BIOMASS, LIVELIHOODS AND INTERNATIONAL TRADE

Challenges and Opportunities for the EU and Southern Africa

Francis X. Johnson
Stockholm Environment Institute, Climate and Energy Programme

and

Frank Rosillo-Calle
Imperial College London, Centre for Energy Policy and Technology

SEI Climate and Energy Report 2007-01

February 2007

Stockholm Environment Institute
Kräftriket 2B
SE -106 91 Stockholm
Sweden
Tel: +46 8 674 7070; Fax +46 8 674 7020
E-mail: postmaster@sei.se
Web: www.sei.se

Communications Manager: Anh ~~Dung~~ Nguyen
Publications Manager: Erik Willis
Web Access: Howard Cambridge
Photo credit (inside front cover): Kalaluka Munyinda, UNZA, Zambia
Photo credit (inside back cover): Francis X. Johnson, SEI

This report is available on line (http://www.sei.se)

Editing: Anil Kumar & Shovna Upadhyay, Winrock International India~~, India~~
Layout & Design: Jaison Jose, Winrock International India~~, India~~

ISBN: 978-91-976022-3-5

CONTENTS

LIST OF FIGURES AND TABLES

PREFACE

This report is an outcome of a workshop held on 29-30 April 2005, in London, entitled, "Biomass, Sustainable Livelihoods, and International Trade: Challenges and Opportunities for the EU and southern Africa." The workshop focused on the intersection of these three topics by addressing the questions of how biomass and bio-energy can contribute to creating livelihoods, while also promoting trade and sustainable development. Special emphasis was placed on international cooperation between two economic blocks: the European Union (EU) and the Southern African Development Community (SADC).

Initially this report was expected to be a point-of-reference on some of the issues raised at the workshop, and in the follow-up discussions that took place among the participants, and their associates during the summer and fall of 2005. However, the fast-moving pace of issues relating to expansion of bioenergy production, consumption and trade during the past year required a different approach. Consequently, over the past year the authors have expanded the report into a longer review, with background and details on the topics and regions. Some of the workshop participants also made contributions to this follow-up effort. It is hoped that the report will stimulate new ideas and partnerships not only for policy analysis/research, but also for the design and implementation of development cooperation programmes.

The rapid changes occurring around the world in relation to these issues during the past year, particularly in the area of biofuels production and trade, complicated the task of writing the report. The dynamic nature of analysis and research that is intended to have strong policy relevance necessarily makes any documentation of this type incomplete. An attempt has been made by the authors, wherever possible, to update the report based on policy developments during the past year.

The workshop served as a starting point for scoping out some key issues and creating contacts and partnerships in the framework of North-South and North-South-South cooperation. The considerable amount of material and the diversity of topics have made it difficult to develop an agenda for further action. The authors have, therefore, expanded significantly on the fundamental themes, with the result that this is not a report on the workshop, but instead a review of current trends and a discussion of how to follow up on some of the key issues. The workshop documents are included in the appendices.

The report is not intended to cover any of the topics comprehensively, and therefore it cannot be regarded as a literature review. The topics are far too broad for such a review, and they draw on highly diverse areas of study and disciplines. It is more appropriate to categorise the report as a "stylised" review, i.e. a review that is undertaken in light of a particular policy research profile, as well as, in recognition of the topical nature of the issues addressed and the associated near-term policy goals. The report mentions, wherever possible, references that can offer the reader a more comprehensive review of specific topics and/or technical details. It is hoped that the report can help to elucidate some heretofore uncovered synergies and conflicts among the various energy, environment, and development objectives that are identified, along with the associated policies and institutions that attempt to achieve such objectives.

ACKNOWLEDGEMENTS AND DISCLAIMER

Thanks are extended to all those who provided valuable assistance in implementing the workshop and in preparing this report:

- Maria Morales, Solveig Nilsson, and Monica Ng Wing Tin were instrumental in organising the workshop and in the logistical arrangements for the participants
- Dr. Jeremy Woods provided valuable assistance in developing the workshop programme, and organising study tours
- David Matthews (Themba Tech.) and John Willmer (Friars Court) hosted study tours
- Nicholas Hughes drafted some of the material on social and environmental impacts and the results of biomass feedstock working groups
- Monica Ng Wing Tin drafted sections on recommendations that resulted from the workshop
- Margaret Matinga provided useful feedback on some of the key issues identified
- Helen Watson provided material on land use and agronomy
- Contributions to various sections on country policy/programme overviews and policy/institutional issues were provided by Edith Chilembo, Vikram Seebaluck, Francis Songela, Mary Swai, and Sudhirendar Sharma
- Yong Chen (SEI) consolidated and edited some of the country case studies

Other useful contributions were provided by some of the participants during and after the workshop. Apologies are extended to those who may have made specific contributions but are not mentioned here.

Thanks to the Swedish International Development Cooperation Agency (Sida) for financial support.

Background on Biomass and Bio-energy

This section provides some working definitions, an overview of current bio-energy use and potential with an emphasis on sub-Saharan Africa, a summary regarding the significance of modern vs. traditional biomass, and a brief discussion on sustainable livelihoods. Note that this report is quite limited with respect to bio-energy options and impacts. Given the complexity and tremendous diversity involved, a full review of modern bio-energy options and their impacts is far beyond the scope of this report. The reader is therefore referred instead to view a review on the topic (World Bank, 2005).

1.1 Biomass resources

Biomass is living matter derived from plants and animals, and energy production sources from biomass are often divided into two main categories: biomass wastes (or residues) and energy crops. Biomass wastes or residues refer to the remaining biomass after harvesting and after processing. The two categories differ significantly in the economics of their utilisation as well as in biophysical terms:

- Biomass wastes and residues include forestry residues; agricultural residues (e.g. sugarcane bagasse, cereal husks, straws), urban organic wastes, and animal wastes. They normally offer the most widely available and least-cost biomass resource options. The principal challenge is to develop or adapt reliable, cost-effective handling methods and conversion technologies (Leach and Johnson, 1999).
- Dedicated energy crops refer to plantations of trees, grasses and other energy crops. Bio-energy plantations are optimised for energy production, through which the harvested biomass is used directly after processing, or serves as feedstock for further production of more specialised liquid, gaseous or solid fuels. The principal challenge centres on lowering biomass production costs, and reducing risks for biomass growers (e.g. stable prices) and energy producers (e.g. guaranteed biomass supply).

These approaches can be—and generally are—mixed, by growing biomass for profitable non-energy purposes (e.g. timber) and using the harvest residues for bio-energy. In some eucalyptus plantations in Brazil, about 80-90% of the biomass is used for timber, with the remaining 10-20% used for energy production internally or for sale to other markets. In some regions, mixed approaches will provide the most attractive long-term option, given huge projected global demands for wood products and the possible scarcity of suitable land in the long-term for dedicated energy crops once basic food and fibre needs are met. Future scenarios for bio-energy trade should include consideration of timber markets, as the two markets may be in conflict in some cases (Smeets et al, 2004).

It is important to assess bio-energy within the overall biomass resource base and the socioeconomic context of the affected communities, i.e. biomass is much too important and complex to be viewed only as a source of bio-energy! The trade-offs among the many different uses of biomass are often summarised in terms of the 4Fs: Food, Feed, Fibre, and Fuel. Even this division into four categories is much too simplified; biomass serves many inter-connected and critical functions/services. These include:

- shelter, housing, household materials;
- livelihoods, entrepreneurship, local business opportunities;
- maintenance of biodiversity;
- ecosystem functions and integrity;
- nutrient cycles and functional synergies;
- water quality, erosion control, watershed maintenance;
- recreation, peacefulness, tranquillity, wildlife observation;
- contribution to human dignity and equality;
- shaping the role of citizens and communities as caretakers; and
- resource base for future generations.

The use of biomass for energy needs to be undertaken in such a way that it does not detract from other uses of biomass to the extent that the overall biomass resource base is degraded. Such constraints do not imply, however, that all uses must be treated equally. The differing valuation applied to different uses by individuals and societies must be weighed together, in a continuous process relating to the evolving economy and ecology of regions, as well as in global terms. It would be inequitable, for example, that a large forest is maintained intact only for recreation,

when nearby inhabitants depend on the resources of that forest for their very survival. By the same token, irreversible damage should not be permitted to forests that have unique cultural or ecological value, where other resources could reasonably be substituted. The resolution of the trade-offs involved at local, national, regional, and global scales will directly impact the future use of biomass in the energy supply.

1.2 Biomass in the global energy supply

Biomass accounts for about 11% of total primary energy consumed globally, more than other renewables and nuclear power together. Fossil fuels continue to account for the overwhelming share of global energy consumption, together accounting for nearly 80% of the total. Other renewables, including hydro, account for only 3% of all primary energy consumption. (Figure 1a). Biomass is also by far the most significant among renewable energy sources, accounting for about 80% of renewables used (Figure 1b). Modern bio-energy could potentially surpass large hydro in the coming years, given the significant rate of growth in liquid and solid biomass use and the increasing reluctance in many regions of the world to accept the environmental impacts of large-scale hydro.

Expansion and trade in bio-energy, and particularly liquid biofuels, has also taken on more strategic political importance in recent years due to a number of issues: higher oil prices and the near-term prospect of a peak in global oil production; regional energy trade disruptions related to gas and oil supplies; and the growing energy import dependence of many regions. In the case of solid biomass, the availability of high-efficiency applications at many scales—including households, small industry, and cogeneration plants—has opened up new markets for bio-energy. Prepared and compacted forms of biomass, such as pellets, have facilitated the growth of bio-energy in many countries and created new livelihoods in rural areas that were in economic decline. Conversion technologies have evolved with the expansion in biomass production and have been optimised for various types of biomass supply and operating conditions.

