gasification of lignocellulosic feedstock), which can be fed into existing natural-gas distribution networks. Gaseous biofuels require processing plants for gas cleanup, carbon dioxide removal, and compression.

For regional dedicated vehicle fleets running on E100 and B100 (i.e., pure ethanol and biodiesel) as well as on bio-compressed natural gas (CNG) or bio-SNG, additional investments in gas station pumps will be required. Experience in Sweden and Switzerland indicates that these costs are relatively small.

In the case of heating and industrial energy systems that rely on forest biomass, the feedstock is typically obtained from roadside chipping of collected logging residues (timber and pulpwood), from thinning sites where use of forest residues is often regarded as a bonus, or from collection sites where used wood would otherwise be transported to dumps or landfills.[iv]

F. Powering or Fuelling Other Industries

Bioenergy has implications for other industries as well. Access to new or improved energy sources can have dramatic benefits for small and large companies alike. If large upfront investment costs are required, however, small- and medium-sized enterprises (SMEs) will find it more difficult to switch fuels relative to larger enterprises that are less risk averse and have greater investment capacity.

In contrast to other renewable energy sources (such as hydro, solar, or wind), bioenergy is capable of being converted into virtually any energy service—electricity, process heat (for cooking and drying), various forms of mechanical power and steam production, etc. It is also largely independent of the short-term supply fluctuations that are typical with wind and solar energy, for instance. In addition, modern bioenergy can convert wastes into a wide range of productive uses, strengthening "co-product" industries and creating related jobs in the process (as is the case with cellulosic ethanol, wood pellets and briquettes used for heating, biodiesel derived from animal fats, and biogas from wet agricultural waste, sewage sludge, or landfill methane).

Using bioenergy as a backup or supplemental energy source can help companies reduce losses due to power outages and/or fuel disruptions. In Finland and Sweden, most of the process energy in chemical pulp mills comes from recovered pulping liquor, and sawmill and wood material industries have become fully energy self-sufficient mainly through the use of bark and sawdust. In both countries, the surplus wood from these industries fuels pulp mills, district heating plants, and even service industries and households (using wood pellets from upgraded sawdust).[v] Excellent examples of energy self-sufficiency and even of selling power to the grid come from the sugar industries of Australia, Brazil, Cuba, Guatemala, India, Mauritius, and several other countries.[vi] These industries serve as models for the 80 sugar cane-growing developing countries in which residues from sugar cane production and processing represent a vastly underutilised energy resource.[vii]

IMPLEMENTATION ISSUES

A. Why and How to Encourage Small-Scale, Local Plants

To create and maintain the bioenergy value chain, all players must operate in synchrony to deliver the product. This can be a challenge when new industries are developing and when the costs, benefits, and interests of actors within the chain differ. Thus, parallel support for the whole value chain must be considered.

This challenge will increase as the number of actors increases. In general, large-scale, vertically integrated operations have logistical and economy-of-scale advantages. But in many developing countries, industry is characterised by SMEs. There are numerous examples of successful cooperative structures where several independent SME biomass producers work together to supply larger facilities or markets. The development benefits of bioenergy are enhanced dramatically when more people own more of the value-added chain.

B. Whether and How to Encourage Job Creation

Where job creation is a high priority, the focus may include the encouragement of labour-intensive bioenergy feedstock, biodiesel versus ethanol production, and/or community-focused bioenergy applications. Of all biofuel feedstock, oilseed crops in developing countries tend to be most amenable to job creation particularly when harvested manually. Moreover, direct use of the oil is sometimes possible, and because the process of converting plant oils into biodiesel is relatively straightforward, biodiesel conversion can often occur at a smaller scale. That said, small-scale and labour-intensive production often gives rise to trade-offs between production efficiency and economic competitiveness. It is important for decision-makers to weigh achievable job-creation potential against the costs of creating and maintaining the jobs.

A few other general tendencies have emerged from the growing body of research on this topic. On average, the ratio of investment cost per job created in the bioenergy sector is lower than that in the industrial, petrochemical, or hydropower sectors. Bioenergy projects based on agriculture tend to generate more employment and earnings than their non-agricultural counterparts.

C. Testing New Fuels, Technologies, and Capacities

üuality control will be critical, particularly in the early stages of biofuel market development. Experience with new biofuel products in Australia, Colombia, and Costa Rica has shown that a few bad consumer experiences can result in large setbacks. Similarly, engine problems that have followed the deployment of a biofuel (most of which can only be partially blamed on the fuels), such as a mix of biofuel and coal-derived ethanol in South Africa, offer cautionary tales that linger long after their resolution. Moreover, an ongoing controversy involving widespread silicon-induced engine misfiring and/or loss of power in the United Kingdom raises the possibility that even misdirected perceptions of bad consumer experiences with ethanol can diminish consumer confidence in biofuels and add another variable of complexity to regulatory processes.[viii]

Avoiding such setbacks will require the development of institutional capacity to assure fuel quality, as well as international standards for both the fuels and the conversion systems (stoves, boilers, engines). Standards for solid and liquid biofuels have been developed at the national level in the European Union (for wood chips, pellets, and biodiesel) and are under development in several other countries, including China. For SMEs active in the biofuels market, checking compliance of their products with quality standards is critical; this requires capacity building as well as testing systems that are not cost prohibitive. See Issue 8, Implementation C for a discussion of sustainability standards and certification.

D. Whether and How to Create Distribution Channels

The costs and benefits of decentralised versus more-centralised bioenergy production and distribution will need to be weighed in different local and regional contexts. In the case of local production for local use, distribution is less of an issue, although achieving satisfactory fuel quality or using reliable conversion systems might be crucial. Where distribution is a greater concern, planning will be needed to distribute bioenergy domestically as well as internationally. In some areas, it may be most cost effective to retrofit existing infrastructure or to co-locate new and old distribution infrastructure. The creation of distribution channels is a serious challenge, requiring infrastructure and an integrated approach in order to avoid failures like those in the United Kingdom, where despite considerable attempts to encourage wood bioenergy development, the market never developed. Institutional development is also required, as evident in the main obstacles encountered in the implementation of cane-based bagasse co-generation efforts worldwide; a lack of standardised and enforceable power purchase agreements with electric utilities; and a lack of financing, particularly for smaller developing countries.[ix]

E. Whether and How to Encourage International Investment

Already, the private sector is undertaking serious capital investments in bioenergy production and distribution around the world, spurred in many areas by strong government incentives. In cases where these returns are less clear, however, international financial institutions (IFIs) may play a critical role in providing investment funding. For instance, in developing countries that lack the enforcement mechanisms or market incentives to successfully attract foreign direct investment, IFIs might play a role in helping to "guarantee" higher risk loans, particularly where projects have potentially large development and climate benefits.

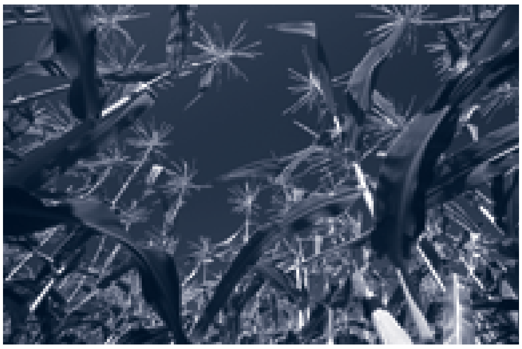
Because the production of ethanol and other biofuels would occur on a profit-making basis, the implementation of investment projects and/or programmes could be based on strategic partnerships between the private and public sectors, possibly with donor community support. The private sector could mobilise, say, the bulk but not all of the financing for the investment components (agriculture, distillation capacity, and agro-industrial systems) and would provide the necessary management capacity. Governments, in turn, would establish "private sector enabling environments" (i.e., conducive fiscal and legal regulation, basic rural infrastructure, etc.); lay down the necessary policy and regulatory frameworks to ensure a social and environmentally responsible implementation process; and underwrite new rural infrastructure investments (assets and services), as well as the rural capacity development required to underpin large private-sector scale-ups in agricultural production systems.