Such modern and efficient uses of biomass are still the exception in global terms. The overwhelming majority of biomass energy—over 85%—is consumed as solid fuels in traditional uses at low efficiencies for cooking, heating, and lighting. The consumers are more than two billion people that rely

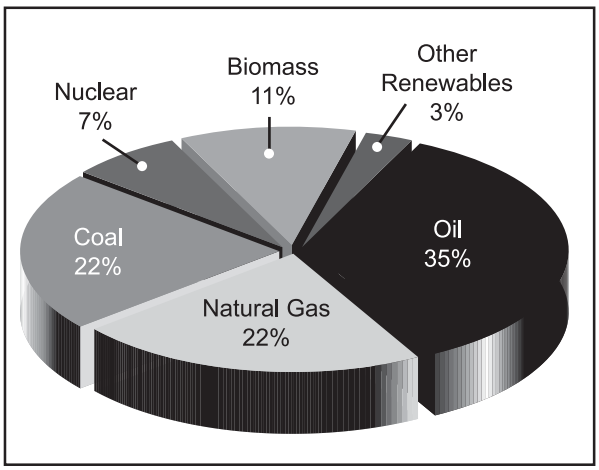


Figure 1a: Shares in 2001 of global primary energy (418 EJ). *Source: UNDP (2004)*

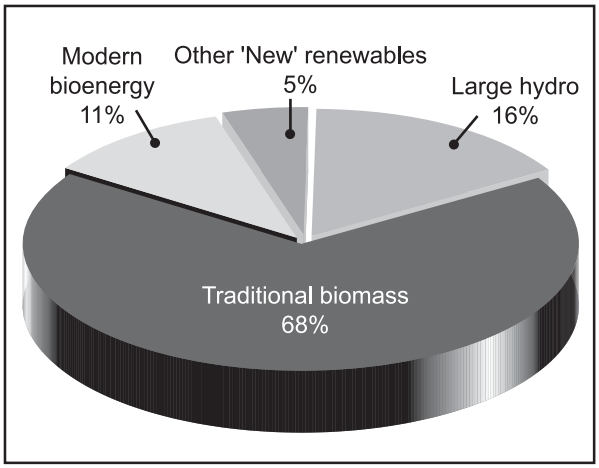


Figure 1b: Shares in 2001 of total renewable energy consumption (57 EJ). *Source: UNDP (2004)*

on traditional biomass fuels and have no access to modern energy services (UNDP, 2004). The impact from lack of access to modern energy is felt in many ways—the harmful effects of indoor air pollution, the tremendous amount of time devoted to gathering firewood and water, the lack of health and education services that require electricity and reliable energy supplies, and many other problems. The two billion people lacking access to electricity have inadequate lighting and few labour-saving devices, as well as limited telecommunications and possibilities for commercial enterprise. Greater access to electricity and modern fuels would open up new economic opportunities, as well as providing basic amenities that are taken for granted in the OECD countries.

1.3 Traditional biomass in sub-Saharan Africa

The dependence on biomass in sub-Saharan Africa is far greater than in any other world region, accounting for over 61% of primary energy consumption, and over 71% if South Africa is excluded (Figures 2a and

2b), with nearly all of this biomass being consumed for traditional uses. Biomass sources for traditional use include residues from agricultural and industry as well as, wood gathered or planted, although the overwhelming majority is from forest-based sources and consumed directly or as charcoal. In some African countries, over 95% of household fuel use is biomass from woodfuel or charcoal.

The use of modern and much more efficient bio-energy has generally been limited to those industries where residues are available on-site as part of the processing, such as timber mills and sugar factories. Some traditional forms of converted biomass, particularly charcoal, have also seen more widespread use in industry. There have also been some limited uses of liquid biofuels for transport and gaseous biofuels for small-scale applications.

The deforestation in developing countries that was observed and discussed in the 1970s was at first attributed to household consumption for woodfuel and charcoal, but subsequent research later showed that the deforestation was in fact attributable mainly to companies and industries that were clearing land for agricultural uses and timber (WEC, 1999). Another significant user of woodfuel in some regions has been local industries that use it to provide energy for small-scale activities such as brick-making. Furthermore, the notion that communities would quickly descend into a "Tragedy of the Commons" in their use of forest resources turned out to be a gross simplification that ignored the role of informal institutions. Local communities that had control over their own resources often showed a marked ability to implement informal customs and institutions that would preserve some land and forest for future uses (Leach and Mearns, 1988).

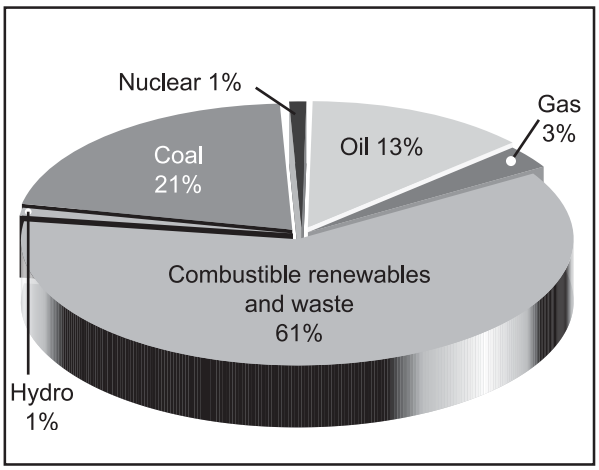


Figure 2a: Primary energy in sub-Saharan Africa, 2001. *Source: UNDP (2004)*

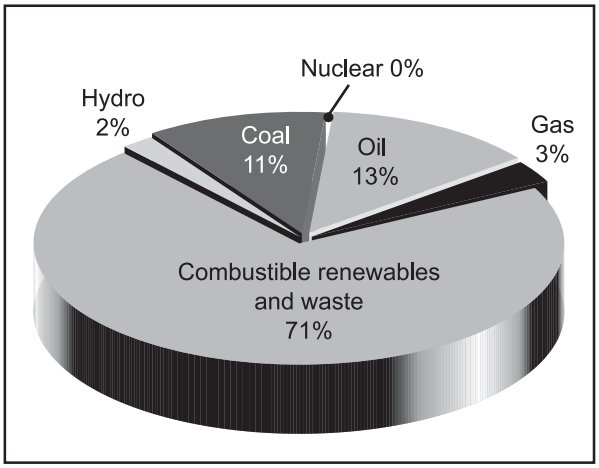


Figure 2b: Primary energy in sub-Saharan Africa (excluding South Africa), 2001. *Source: UNDP (2004)*

Household use of fuelwood and charcoal has serious impacts on health. Some estimates have suggested that indoor air pollution results in the premature death of 1.6 million persons in sub-Saharan Africa, with a disproportionate number of them being women and children, as they spend more time indoors. Consequently, indoor air pollution ranks with AIDS, malaria, and tuberculosis as the leading cause of death in the region. Where liquid fuels such as kerosene are used, safety and health have also become major concerns, due to the difficulty in controlling its use. Cleaner and safer renewable fuels, such as gel fuel made from bio-ethanol, have been proposed as a solution to health and safety issues that can take advantage of the region's under-utilised agricultural capacity (Utria 2004).

Although consumption of biomass for traditional uses can be sustainable under certain conditions, it is difficult in the longer-term to sustain traditional uses of biomass, not only due to their low efficiency but because of the difficulty in controlling the level and quality of energy services provided. A transition from traditional to modern bio-energy in the developing world is thus an important element in the global transition to sustainable energy.

1.4 From traditional to modern bio-energy

The transition from traditional uses of biomass for energy to more efficient and higher quality "modern" bio-energy, is important for many reasons, but foremost for the following:

- Modern bio-energy provides higher quality energy services that are more versatile and more efficient than

traditional bio-energy. Traditional use of solid biomass as fuel can only deliver poorly-controllable heat, whereas modern bio-energy can deliver a variety of efficient and well-controllable energy services (Leach and Johnson, 1999).

■ Assuming that environmental impacts are appropriately incorporated into overall system designs, modern bio-energy is much more likely to be sustainable in the long-term compared to traditional uses, due to savings in land, water, and other resources as a result of higher efficiency and greater precision in matching the mode of implementation to the differing needs of energy users in particular applications.

Like other renewable sources, bio-energy can make valuable contributions in climate mitigation and in the overall transition towards sustainable energy. At the same time, bio-energy also has a rather special status among renewable energy sources. Modern bio-energy will inevitably play a leading role in the global transition to clean and sustainable energy because it has two decisive advantages over other renewables:

■ Biomass is stored energy like fossil fuels, it can be drawn on at any time. This is in sharp contrast to daily or seasonally intermittent solar, wind, wave and small hydro sources, whose contributions are all constrained by the high costs of energy storage;

■ Biomass can produce all forms of energy, i.e. energy carriers, for modern economies: electricity, gas, liquid fuels, and heat. Energy from solar, wind, wave and hydro are limited to electricity and in some cases heat. Indeed, biomass energy systems can often produce energy in several different carriers from the same facility or implementation platform, thereby enhancing economic feasibility and reducing environmental impacts.