The successful implementation of such a partnership would require active participation by multilateral and financial institutions. Existing development cooperation budgets for energy, agriculture, rural infrastructure and development, and employment-creation programmes could be pulled together to underwrite integrated and synergic "agro-energy and rural development programmes." In the short-term, it would be essential to support pilot or demonstration projects in representative countries, through which key implementation issues could be tested and fine-tuned, and to assist governments in the elaboration of the necessary multi-sector policy frameworks (energy, agriculture, rural development, trade, etc.). In the subsequent scale-up phases, IFIs could play a key role in the mobilization of flexible "climate change" funding instruments (Global Environment Facility, carbon funds, bilateral environmental programmes, etc.) to leverage and support large private sector investments. They could also use conventional concessional financing instruments to underwrite public investments in new rural infrastructure and capacity development, as well as finance support to the private sector (via the International Finance Corporation, investment corporations, etc.)

BOX 5.

USING BILATERAL COOPERATION TO FINANCE BIOFUEL DEVELOPMENT IN BRAZIL[x]

One practical and innovative example of using bilateral cooperation to finance biofuel development is the cost-restructuring mechanism developed between Germany and Brazil to value associated greenhouse gas emissions reductions. In 2003, Germany agreed to contribute 100 million Brazilian Reais (US$32.5 million) over 10 years to the Brazilian National Vehicle Manufacturers Association (ANFAVEA) to finance the production of 100,000 additional ethanol-driven cars, thereby helping to reduce carbon dioxide emissions. The German government will also support the efforts of Brazilian state entities to achieve this reduction by awarding 1,000 Brazilian Reais (US$325) per ethanol-fueled vehicle used. In exchange, the German government will receive a certificate for the associated emissions reductions.



Section 3: Key Sustainability Issues

Issue 3 — Health and Gender Implications of Modern Bioenergy

INTRODUCTION

In most families worldwide, women are overwhelmingly the primary caretakers of the home. The world's poorest households typically depend more on basic energy services (such as heat for cooking and power for processing food) than on energy for transportation.[xi] Because traditional uses of bioenergy (e.g., direct burning of wood and other biomass) affect the health of women more severely than men, they contribute to the relative disempowerment of women as a gender group. Cooking and heating at the household level in impoverished rural areas of the developing world are two of the most critical technological and economic challenges in the energy and poverty equation.

The most dramatic gender-differentiated and health benefits from modern bioenergy use relate to household applications. Dubbed the "kitchen killer," smoke inhalation from cooking with traditional biomass indoors is one of the leading causes of disease and death in the developing world, responsible for more fatalities each year than malaria. Generally, the poor in Southeast Asia and Sub-Saharan Africa suffer the highest death toll, above that in Latin America and the Caribbean, Eastern Europe, and the Mediterranean.

Household use of traditional bioenergy locks people in the developing world, particularly women, into a cycle of poverty and ill health. Access to more-efficient technologies and modern energy sources, in contrast, can reduce health and safety problems associated with energy acquisition and use, help lift people out of poverty, and enable women and girls to live more productive and enjoyable lives.

ISSUES THAT NEED TO BE ADDRESSED IN THE LOCAL CONTEXT

A. Ability to Reduce Indoor Air Pollution, Lower Infant Mortality, and Raise Life Expectancy

The current deadly situation in poor households dependent on traditional biomass could be improved dramatically by: (1) promoting more efficient and sustainable use of traditional biomass; and (2) enabling people to switch to modern cooking fuels and technologies.

The appropriate strategy will depend on local circumstances. Generally, where substitution for modern alternatives is not (yet) feasible, and where dependency on traditional fuels will likely continue (as in the next 2–3 decades in Africa), traditional bioenergy use must be improved and made sustainable. New fuels must meet users' needs, and analysis must be undertaken to assess whether there will be competition between bioenergy for cooking and for other purposes (such as use in the transport sector, in the case of liquid biofuels).

Clean energy sources, including modern biomass-derived cooking fuels, can drastically reduce harmful indoor air pollution, leading to reductions in respiratory diseases such as pneumonia in children and chronic obstructive pulmonary disease in adults, particularly women. Biomass-derived cooking fuels provide one option for such energy upgrading. It is critical to ensure that these fuels and associated technologies are designed to minimise harmful emissions and that their use is safe. This requires attention to safe storage as well as the risk of burns and explosions.

Health risks associated with the production of biomass feedstock are similar to those of modern agriculture, including exposure to pesticides (if used) and the operation of hazardous machinery. With regard to decentralised liquid or gaseous biofuel conversion, small-scale plants need special concern for labour safety, as hazardous or explosive materials such as methanol or methane are processed. See Issues 7 and 8 for more on broader health risks of large-scale production, including risks associated with genetically modified organisms (GMOs) and emissions, as well as potential benefits including the role of sustainable bioenergy in minimizing health harms from environmental shocks such as droughts and flash floods.

B. Ability to Reduce Time, Effort, and Injury Associated With Traditional Fuel Gathering and Cooking

The impacts, typically on women and girls, of walking long distances, carrying heavy loads, and collecting fuel in dangerous areas could all be reduced if physical and economic access to modern bioenergy is provided. In the worst cases, women and young girls have been the targets of assaults and rapes while collecting fuel away from the safety of their homes. While modern biofuels free women from collecting firewood, however, they could also generate additional work if women produce the biomass to make the fuel (such as for biogas).

Women suffer lifelong harm due to the literacy and economic opportunities they forgo when they are withdrawn from school to gather fuel and attend to other domestic chores. Women who have access to modern fuels face a lighter cooking burden, which frees up more time to pursue educational, social, and economic opportunities. They are also more likely to have the chance to partake in wider networks and to seek opportunities for self improvement and social engagement through enhanced access to radio, television, and other communications technologies.

Women who enjoy higher levels of health, literacy, and formal employment tend to give birth to fewer children. Their increased self-esteem and ability to make decisions about their own lives make them more willing and able to postpone and avoid reproduction.

C. Ability to Minimise Public Health Risks from Oxygenate Use in Transport Fuels

Airborne lead poses a serious yet tractable public health risk, particularly to children. Phase-outs of tetra-ethyl lead additives in gasoline have reduced public exposure to lead particles in most regions, with the exception of a handful of countries where leaded gasoline is still common. High lead exposure can cause adverse neurological effects, leading to concerns such as hypertension, high blood pressure, heart disease, learning impairments, and intelligence deficits. The health benefits of phasing out lead from gasoline far outweigh the economic and other costs. Modern biofuels could leverage social and macroeconomic co-benefits that do not accompany alternative additives and lead phase-out strategies.

HEALTH RISKS ASSOCIATED WITH THE PRODUCTION OF BIOMASS FEEDSTOCK ARE SIMILAR TO THOSE OF MODERN AGRICULTURE, INCLUDING EXPOSURE TO PESTICIDES (IF USED“ AND THE OPERATION OF HAZARDOUS MACHINERY.

Methyl tertiary butyl ether (MTBE), an alternative oxygenate additive and possible carcinogen, can threaten public health via leaks and spills into groundwater, in which it degrades very slowly.

In addition, raising the concentration of aromatic compounds in gasoline can increase risks from benzene exposure.

While the combustion of pure ethanol does not pose any major public health risk, a possible public health disadvantage to the use of ethanol as an alternative gasoline oxygenate is that in blends, ethanol fuels may bring about higher emissions of acetaldehyde, a suspected carcinogen. To date, all gasoline blends appear to have some kind of health shortcoming, and the relative merits of different blends continues to be subject of scientific and policy debate.[xii]

IMPLEMENTATION ISSUES

Production capacity and distribution networks for cleaner-burning and more-efficient stoves and modern biofuels will need to be developed in many regions. Women will also need greater access to credit, carbon funds, information, and other resources that enable them to learn about and decide to obtain modern biomass resources and technologies. This could have a significant impact on renewable energy markets while also reducing the health and environmental impacts of energy use.

In addition to access to finance and better products and technologies, human capital development will be vital. Public acceptance will require education and awareness-raising that is targeted to each specific group in an appropriate way. Other implementation issues with regard to health and gender are similar to those pertaining to Issue 1.

BOX 6.

PHILIPPINE STOVE AND BIOFUEL COOPERATIVE: AN INNOVATIVE PUBLIC-PRIVATE PARTNERSHIP [xiii]

A new cooking stove that can run on kerosene as well as a number of plant oils (including jatropha, peanut, sunflower, and used cooking oil) is being developed and disseminated in the Philippines. The stove is easy to operate and mostly manufactured locally in order to increase purchasing power and keep production costs low. It is the result of an innovative public-private partnership between the University of Hohenheim (Germany), the Bosch and Siemens Home Appliances Group, the European Nature Heritage Fund (Euronatur, Germany), the German Ministry for Economic Cooperation and Development (BMZ), and Leyte State University (Philippines).