For developing countries, modern bio-energy has several other advantages providing development benefits in addition to improving energy services:

■ Provides rural jobs and income to people who grow or harvest the bio-energy resources (it is more labour-intensive than other energy resources);

■ Increases profitability in the agriculture, food-processing and forestry sectors. Biomass residues and wastes—often with substantial disposal costs—can instead be converted to energy for sale or for internal use to reduce energy bills;

■ Helps to restore degraded lands. Growing trees, shrubs or grasses can reverse damage to soils, with energy production and sales as a valuable bonus.

In a nutshell, modern bio-energy systems offer developing countries an opportunity to transform the inefficient traditional biomass sector into an efficient and competitive bio-energy industry. Technical advances are steadily improving the economic attractiveness of this transition, while at the same time social and environmental concerns are making them more politically attractive.

1.5 Bio-energy conversion options

The scales at which modern bioenergy conversion systems become economically competitive vary considerably with the local conditions and the nature of the energy demand. At one end, there is increasing interest in large-scale plantations up to 100,000 ha for production of liquid biofuels and cogeneration applications. At the other end are village-scale systems, such as the famous 5 kWh biogas-diesel generator system in Pura in southern India, which provides electricity and clean drinking water to households. The use of nearby sources of biomass residues in combination with dedicated energy crops could increase sustainability and ease system management. This section briefly reviews bio-energy conversion options.

There are different routes for converting biomass to bio-energy, involving various biological, chemical, and thermal processes. The major routes are depicted in Figure 3. The conversion can either result in final products, or may provide building blocks for further processing. The routes are not always mutually exclusive, as there are some combinations of processes that can be considered as well. Furthermore, there are often multiple energy and non-energy products or services from a particular conversion route, some of which may or may not have reached commercial levels of supply and demand. The descriptions in this section are only intended to provide a simple overview of the conversion processes, routes and products, and not any type of exhaustive or comprehensive accounting.

❑ Biological conversion

Biological conversion is well-established, with the two main routes being fermentation and anaerobic digestion. Sugar and starch crops provide the feedstocks for the process of fermentation, in which a catalyst is used to convert the sugars into an alcohol, more commonly known as bio-ethanol. Alternatively, any lignocellolosic source can be used as feedstock by hydrolysing it, i.e. breaking it down into its

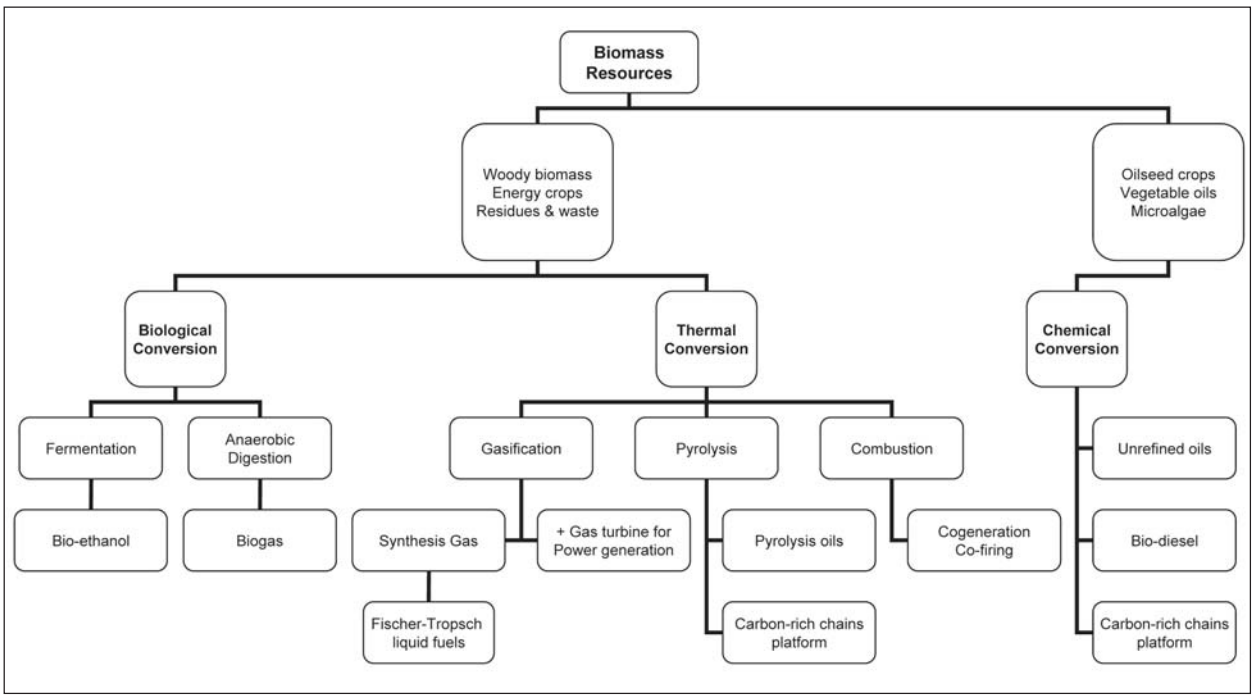


Figure 3: Various conversion routes for biomass to bioenergy

components. The reaction is catalysed by enzymes or acids. Acid hydrolysis offers a more mature conversion platform, but enzymatic hydrolysis appears to offer the best long-term option in terms of technical efficiency. Lignocellulosic conversion would greatly increase the supply of raw materials available for bio-ethanol production. The lignin residues could be used as fuel for the energy required and even provide surplus energy, resulting in significantly improved energy balances and reductions in GHG emissions.

Anaerobic digestion uses micro-organisms to produce methane from various biomass source in a low oxygen environment. Methane gas can be used directly for cooking or heating, as is common in China, or it can be used for electricity or for heat production. For transport applications, biogas is used in compressed form, as is natural gas. Biogas can also be upgraded, i.e. cleaned of impurities and then fed into natural gas pipelines. Both bio-ethanol and biogas are commonly used in buses and other fleet vehicles in cities such as Stockholm and in the Midwestern region of the U.S. The waste stream from bio-ethanol production, known as vinasse, can be further converted through anaerobic digestion, creating a further step in a "cascade" of energy extraction processes.

❑ Combustion

Combustion is simply thermal processing, or burning of biomass. In a simple case, this process can take place in the combustion chamber in a furnace. Combustion technologies play a key role throughout the world, producing about 90% of the energy obtained from biomass (including traditional uses). Combustion technologies convert biomass fuels into several forms of useful energy, such as hot water, steam and electricity. Commercial and industrial combustion plants can burn many types of biomass ranging from woody to municipal solid waste (MSW). The hot gases released as biomass fuel contain about 85% of the fuel's potential energy.

A biomass-fired boiler is an adaptable technology that converts biomass to electricity, mechanical energy or heat. Biomass combustion facilities that generate electricity from steam-driven turbine generators have a conversion efficiency of 17% to 25%, but with cogeneration can increase this efficiency to almost 85%. The large-scale combustion systems use mostly low-quality fuels, while high-quality fuels are more frequently used in smaller systems (IEA, 2005). Combustion technology still needs to be optimised. In particular, there is a need to meet demand for lower costs, by increasing fuel flexibility, lowering emissions and increasing efficiency. Other technical issues that need to be addressed include flue gas cleaning, particulate formation, multi-components and multi-phase systems, NOx and SOx formation, improved safety and simplified operations.

❑ Co-firing

Co-firing is opening many new possibilities for the

utilisation of biomass in much larger-scale, if some of the technical, social, and supply problems can be overcome satisfactorily. Co-firing of biomass with fossil fuels, primarily coal or lignite, has received much attention particularly in the EU and USA. Biomass can be blended with coal in differing proportions, ranging from 2% to 25% or more. Extensive tests show that biomass energy could provide, on average, about 15% of the total energy input with only minor technical modifications. Since large-scale boilers for electric power range from 100 MW to 1.3 GW, the biomass potential in a single boiler ranges from 15 MW to 150 MW.

The main advantages of co-firing include:

- existence of an established market for CHP;
- lower investment compared to biomass-only plant (i.e. minor modification in existing coal-fired boiler);
- flexibility in arranging and integrating the main components into existing plants (i.e. use of existing plant capacity and infrastructure);
- favourable environmental impacts compared to coal-only plants;
- potentially lower local feedstock costs (i.e. use of agro-forestry residues);
- waste disposal benefits (i.e. use of biomass-based wastes reduces need for land-based waste disposal)
- potential availability of large amounts of feedstock (biomass/waste);
- higher efficiency for converting biomass to electricity compared to 100% wood-fired boilers. Biomass conversion efficiency would be 33-37% when fired with coal, compared to 20-30% for biomass-only; and
- special permits (i.e. related to waste combustion) are not required in most cases

Currently, about 40% of the world's electricity is produced by coal-fired power stations in over 80 countries. About 100 GWe of coal-fired plant capacity is over 40 years old, rising to as much as 500 GWe within the next 20 years. More co-utilisation of coal with natural gas and biomass would also reduce GHG emissions. Globally, co-firing with biomass could be deployed on an installed plant capacity of 100 GWe. A European study found that the cost of CO_2 reduction for CHP based on either coal or biomass was around half the cost of exchanging old coal-fired power stations with new clean coal technology (IEA, 2005).

❑ Gasification

Gasification is another major alternative, currently one of the most important RD&D areas in biomass for power generation, as it is the main alternative to direct combustion. The importance of this technology relies in the fact that it can take advantage of advanced turbine designs and heat-recovery steam generators to achieve high energy efficiency. The first successful demonstration of biomass gasification at commercial scale was at Värnamo in southern Sweden, in a demonstration programme funded by the EC and the Swedish Energy agency, and carried out during 1996-2000, using a pressurised design (Sydkraft, 2001). The technical functioning had high reliability, and future improvements are aimed at refinements and cost-saving measures.