More than 100 Philippine households and small restaurants have tested the stove, which sells for approximately US$38. The partnership expects the price to go down as production becomes more cost-effective. The stove poses no risk of explosion or uncontrolled burning, and emissions are 10 times lower than those of high-quality kerosene stoves. Moreover, the cooking time is 30–40 percent shorter than that of firewood stoves, substantially reducing women and children's exposure to indoor air pollution and freeing up time for other productive activities.

The partnership also provided initial financing for a local coconut oil production cooperative involving 400 Philippine families. A coconut garden smaller than 25 by 40 square meters can supply about two liters of oil per week, enough to fuel the stove for the average Philippine family (5.2 persons). Using coconut press cake residues as animal fodder, the cooperative has achieved a 20-percent increase in revenue and managed to supply coconut oil at a lower price than kerosene (US$0.55 per liter versus US$0.69 per liter, although at least part of this difference can be attributed to a much higher tax rate on kerosene).

Section 3: Key Sustainability Issues

Issue 4 — Implications for the Structure of Agriculture

INTRODUCTION

Modern bioenergy in its many forms holds promise for new jobs and income creation opportunities for rural farmers, foresters, and labourers, as well as improved access to and quality of energy services. At the local level, enhanced access to energy is important for improving agricultural productivity and profitability. Energy is also required for post-harvest value-added activities such as processing, packaging, and transport.

The benefits to farmers are not assured, however, and may come with increased costs for others. First, the demand for land to grow bioenergy crops could put pressure on competing land uses for food crops, resulting in a likely increase in food prices. Second, as with many industrial activities, significant economies of scale can be gained from processing and especially distributing biofuels on a large scale, as illustrated by the prevailing trend towards concentration of ethanol ownership in Brazil and the United States—thus favouring large producers. The transition to liquid biofuels can be especially harmful to farmers who do not own their own land, and to the rural and urban poor who are net buyers of food, as they could suffer from even greater pressure on already-limited financial resources. This is one of the most significant threats associated with liquid biofuel development and calls for careful consideration by decision-makers.

At their best, liquid biofuel programmes can enrich farmers by helping to add value to their products. But at their worst, biofuel programmes can result in concentration of ownership that could drive the world's poorest farmers off their land and into deeper poverty. Most likely, the biofuel economy of the future will be characterised by a mix of production types, some dominated by large, capital-intensive businesses, some marked by farmer co-ops that compete with large companies (possibly protected by supportive policies), and some where liquid biofuels are produced on a smaller scale and used locally. Regardless of the scale of production, however, one thing is clear: the more involved farmers are in the production, processing, and use of biofuels, the more likely they are to share in the benefits.

The second generation of liquid biofuel production facilities will create a market for far greater amounts of agricultural biomass, and promises to create higher-value co-products (and thus greater wealth generation). However, it will also require the

THE MORE INVOLVED FARMERS ARE IN THE PRODUCTION, PROCESSING, AND USE OF BIOFUELS, THE MORE LIKELY THEY ARE TO SHARE IN THE BENEFITS.

development of more capital-intensive, complex production facilities, giving a further edge to large companies. Already, large investments are signalling the emergence of a new "bio-economy" in the coming decades. They also point to the possibility that still-larger companies may enter the rural economy, putting the squeeze on farmers by controlling the price paid to feedstock producers in a given area and owning the rest of the value chain. If so, the real profits are likely to go not to those who can produce large quantities of feedstock, but to those with the proprietary technology to ply this biomass into fuels and products. Thus, the entire bioenergy chain needs to be analysed in order to identify and overcome actual and/or potential barriers and inefficiencies.

Forestry-based bioenergy, such as that derived from wood pellets and wood chips, can create new opportunities for small- and medium-sized enterprises (SMEs). In general, forest products and perennials will play an important role in the future of bioenergy.

ISSUES THAT NEED TO BE ADDRESSED IN THE LOCAL CONTEXT

A. Which Crops Are Most Promising?

The diversity of potential liquid biofuel feedstock is both an advantage and a disadvantage. It enhances the security of supply and increases the resilience and ecological benefits of biomass production systems, compared with monocultures of one or a few crops. On the other hand, a range of potential feedstock with differing physical and chemical characteristics creates challenges for handling and processing. It can also result in differing characteristics of the final biofuel product.[3]

Much work remains to be done to determine which crops and crop species are most suitable for different liquid biofuel applications, soil types, farming systems, and cultivation contexts. Key factors to be considered when selecting feedstock include: economic viability, suitability for different biofuel applications, yield per hectare, input requirements, yield increase potential, crop versatility, drought and pest resistance potential, competing uses, price volatility, and opportunity costs. (See Table 1 for a comparison of various feedstock types.)

[3] This highlights the need for internationally agreed-upon fuel specifications and certification/labeling systems.

Table 1. Preliminary Assessment of Biofuels Feedstock

CROP TYPE	CROP REQUIREMENTS			
	SOIL	**WATER**	**NUTRIENTS**	**CLIMATE**
Cereal	less disruption of soil; very constant yield; humus balance is negatively influenced by annual removal of straw	–	medium	moderate
Hemp	deep soil with good water supply, pH balance between 6 and 7	some moisture the entire season	moderate, no pesticide needed	varied environmental conditions, preferably warmer climates
Jatropha	undemanding, does not require tillage	can be cultivated under both irrigated and rain-fed conditions	adapted to low fertility sites and alkaline soils, but better yield can be achieved if fertilisers are used	Tropical and subtropical but also arid and semiarid.
Maize	soil should be well-aerated and well-drained	efficient user of water	require high fertility and should be maintained continuously	temperate to tropic conditions
Miscanthus	good water supply, brown soils with high humus percentage, optimum pH between 5.5 and 7.5	crucial during the main growing seasons	low	adapted to warmer climates but fairly cold-tolerant
Oil Palm	good drainage; pH between 4 and 7; soil flat, rich, and deep	even distribution of rainfall between 1,800 and 5,000 throughout the year	low	tropical and subtropical climate with temperature requirement of 25–32°C
Poplar	deep, moist soil, medium texture, and high flood tolerance	high; irrigation may be needed	high	arctic to temperate
Potato	deep, well-drained, friable, well-aerated, porous, pH between 5 and 6	high; irrigation required	high fertiliser demand	optimum temperature of 18–20°C
Rapeseed	mild, deep loamy, medium texture, well-drained	600 mm minimum yearly precipitation.	similar to wheat	sensitive to high temperatures, grow best between 15 and 20°C
Rice	needs permeable layer and good drainage	very high, grown in flooded fields	relatively high input of fertilisers, very intensive systems	constant temperatures in tropical areas, optimum around 30°C
Sorghum	light-to-medium textured soils, well-aerated, well-drained, and relatively tolerant to short periods of water logging	shows a high degree of flexibility towards depth and frequency of water supply because of drought resistance characteristics	very high nitrogen feeding crop	optimum temperatures for high producing varieties are over 25°C
Soybean	moist alluvial soils with good organic content, high water capacity, good structure, loose soil	high	optimum soil pH of 6 to 6.5	tropical, subtropical, and temperate climates
Sugarbeet	medium-to-slightly heavy texture, well-drained, tolerant to salinity	moderate, in the range of 550 to 750 mm/growing period	adequate nitrogen is required to ensure early maximum vegetative growth, high fertiliser demand	variety of temperate climates
Sugarcane	does not require a special soil type, but preferably well-aerated with a total available water content of 15 percent or more	high and evenly distributed through the growing season.	high nitrogen and potassium needs but at maturity, the nitrogen content of the soil must be as low as possible for a good sugar recovery	tropical or subtropical climate
Sunflower	grown under rain-fed conditions on a wide range of soils	varies from 600 to 1,000 mm, depending on climate and length of total growing period	moderate	climates ranging from arid under irrigation to temperate under rain-fed conditions
Switchgrass	ranging from prairies to arid or marsh	drought-resistant and very-efficient water use	low	warm-season plant
Wheat	medium textures	high	high	temperate climates, in the sub-tropics with winter rainfall, in the tropics near the equator, in the highlands with altitudes of more than 1,500 m, and in the tropics away from the Equator where the rainy season is long and where the crop is grown as a winter crop.
Willow	sandy, clay, and silt loams	substantial quantities of water	significant nutrient uptake	can tolerate very low temperatures in winter, but frost in late spring or early autumn will damage the top shoots.