Gasification technology is not new; the process has been used for over 150 years. In the 1850s, much of London was illuminated by "town gas", produced from the gasification of coal. Currently, gasification only for heat production has reached commercial status. Biogass gasification for electricity production has reached commercialisation in the past 5-10 years with over 90 installations and over 60 manufactures around the world. The main attractions of gasification are (Walter et al, 2000):

- higher electrical efficiency (e.g. 40%+ compared with combustion 26-30%);
- possibility for substantial new developments e.g. advanced gas turbines, fuel cells, etc.;
- possible replacement of natural gas or diesel fuel use in industrial boilers and furnaces;
- distributed power generation where power demand is low; and
- displacement of gasoline or diesel in an internal combustion (IC) engine.

❑ Pyrolysis

The main advantage that pyrolysis offers over gasification is a wide range of products that can potentially be obtained, ranging from transportation fuel to chemical feedstock. Considerable amount of research has gone into pyrolysis in the past decade in many countries. After many ups-and-downs, the first commercial plants are coming into operation. Any form of biomass can be used (over 100 different biomass types have been tested in labs around the world), but cellulose gives the highest yields at around 85-90% wt on dry feed. Liquid oils obtained from pyrolysis have been tested for short periods on gas turbines and engines with some initial

success, but long-term data is still lacking. (Brammer, 2006).

Pyrolysis of biomass generates three main energy products in different quantities: coke, oils and gases. Flash pyrolysis gives high oil yields, but still needs to overcome some technical problems needed to obtain pyrolytic oils. However, fast pyrolysis is one of the most recently emerging biomass technologies used to convert biomass feedstock into higher value products. Commercial interest in pyrolysis is related to the many energy and non-energy products that can potentially be obtained, particularly liquid fuels, and also the large number of chemicals (e.g. adhesives, organic chemicals, and flavouring) that offer companies good possibilities for increasing revenues.

❑ Chemical conversion from oil-bearing crops

Oils derived from oilseeds and oil-bearing plants can be used directly in some applications, and can even be blended with petroleum diesel in limited amounts. Some restrictions are necessary depending on the engine type and measures are also needed to avoid solidification of the fuel in cold climates, since they differ in freezing points. Because the effect on engines varies with both engine type and the raw material used, there is still debate on how much straight vegetable oil (SVO) can be blended with petroleum diesel without damaging the engine or its associated parts. Consequently, SVOs, as well as used cooking grease and other sources of raw oils, are generally used for local applications based on experience with specific applications, and are less likely to be internationally traded as a commodity for direct use.

The refined versions of SVOs, on the other hand, can potentially be fully interchangeable with petroleum diesel, and are therefore preferred for international trade. The raw oils can be imported and the refining done locally, as is the case with petroleum. The chemical refining process is referred to as transesterification, since it involves the transformation of one ester compound into another, a process that also transforms one alcohol into another. Glycerol—a viscous, colourless, odourless, and hygroscopic[1] liquid—is a valuable by-product of the process, and is an important raw material for various pharmaceutical, industrial, and household products.

[1] Refers to substances that readily absorb water from their surroundings.

Yet another set of options associated with these bio-chemical conversion processes relates to the creation of various carbon-rich compounds from glycerol and the fatty acids that comprise it. The carbon-rich chains form building blocks for a variety of products that could potentially be produced, which are to some extent bio-degradable and are the result of biological processes. Such platforms might be based on the carbon chains C_2 and C_3, which would in some respects lead to bio-refining processes that are analogous to the petroleum refining process. Movement towards a bio-based economy is generally recognised as a fundamental characteristic of the overall transition to sustainability (NAAC, 2001). Such platforms are not reviewed in this report, but the tremendous future potential warrants much more investment in research, development, and demonstration.

❑ Bio-diesel from algae

An interesting option for the future is the production of bio-diesel from algae. The production of algae to harvest oil for bio-diesel has not yet been undertaken on a commercial-scale, but feasibility studies have suggested high yields, as some algae have oil content greater than 50%. In addition to its projected high yield, algae-culture—unlike crop-based biofuels—is much less likely to conflict with food production, since it requires neither farmland nor fresh water. Some estimates suggest that the potential exists to supply total global vehicular fuel with bio-diesel, based on using the most efficient algae, which can generally be grown on algae ponds at wastewater treatment plants (Briggs, 2004). The dried remainder after bio-diesel production can be further reprocessed to make ethanol. The possibility to make both bio-diesel and bio-ethanol from the same feedstock could accelerate biofuels market expansion considerably.

Several pilot projects and initiatives have started during the past year. A company in New Zealand recently produced its first sample of bio-diesel fuel made from algae found in sewage ponds. Unlike previous attempts, the algae were naturally grown in pond discharge from the nearby sewage treatment works (NZT, 2006). In South Africa, in November 2006, a commercial-scale bio-diesel project was announced. Using American-made, closed bioreactors, it is expected to produce 37.9 million litres a day of bio-diesel within a couple of years. The bioreactors will initially use sunflower oil as feedstock, but one of the plants will be used as a pilot plant for using oils from

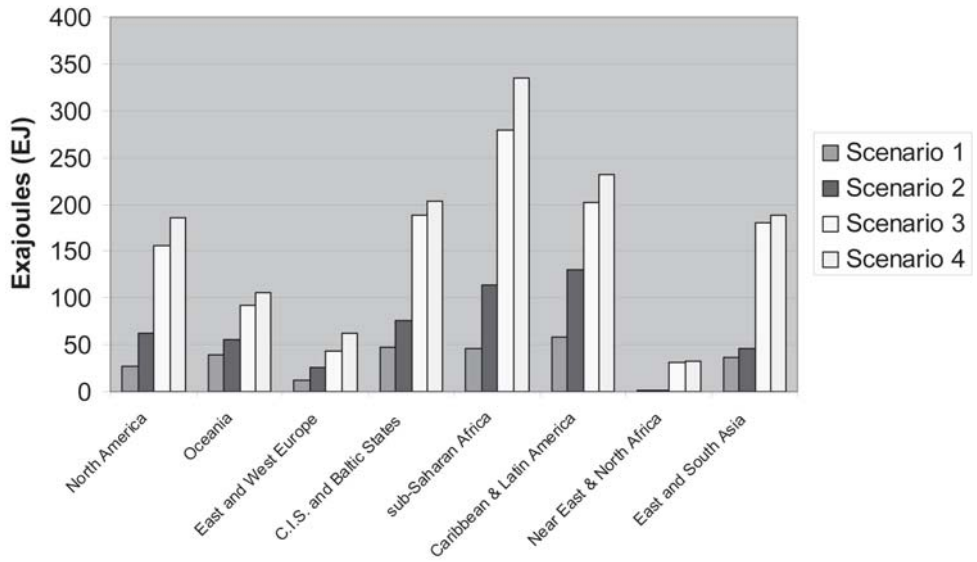


Figure 4: Global 2050 bio-energy potential for residues & abandoned agricultural land

Scenario/assumptions for Figure 4	1	2	3	4
Feed conversion efficiency	high	high	high	high
Animal production system (pastoral, mixed, landless)	mixed	mixed	landless	landless
Level of technology for crop production	very high	very high	very high	super high
Water supply for agriculture	rain-fed only	rain-fed + irrigation	rain-fed + irrigation	rain-fed + irrigation

Source: Smeets et al (2004)

algae, and it is envisioned that eventually only algae-based oils will be used (Green Star, 2006).

1.6 Global bio-energy potential

Biomass that is produced in tropical and sub-tropical climates has an average productivity that is over 5 times higher than that of biomass grown in the temperate regions of Europe and North America (El Bassam, 1998). Since developing countries are located predominantly in the warmer climates and lower latitudes, they have a tremendous comparative advantage. However, most research and development funding, as well as a considerable amount of direct subsidies are provided for the production of biomass in the EU and in North America, where technology and strong infrastructure can compensate somewhat for the natural disadvantage.

A recent study found that the bio-energy potential in sub-Saharan Africa—after accounting for food production and resource constraints—is the most of any of the major world regions (Smeets et al, 2004). Using four scenarios, the potentials were estimated using the IMAGE model and included various categories of biomass, among which residues and abandoned agricultural land were the most significant globally (Figure 4). The high potential results from the large areas of suitable cropland in the region, large areas of pasture land presently used and the low productivity of existing agricultural production systems. Estimates of the long-term bio-energy potential for the region can serve as guidelines for development strategies that can harness the biomass resource base in a sustainable manner.

Overall, the global potential range from 30% to over 200% of current total energy consumption (recall Figure 1a). Other sources of bio-energy that are not included in the potential above include animal wastes, organic wastes such as MSW, and bio-energy from natural forest growth. Inclusion of such sources would increase the potential by an additional 10% to 50%, depending on the assumptions (Smeets et al, 2004). It is also important to note that water-based bioenergy production is generally not included in these estimates, the potential for which could be quite large, such as in the case of algae-oils that are used for bio-diesel production (Briggs, 2004).

It is important to note that these are techno-economic

potentials, and there will inevitably be social and cultural issues that would restrict use of some lands for energy production. Nevertheless, the tremendous potential for bio-energy, after accounting for food production, means that the margin for future development is significant. The concentration of the potential in sub-Saharan Africa in combination with the lack of potential in Europe poses interesting questions for future development and trade in bio-energy. The bio-energy and biofuels policies followed in the EU could offer new export market opportunities for sub-Saharan Africa and other developing countries.

Given the high level of poverty and malnutrition found in many developing countries, food security will generally take preference over energy production. The food vs. fuel debate is sometimes used to discourage bio-energy development, even though there is not necessarily a negative correlation between food and fuel, and in fact there are many positive economic linkages that can arise (Moreira, 2003). A recent study suggested that there are synergies between food and fuel production, with the result that production increases for food and fuel will go hand-in-hand, especially, as new agro-industrial biotechnology methods are deployed. Furthermore, where equity concerns can be addressed, the income provided from bio-energy production can in some cases more than compensate for displaced food production. Where large-scale displacement occurs, it is vital that policies and institutions re-direct such income towards investment in greater agricultural productivity and address distributional issues related to the benefits accrued.

Another issue that will inevitably arise in the long-term in some regions of sub-Saharan Africa is the availability of water for irrigation in agriculture, which might reduce the potentials achievable in scenarios 2, 3 and 4. Some regions and countries, particularly South Africa, are projected to be water deficient by 2015 or 2020. However, there is already a significant amount of irrigation in some regions, and therefore what may be more important than the total are incremental decreases or changes in the scope of irrigation in different hydrological zones. Further, the scope for improvements in irrigation in agriculture as well as in biomass production is quite significant.

1.7 Biomass and sustainable livelihoods

The bio-energy development strategies for particular regions, such as southern Africa, should be based on socio-economic priorities in combination with the overall resource base that is available and the subset of that resource base that can be harvested for bio-energy use. A consideration of these broader issues must include the extent to which development of biomass resources can help create, maintain, and expand sustainable livelihoods for the local population as well as for those in areas that are connected socially, economically, and ecologically to the local or regional communities involved. There are many definitions of sustainable livelihoods in policy research literature, but the following definition seems to be both concise and comprehensive:

"A livelihood comprises the capabilities, assets (including both material and social resources) and activities required for a means of living. A livelihood

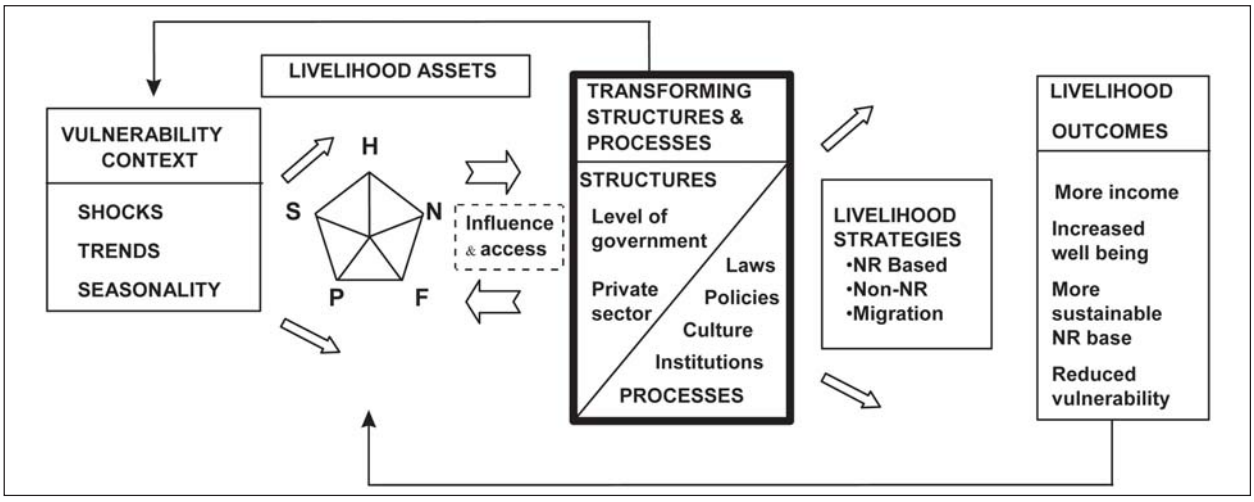


Figure 5: Sustainable Livelihoods Approach

KEY: H=Human; N=Natural; F=Financial; P=Physical; S=Social; NR = Natural Resource
Source for diagram: (DFID, 1999)

is sustainable when it can cope with and recover from stresses and shocks and maintain or enhance its capabilities and assets, while not undermining the natural resource base (Scoones, 1998)."

The sustainable livelihoods framework is based on five components: context, assets, transforming structures and process, strategies, and outcomes (Figure 5). It has been used by donor agencies and researchers in conducting analysis and in evaluating projects, proposals, and programmes. The framework is dynamic, i.e. there are feedbacks across these components.

Although the creation of working days is sometimes used as the key indicator of creating or maintaining livelihoods, other indicators are perhaps just as important in terms of enhancing social capital, improving the quality of work, and ensuring the future availability of the natural resource base. Altogether, five indicators have been identified (Scoones, 1998):

- creation of working days;
- poverty reduction;
- well-being and capabilities;
- livelihood adaptation, vulnerability, and resilience; and
- natural resource base sustainability.

In terms of jobs and working days, it is important to note that bio-energy generates far more jobs than any other energy sources – both renewable and non-renewable. Furthermore, these jobs are created mainly in rural areas where poverty is worst, and thus can help to slow down or even reverse migration to urban centres. It is difficult to generalise about the impact of bio-energy development with respect to the other four indicators. Rapid degradation of forests and soils for short-term profit will obviously not lead to sustainable livelihoods, whereas carefully managed growth strategies can not only maintain the resource base, but even enhance it.

In the case of biomass resources, the livelihoods of greatest interest here will be the ones created in rural areas, given that biomass offers special development opportunities for rural areas. It is worth noting, however, that many people living in so-called "peri-urban" areas—those living in between cities and villages—earn their livelihoods from resource-based sources, such as distributing and making charcoal and using wood gathered in rural areas. Charcoal production, sale and distribution is therefore a major source of livelihood in both rural and peri-urban areas.

Policies and institutions need to be aimed at supporting people and communities in developing strategies that can improve their livelihoods, and such strategies must include preparations for adaptive actions as well as addressing well-being in the near-term. Three types of strategies can be identified: (1) improving agricultural productivity (intensive or extensive); (2) diversification of livelihoods; (3) migration, i.e. seeking livelihood elsewhere.

Within this framework, one might consider different options available for expanding bio-energy production, either for local or export markets or some combination of the two. Improvements in the intensive productivity of food crops could free some land for bio-energy production, or plots of un-or-under-utilised land could be added for extensive changes to production. A diversification strategy might include gathering and selling of biomass residues to industrial or household buyers, as supplement to other incomes and a buffer in the event that food markets or climatic conditions change. Migration might be chosen where trading opportunities can be enhanced or where climatic differences might allow livelihoods with fewer resources, e.g. expanding into bio-energy crops might be taken up on land with less rainfall where bio-energy crops may need less water than other alternatives.

Overall, the relationship between policy and livelihood creation is complicated and not well-understood, both with respect to analytical models as well as how policy can be influenced in practice so as to promote sustainable livelihoods. Such questions require broad policy analysis and research in terms of the development implications across the tremendous diversity of socio-economic circumstances. Although such analysis is beyond the scope of this report, an overview of some of these issues is considered in the context of case studies, which examines how different regions and countries are approaching biomass resource development and bio-energy policy formulation.

SADC Regional Overview

A large region that is undergoing a process of economic integration—the southern African Development Community (SADC)—is of special interest for the topic of concern here. An economic bloc was chosen rather than an ecologically-defined region (e.g. a river basin) because of the emphasis on markets and trade. At the same time, biomass resources are spatially constrained as well as being constrained by the availability of land, water and other resources. Greater economic integration within SADC would allow biomass resource development to be better allocated to those areas where it is most productive, rather than being overly constrained by national priorities and policies. Consequently, the expanded trade in biomass and biofuels could exploit efficiencies both regionally and globally, whereas current bio-energy markets and policies tend to be oriented towards local or national levels.

SADC was created in 1992 and currently includes fourteen member states, as shown in the map (Figure 6). Its objectives include regional integration, peace and security, maximising productive employment, promoting economic development, and achieving sustainable utilisation of natural resources. In many respects, these objectives are similar to those of other economic blocs such as the EU. In the case of SADC there is a special emphasis on food security, poverty alleviation and addressing major health threats, particularly HIV/AIDS.

Figure 6: Map of the Southern African Development Community (SADC) as of 2005

2.1 Land use patterns

As shown in Table 1, the SADC region encompasses a sizable area, larger than Brazil, China, or the U.S. and more than three times the size of India. It has a considerable amount of forested lands, nearly as much as the U.S. and China combined. The region has an even greater amount of pastures, grasslands, and other areas that fall under the agricultural heading. It does have some arid and semi-arid areas where agriculture is highly limited. It however, does not have significant mountain ranges that render major areas uninhabitable (such as is the case in China).

The present amount of land cultivated is quite small—less than 6%—the comparable figures elsewhere in the world are generally much higher. Not only is the amount of land cultivated small, but the productivity levels of agricultural systems are quite low by world standards. A great deal of pasture land could be made available for uses, i.e. for fuel and fibre (Smeets et al, 2004).