Source: Daimler Chrysler, WWF, Ministry of Agriculture of Baden Wuerttemberg, and UNEP.

B. Structural Implications of Various Crops

Some feedstock is better suited for large-scale production while others are more appropriate for small-scale applications. The inedible oilseed jatropha, for example, must currently be harvested by hand, making it a labour-intensive crop and suitable for areas with underemployment problems (although work is being done to develop mechanical harvesters). In many instances, the relatively low energy density and bulky nature of biomass limit the distance that unprocessed feedstock can be transported cost-effectively. While sugar cane used for fuel ethanol production is typically grown on large plantations, the size of the cane processing plants is limited due to the fact that the crop has to be processed within 48 hours of being harvested.

Even variations of the same crop can demonstrate dramatically different agricultural structures. For instance, grain sorghum's prevalence as a staple food crop in Africa (used for flour and beer) lends support to its consideration as an ethanol feedstock for the region; however, agronomic research shows that sweet sorghum varieties (used primarily for sugars) in fact have the most optimal characteristics for ethanol production. Sweet sorghum grows rapidly, even under sub-optimal conditions (enabling it to be harvested multiple times in a year), requires less water than sugar cane, and is well suited to pooled smallholder cultivation. Additionally, some sweet sorghum varieties have biomass qualities comparable to sugar cane (i.e., the sugar from its stems can be extracted and fermented, while the fibrous residues can be used as a boiler fuel, much like bagasse from sugar cane).[xiv]

C. Historical Land Tenure, Production Chain Ownership, and Credit Availability

The poorest members of a society typically do not have official title to their land, and in some cases rely on alternative land tenure arrangements (e.g., utilizing resources on government-owned land or participating in community ownership structures). While global market forces unleashed by the merging of the agriculture and energy industries could lead to new and stable income streams, they could also increase marginalization of the poor and indigenous peoples and affect traditional ways of living if they end up driving small farmers without clear land titles from their land and destroying their livelihoods. This scenario can be avoided in the biofuels sector if strong legal structures are put in place (including land title laws) and properly enforced.

As mentioned previously, ownership of value-added parts of the production chain is also critical for realizing the rural development benefits and full economic multiplier effects associated with bioenergy. Where biomass producers have a stake in these value-added segments (e.g., in the processing stages), the benefits are manifold. First, producers are buffered from the risk of falling agricultural commodity prices, because while low prices hurt farm incomes, they can serve to benefit the bottom lines of biofuel/bioenergy production facilities and thus increase the income of those who take part in ownership. Second, farmer ownership of the processing facility reduces feedstock supply risk for the plant, since farmers have a vested interest in ensuring a high-quality supply of feedstock for the facility. Finally, the economic multiplier effect in rural communities is dramatically enhanced when farmers receive a greater share of the profits from value-added activities.

Section 3: Key Sustainability Issues

Lack of access to banking services is often a serious impediment to development in poor areas. Compounding this problem is the tendency for lenders to be wary of financing unfamiliar technologies and new business models. (See Issue 1, Implementation A for a discussion of financing options.)

IMPLEMENTATION ISSUES

A. Should Public Policy Favour Smaller-Scale Bioenergy Production?

A variety of bioenergy production scales and ownership structures are possible. These include but are not limited to small-scale local production for local use, small-scale production for local use with excess for sale, smallholder production of feedstock that is processed in a central conversion facility, feedstock purchasing from small-to-medium sized producers with concentrated ownership of processing and distribution, and concentrated ownership of the entire production chain.

Policies that affect the uncertainty of bioenergy markets are highly relevant to the scale of bioenergy production. Smaller farmers, even if highly motivated, tend to be less likely to shift their production to bioenergy, particularly if they live in marginal areas and have fewer options to counteract risks and higher discount rates—unless price expectations are very high. Relative to small-scale farmers, large-scale agricultural producers and other actors are much more inclined to enter bioenergy markets.