The aggregate figures in Table 1 do not necessarily indicate anything about the land available for expanded agricultural or biomass production, as many other characteristics have to be considered. Socio-economic, cultural, environmental, and ecological factors would all have to be taken into account. The proximity of available land to markets, distribution centres, and urban areas would also impact development options. However, the aggregate data do suggest the considerable-scale of available land resources in comparison to the current low levels of utilisation. It remains to be considered the various alternatives for utilising agricultural and forest-based resources differently so as to take better advantage of the bio-energy potential.

2.2 Income and population

In economic terms, several countries in the region are among the poorest in the world, with per capita incomes less than a dollar per day, as listed in Table 2. The lower cost of living in these countries, relative to global conditions, offsets some of these income effects, with Purchasing Power Parity GDP generally several times higher than nominal GDP. In general, the poorer countries in SADC also have a higher

Table 1: Land use summary for SADC and selected countries/regions in 2003-2004

Country/region	Total land area	Forest area		Agricultural areas (a)		Cultivated area (b)	
UNITS:	million ha	million ha	share of total land area	million ha	share of total land area	million ha	share of total land area
Angola	124.7	69.8	56%	57.6	46%	3.6	2.9%
Botswana	56.7	12.4	22%	26.0	46%	0.4	0.7%
Congo	226.7	135.2	60%	22.8	10%	7.8	3.4%
Lesotho	3.0			2.3	77%	0.3	11.0%
Madagascar	58.2	11.7	20%	27.6	47%	3.6	6.1%
Malawi	9.4	2.6	27%	4.4	47%	2.6	27.5%
Mauritius	0.2			0.1	56%	0.1	52.2%
Mozambique	78.4	30.6	39%	48.6	62%	4.6	5.8%
Namibia	82.3	8.0	10%	38.8	47%	0.8	1.0%
South Africa	121.4	8.9	7%	99.6	82%	15.7	12.9%
Swaziland	1.7			1.4	81%	0.2	11.2%
Tanzania	88.4	38.8	44%	48.1	54%	5.1	5.8%
Zambia	74.3	31.2	42%	35.3	47%	5.3	7.1%
Zimbabwe	38.7	19.0	49%	20.6	53%	3.4	8.7%
Total SADC	**964.1**	**368.3**	**38%**	**433.2**	**45%**	**53.4**	**5.5%**
EU-15	313.0	115.7	37%	140.4	45%	84.55	27.0%
Brazil	845.9	543.9	64%	263.6	31%	66.6	7.9%
China	932.7	163.5	18%	554.9	59%	154.9	16.6%
India	297.3	64.1	22%	180.8	61%	169.7	57.1%
United States	915.9	226.0	25%	409.3	45%	175.5	19.2%

Sources: FAOSTAT 2005; World Resources Institute 2005
Note: (a) Agricultural areas includes temporary and permanent pastures, permanent crops, and temporary crops
Note: (b) Cultivated areas includes permanent crops and temporary crops

proportion of the population working in agriculture. The population density is fairly low by global standards, although with considerable variation.

Some care is needed in interpreting land use and demographics, as the categories are not necessarily defined in the same way in different countries. For example, the share of persons earning their livelihood from agriculture ends up being quite high, and in fact greater than the rural population in China. Nor is the international comparison particularly revealing in some cases. Thus, although India has a higher share of rural population, the distance to a major city tends to be much greater in many rural areas of the SADC region compared to India. Consequently, access to infrastructure is severely limited in many rural areas within SADC, rural industries are more isolated, and it is costly to get products to market. The creation of rural-based industries such as those associated with biomass and bio-energy are especially appealing for a region that is predominantly rural. At the same time, getting these products to international markets will tend to be more complicated in comparison to opportunities for local and regional markets.

2.3 Energy/development indicators

With the exception of South Africa and Mauritius, the countries in the SADC region are characterised by low national rates of electrification and high levels of traditional biomass use, as given in Table 3. In the region's most populous country—DR Congo—traditional biomass makes up 95% of all energy consumption. The use of liquid fuels is also quite low, with the exception of Mauritius and Angola, the latter country being the only major oil producer in the region. It is interesting to note that Angola has the lowest electrification rate, in spite of the availability of oil revenues. It is an example where conflict and corruption have worked against modern energy

Table 2: GDP and population summary for SADC and selected countries/regions in 2003-2004

Country/region	GDP/capita (USD)		Total population		Rural population	Agricultural population (b)
UNITS:	nominal GDP	GDP - PPP (a)	1000s	density (p/km2)	share of total	share of total
Angola	1304	2457	13.6	10.9	64%	71%
Botswana	5702	10169	1.8	3.1	49%	44%
Congo	111	633	52.8	23.3	69%	62%
Lesotho	633	2074	1.8	59.4	82%	39%
Madagascar	251	854	17.4	29.9	74%	73%
Malawi	152	569	12.1	128.7	84%	76%
Mauritius	4833	12215	1.2	601.5	57%	10%
Mozambique	320	1247	18.9	24.1	64%	76%
Namibia	2233	6449	2.0	2.4	68%	47%
South Africa	4587	10798	45.0	37.1	43%	13%
Swaziland	2172	4995	1.1	62.6	77%	32%
Tanzania	308	673	37.0	41.8	64%	77%
Zambia	478	870	10.8	14.5	65%	68%
Zimbabwe	491	2309	12.9	33.3	65%	61%
Total SADC	**1267**	**3142**	**228346**	**24**	**63%**	**57%**
EU-15	29291	26900	380.1	121.4	22%	4%
Brazil	3325	8049	178.5	21.1	17%	15%
China	1272	5642	1311.7	140.6	61%	65%
India	622	3080	1065.5	358.4	72%	52%
United States	39935	39496	294.0	32.1	20%	2%

Sources: FAOSTAT 2005, World Bank 2005
Note: (a) PPP = Purchasing Power Parity, which reflects better differences in cost of living, whereas Nominal GDP accounts more appropriately for the value of international trade.
Note: (b) Agricultural Population refers to those persons who earn their livelihoods from agricultural activities along with their non-working dependents

Table 3: Energy/development indicators for SADC countries for 2002

	Electrification rate		Liquid fuels consumption (petrol, LPG, others)			Traditional biomass energy consumption	
UNITS:	share with electricity access	1000 TJ	share of total energy	GJ per capita	1000 TJ	share of total energy	GJ per capita
Angola	5.0%	58	46%	4.3	40	32%	2.9
Congo	8.3%	12	2%	0.2	703	95%	13.3
Madagascar	8.3%	26	17%	1.5	123	81%	7.1
Malawi	5.8%	9	11%	0.7	68	84%	5.6
Mauritius	100.0%	32	58%	26.2	14	25%	11.5
Mozambique	8.7%	19	9%	1.0	171	80%	9.1
Tanzania	9.2%	40	13%	1.1	247	83%	6.7
Zambia	18.4%	21	6%	1.9	329	88%	30.4
Zimbabwe	40.9%	40	8%	3.1	335	66%	26.0
SACU*	56.5%	817	12%	15.8	781	12%	15.1
Total SADC	15.4%	1074.0	12%	4.7	2811.0	31%	12.3

*South African Customs Union: Botswana, Lesotho, Namibia, South Africa, and Swaziland
Sources: FAOSTAT 2006, UN 2005, IEA 2005

services, in spite of significant domestic energy resources.

Not much can be deduced from the differences in energy consumption without further information and more detailed analysis. Nor is the data on traditional biomass consumption equally reliable across the countries. One anomaly observed here is the high per capita consumption of traditional biomass in Zambia compared to most other countries; it is nearly five times that of Tanzania and nearly six times that of Malawi. Furthermore, electricity access is twice as high in Zambia as in Tanzania and three times as high as in Malawi. Conventional economic analysis might suggest that consumption of one form of energy should go down when another goes up. However, in these countries, electricity is too highly-valued to be used for cooking, or heating. Where electricity is available, it would generally be directed towards the higher valued uses, such as lighting, motors, etc., which can lead to income-generating activities.

2.4 Biomass use in the SADC region

A thorough review of current biomass use in the region is not feasible here, but some basic indicators can be obtained in terms of what is currently being used. With respect to forest-based resources, wood fuel charcoal and round wood account for most of the available resources used. Other wood products, such as pulp and paperboard, are quite small by comparison. Table 4 contains some indicators for consumption. The per capita consumption of wood fuel and the production of round wood in various countries are distributed for the most part around the mean values. Such tight distribution is not true for charcoal, although there is considerable uncertainty, as wood and charcoal data are notoriously difficult to estimate. The high consumption of charcoal per capita in Zambia appears to be the main cause of its overall high level of traditional biomass consumption. The DR Congo accounts for over 40% of wood fuel use in the SADC region.

Demand for charcoal is likely to continue to grow, in spite of the opportunities to substitute modern energy sources, since these sources will almost always be more expensive. The rural population as well as a significant share of the urban population outside of South Africa is dependent on fuelwood and/or charcoal for daily energy needs. Contrary to popular belief, in many areas the use of charcoal has not yet exceeded levels at which it can be characterized as sustainable, and is not a major contributor to deforestation (Chidumayo 2002). The price of charcoal is generally relatively stable, regardless of the distance transported, i.e. it is

Table 4: Selected forest product consumption indicators in SADC countries, 2002

	Wood fuel			Wood charcoal			Round wood		
Country	1000 m3	share of SADC total	m3 per capita	1000 tonnes	share of SADC total	kg per capita	1000 m3	share of SADC total	m3 per capita
Angola	3320	2.2%	0.24	221	4.0%	16.20	4436	2.4%	0.33
Botswana	645	0.4%	0.36	62	1.1%	34.65	750	0.4%	0.42
DR Congo	67285	43.6%	1.28	1535	27.7%	29.08	70938	38.5%	1.34
Lesotho	2034	1.3%	1.13	82	1.5%	45.44	2034	1.1%	1.13
Madagascar	10202	6.6%	0.59	795	14.4%	45.68	10299	5.6%	0.59
Malawi	5029	3.3%	0.42	409	7.4%	33.77	5549	3.0%	0.46
Mauritius	9	0.0%	0.01	0	0.0%	0.08	17	0.0%	0.01
Mozambique	16724	10.8%	0.89	100	1.8%	5.30	18043	9.8%	0.96
Namibia	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
South Africa	12000	7.8%	0.27	41	0.7%	0.91	30616	16.6%	0.68
Swaziland	560	0.4%	0.52	n/a	n/a	n/a	890	0.5%	0.83
Tanzania	21125	13.7%	0.57	1243	22.5%	33.63	23439	12.7%	0.63
Zambia	7219	4.7%	0.67	1041	18.8%	96.28	8053	4.4%	0.74
Zimbabwe	8115	5.3%	0.63	9	0.2%	0.70	9108	4.9%	0.71
SADC	**154268**		**0.68**	**5538**		**24.25**	**184172**		**0.81**

Source: FAOSTAT 2006
n/a = data not available

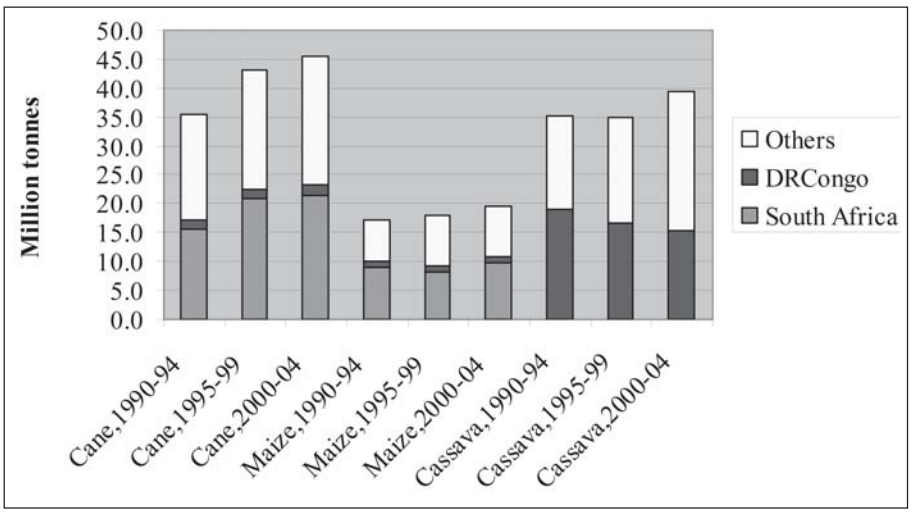


Figure 7: Five-year average production levels in SADC for selected ethanol feedstock

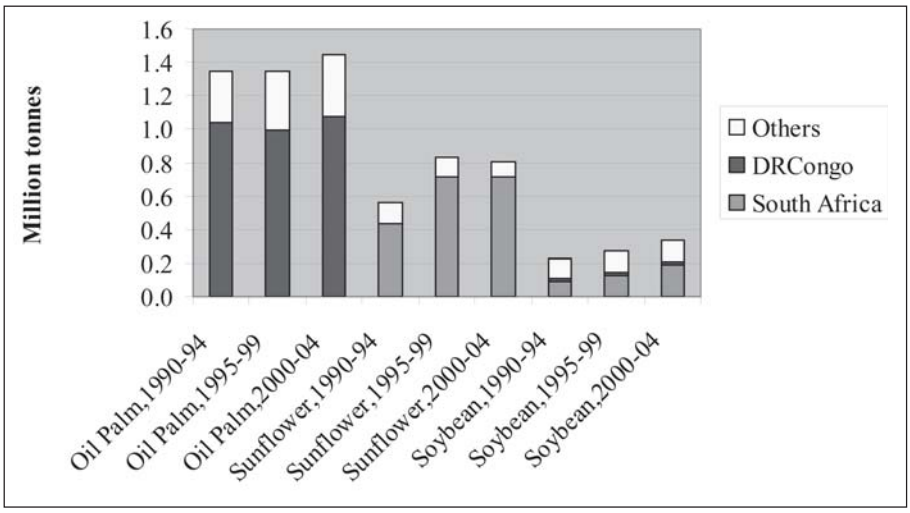


Figure 8: Five-year average production levels in SADC for selected bio-diesel feedstock
Source for Figures 7 and 8: FAOSTAT 2006

a regional commodity in many respects (Chaposa 2002) although cross-border trade is difficult due to taxes and controls. South Africa and Madagascar also have a sizeable international export market for charcoal (UN, 2005).

In terms of agricultural biomass and bio-energy resources, the three main categories of interest are: crop residues, animal residues, and biofuel crops. Estimates of crop and animal residue availability and energy content have been conducted for a variety of sources and locations and the summaries are available in some recent publications (World Bank, 2005; Kartha and Larsen, 2000). Residue availability can vary from 5% to 50% of total harvest, depending on the type of crop, while energy content will depend on moisture and constituents. The economics are dependent on efficient methods for gathering, compacting, and transporting the residues. The high costs associated with processing residues in combination with the variation in their composition have generally led to lower economic potentials than expected. For some specific applications and locations, such as sugarcane trash in Brazil, it appears that the economics are favourable where efficient cogeneration systems are installed (GEF 2005).

Due to logistical constraints and market structures, liquid biofuels are of greatest interest for international trade. Sugarcane, maize, and cassava are the crops most likely to be used as feedstock for bio-ethanol production in the near term. Oil palm, sunflower, and soybean appear to be the most likely crops in the near term for production of bio-diesel. South Africa and DR Congo are currently the largest producers in SADC of biofuel crops. Other crops being considered are sweet potatoes and sweet sorghum for bio-ethanol and jatropha and castor oil for bio-diesel. Sweet

sorghum and jatropha are considered to be promising crops, but there is very little experience with them in Africa as energy crops.

South Africa produces nearly half of the sugarcane in the region and more than half of the maize, while DR Congo produces nearly half of the cassava, as shown in Figure 7. Sugarcane production has increased significantly in SADC in the past 10-15 years, while maize and cassava have increased only slightly. Although cane is far more efficient for ethanol production than starch crops such as cassava and maize, cane is less amenable for small-scale production. Starch crops, in spite of the lower efficiency, may have benefits in terms of livelihoods creation. Starch crops are planted annually, (cane has a multi-year cycle) allowing more flexibility and requiring less up-front investment. As cassava and maize are grown for subsistence purposes (outside of South Africa) while cane is often grown for sugar export, diversion to fuel production is more likely to adversely affect food availability in the case of cassava. South Africa has a significant surplus of maize, and this surplus could be directed towards fuel production. However, there are equity concerns with the scenario of South Africa making ethanol from subsidised maize production, and thereby hurting other SADC members.

2.5 SADC biofuels strategy

A Joint Meeting of the SADC Senior Officers of Food, Agriculture and Natural Resources and Infrastructure and Services was held in Gaborone on 12 October 2004, to create awareness on 'Farming for Energy', a potential area of development, which could create rural employment and increase the region's capacity to produce biofuel (SADC, 2004). The participants noted the rocketing price of fossil oil and expressed their concern on its devastating effect on SADC economies. They agreed that biofuels such as ethanol and bio-diesel made from various organic sources would be viable alternative sources for energy. Participants noted that fuel production through farming would be creating rural employment, and that it would also be in line with the Kyoto Protocol and the recommendations of the World Summit on Sustainable Development. The participants called upon SADC trading partners to facilitate the global trade and investment in biofuels. The participants also emphasized the need for adaptive agricultural and energy research and extension development to enhance the transfer of biofuel technologies especially at grass root level.

The meeting led SADC to commission a study aimed at developing a SADC biofuels strategy, which was completed in late 2005. The study reviewed the various biofuels crops that were feasible in different regions and the opportunities for developing new markets for biofuels using these crops. The major crops identified for bio-ethanol included sugarcane, maize, and cassava. For bio-diesel, jatropha and soy were among the crops identified. The potential is quite significant for both bio-ethanol and bio-diesel, although considerable investment will be needed to bring agricultural practices up to the required level of technical capacity, scale of operations, and intensity of production (SADC, 2005).

Different regional strategies might be pursued, depending on the relative weight given to exports vs. local consumption. One advantage of local consumption for bio-diesel is that the oil-based fuels can be used in their unrefined form, saving the costs associated with esterification. Trials would need to be undertaken to determine the different types of equipment that could use unrefined forms without difficulty. Such an advantage does not exist for bio-ethanol. However, priority for intra-regional use of bio-ethanol (as opposed to exports outside the region) would have some synergies with existing policies that have yet to be fulfilled, particularly the plan for lead phase-out in petrol in many countries in the region. One strategy to take advantage of different feedstocks might be to produce ethanol from the starch crops (maize, cassava, and others) for local use, while sugar producers make ethanol intended for export markets. Yet this strategy would deprive small farmers of hard currency benefits unless some type of revenue-sharing scheme was established across different sectors of the industry.