Policy makers deciding whether or not to specifically encourage small-scale bioenergy production might want to consider the implications of scale for public finances. All else being equal, smaller-scale bioenergy industries offer higher social returns on public investments. üuantitatively, substantial supplies and associated public revenues can still be attained on a small scale by incubating the pooling of resources, facilitating collective ownership, and enforcing fair pricing laws. Experience in Brazil, France, Germany, Mauritius, and the United States has shown that biofuel production facilities that are small and locally owned tend to bring about higher local revenues and lower social spending.

üualitatively, governments tend to get higher returns on investments by fostering small-scale production due to the lowered demand for social-welfare spending and the greater economic multiplier effects incurred where money is earned and spent by community members who obtain new or higher-paying jobs or businesses. Relative to large-scale producers, small-scale farmers or labourers generally buy more of their basic necessities and luxuries, and pay more of their sales and other taxes, near where they live and where they might have originally obtained their credit, price supports, etc. On the other hand, the social benefits associated with small-scale production may come at the cost of lower production efficiency. This means, all else being equal, that smaller-scale production will probably necessitate higher government subsidies than larger-scale production. Consequently, decision-makers face an important trade-off for the allocation of scarce government resources.

B. Role of Co-ops, Agriculture Extension Services, and Capacity Building

Local benefits can be enhanced by organizing small-scale producers as a group to meet the feedstock volume and reliability needs of conversion facilities. In areas where large corporations dominate the bioenergy industry, farmer cooperatives play a useful role in linking these large firms to independent growers.

In Mauritius, a share of the benefits from large-scale co-generation plants flows to low-income farmers as a result of both direct policy interventions and an innovative revenue-sharing mechanism.[xv] Similarly, in the two largest ethanol-producing countries, Brazil and the United States, the industry is dominated by large corporations but farmer cooperatives also play a role and bring benefits to smaller farmers.

Agricultural extension services play a critical role as well in disseminating best practices, facilitating farmer-to-farmer participatory learning, and encouraging and responding to small-farmer requests for technical advice. International capacity-building activities could help to build the know-how that is a prerequisite for extension services, thus fostering more sustainable small-scale bioenergy production.

International capacity building is particularly critical at this early stage of the bioenergy industry, where the expertise unique to bioenergy cropping practices, such as carbon-cycle cropping considerations, is concentrated in only a few countries. This remains true for low-level technologies as well as more advanced ones. In Malawi, which has been at the forefront of biofuels development in Africa, a technology transfer programme focusing on the use of biogas from stillage failed due to insufficient training and capacity-building efforts. And in Kenya, a foray into fuel ethanol fell prey to mistakes and setbacks that included large facility cost overruns, poor strategic planning and decision-making, and insufficient understanding of the economics of ethanol production. Such experiences attest to the need for international capacity-building efforts that are consistent with broader institutional goals such as good governance, administrative training, transparency, and accountability.

In this context, UN-Energy and UNESCO are leading a renewable energy review that is collecting information and organizing it into a matrix with supporting analytical text to be turned into a web-based tool. In a similar vein, FAO has developed management models aimed at increasing the competitiveness of rural agro-industries via bioenergy and has created renewable energy manuals for training agricultural and forestry extension workers. At the international level, FAO has launched the International Bioenergy Platform (IBEP) as a framework for bioenergy cooperation. It focuses on assistance to developing countries on information and data for decision-making and on methods and approaches to assess bioenergy potentials and sustainability. FAO also hosts the Global Bioenergy Partnership (GBEP), which is active in the promotion of multi-stakeholder cooperation, bioenergy trade, and biofuel sustainability.

Technical cooperation on a bilateral or trilateral basis is also playing a crucial role, including South-South partnerships between Brazil and the countries of Cameroon, Ghana, Guinea-Bissau, Mali, and Mexico (for biodiesel production) as well as South-South-North partnerships linking Brazil, India, France, and the United Kingdom to Haiti, Malawi, Mozambique, Nigeria, Senegal and South Africa (mainly for ethanol).[xvi]

INTERNATIONAL CAPACITY BUILDING IS PARTICULARLY CRITICAL AT THIS EARLY STAGE OF THE BIOENERGY INDUSTRY, WHERE THE EXPERTISE UNIQUE TO BIOENERGY CROPPING PRACTICES, SUCH AS CARBON-CYCLE CROPPING CONSIDERATIONS, IS CONCENTRATED IN ONLY A FEW COUNTRIES.