Another set of scocio-economic issues relates to the scale of operations, incentives for small farmers, and the distribution of benefits from a biofuels programme. Although all categories of biomass can in principle be grown on different types of estates or plantations, an emphasis on small growers would provide livelihoods across the greatest section of the population. On the other hand, where export markets are important and for crops that are mature like sugarcane, estates or plantations of some kind will likely be needed to reach economies-of-scale. Modern bio-energy applications in other end-use sectors, i.e. for heat and power production and for direct uses, although less directly relevant for bio-energy trade, do have

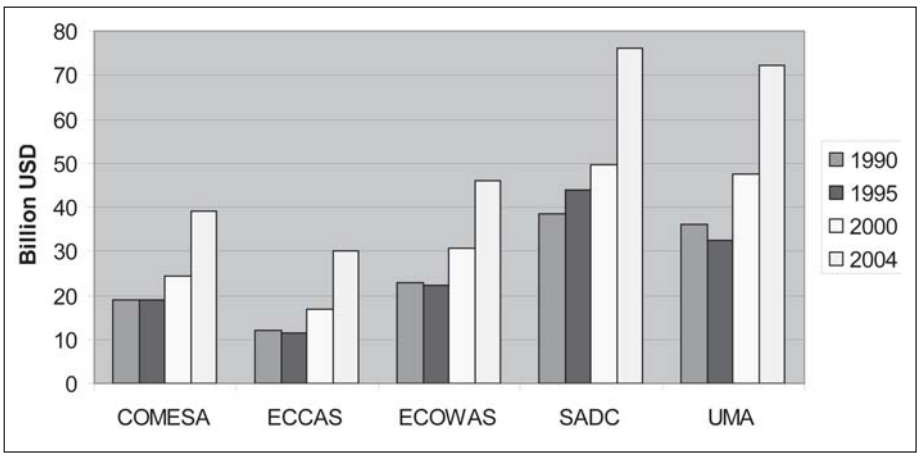


Figure 9: Value of exports in different economic groups or zones in Africa
Source: UNCTAD (2005)
KEY to Abbreviations: Common Market for Eastern and Southern African (COMESA); Economic Community of Central African States (ECCAS); Economic Community of West African States (ECOWAS); Southern African Development Community (SADC); Union du Maghreb Arabe (UMA) / Arab Maghreb Union (AMU).

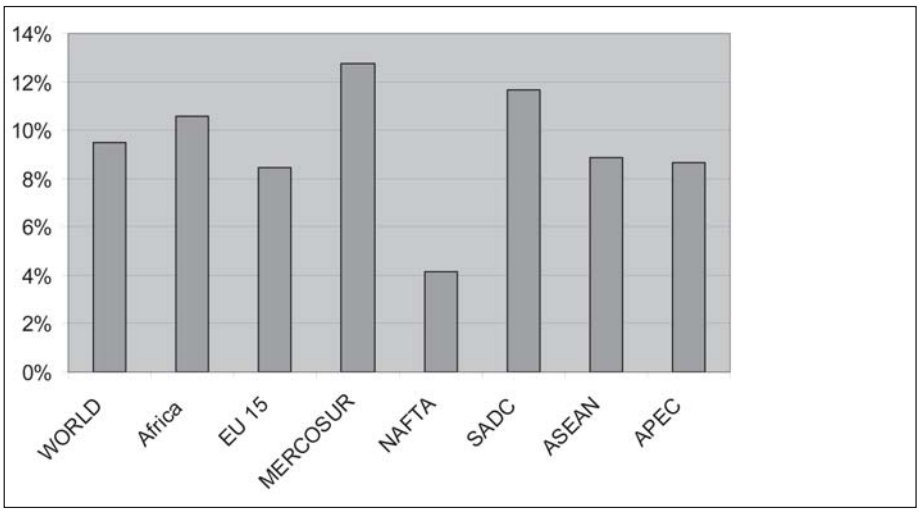


Figure 10: Annual average growth rates in exports in different economic zones, 2000-2004
Source: UNCTAD (2005)
KEY to Abbreviations: EU 15 refers to the European Union before the 10 accession states joined in 2004; Mercado Comun del Cono Sur (MERCOSUR); North American Free Trade Area (NAFTA); Southern African Development Community (SADC); Association of Southeast Asian Nations (ASEAN); Asia Pacific Economic Cooperation (APEC).

important synergies that need to be considered. Some of these relationships are addressed in later sections of this report.

2.6 International trade

There are a number of other economic trade zones operating in various regions and/or groupings in Africa that have been reducing trade barriers and increasing the opportunities for cross-border investment. The evolution of exports for the five most significant of these zones is shown in Figure 9. The SADC region continues to be the largest among these zones in economic terms. Although all zones showed significant increases during the past five years, the increase in SADC exports was the highest.

There are a wide variety of economic zones and free-trade areas worldwide, most of which have experienced export growth during the period 2000-2004. Some of these are listed in Figure 10, which compares the annual average growth rates in exports during the same period with that of SADC, as well as the world average and the African average. The SADC rate was higher than the world and African averages, as well as the averages of several other zones.

Such average trade figures in and of themselves do not necessarily provide the best indication of trade performance, since more detailed analysis would be needed in terms of the classes of products, directions

of trade and investment, exchange rates, payments, etc. However, they do provide some general indication regarding the expansion that is occurring in the region as a result of recent economic integration efforts.

2.7 Opportunities and constraints

The main point that arises from the preceding sections is that southern Africa has a low population density, a high share of population engaged in agriculture, a significant amount of land that is potentially available for alternative uses, plentiful biomass resources, and a fairly dynamic set of opportunities for expanding trade. Consequently, not only does one expect there to be significant opportunities for increasing use of biomass resources in the region, but it appears that there may be significant potential for exports of biofuels and biomass resources. Land constraints appear unlikely in any near-term scenario, although other resources—notably water—may turn out to be limiting factors, although such considerations are beyond the scope of this report. The reader is instead referred to other recent references on this issue (Berndes et al, 2002).

One major barrier to expansion of international trade in the SADC region is the high cost of road transport, which is several times higher than the world average (UNCTAD 2005). The landlocked countries of the region, such as Zambia and Malawi, experience considerable difficulties in getting their products to market. For international shipping by tanker, there are several ports in Mozambique and South Africa that could accommodate expanded trade in biomass and biofuels and these shipping costs would be quite low. In the case of liquid biofuels such as bio-ethanol, the costs would amount to only 1-2 cents/litre (Johnson and Matsika, 2006). For solid biomass trade, the costs would be slightly higher due to some minor additional handling costs for dry products (Hamelinck et al, 2003).

A major cost issue in trade of bulk products such as biomass and biofuels is that shipping by sea can be an entire order of magnitude cheaper or more on a unit basis compared to road transport. Consequently, regional coordination strategies become quite important and facility-siting for production that is intended for export markets becomes a key issue. Some strategies would therefore aim to locate biomass conversion or processing facilities near ports, while raw materials might be shipped from inland destinations (Batidzirai et al, 2006). Cost-sharing arrangements would need to be established between inland biomass producers and operators located near the coast, and such arrangements could be facilitated by some of the various economic integration policies being pursued within SADC.

Markets for Modern Bio-energy

This section provides an overview of some aspects of biomass markets, including land use, harvesting and delivery, implementation issues, and social and environmental impacts. Reference is made, where appropriate, on differences across the three categories of feedstock: sugar crops, woody biomass, and oil crops. The main sugar crop of concern here is sugarcane, which is by far the most important economically for developing countries. Other sugar crops that are considered promising for the future are sweet sorghum and the tropical sugar beet. These crops are generally not addressed here, although some of the same principles as those for sugarcane would be applicable.

The overview is not intended to be comprehensive and mainly addresses issues that arose at the workshop (summarised in Annex 1). This section of the report is generally oriented towards dedicated energy crops, as opposed to residues or to the gathering of biomass from common property forest resources. Some of the aspects considered here also apply to the use of residues, although often at a much smaller-scale. Harvesting of common property forest resources for bio-energy, albeit the most common form of biomass consumption in Africa, is mentioned only briefly here, since it is less relevant for international trade and also since the sustainability issues it raises are rather complicated to review.

3.1 Land use and ownership

Bio-energy is inherently land-intensive and land-sensitive, and as such the associated impacts are generally more significant than those of other renewable energy systems. Land use assessment is an important factor in determining the actual biomass accessibility, which is one of the most difficult and sensitive tasks of any biomass for energy analysis. The potential impacts on land use and land ownership are diverse and complex. Positive impacts might include creation of rural livelihoods, regeneration of abandoned land, and erosion control. Negative impacts might include degradation in ecosystem habitats, loss in uses of land by indigenous peoples, or competition with food crops. The implications and the overall assessment of costs and benefits are highly dependent upon locations, scale, managerial skills and public acceptance.

It is fairly straightforward to distinguish the case of residues vs. dedicated energy crops, regarding the impact on land use. The use of residues from agricultural, forestry, or animal husbandry will often have minimal impact on land use if sufficient residues are left for soil conditioning and associated uses. Often such residues are burned or require separate disposal, so their use for bio-energy creates value-addition. In the case of dedicated crops or plantations, the impact would be far more significant, as large amounts of land may need to be cleared, restructured, or consolidated.

The main options for land ownership generally follow one of three models or some combination of these models:

- large estates owned and managed by private companies, i.e. feedstock production and conversion are vertically-integrated elements of the same enterprise;
- medium-scale growers who provide feedstocks to public and/or private companies for processing, based on standardised terms-of-sale; or
- small-scale farmers who provide feedstock to public and/or private companies, generally through a cooperative or some similar institution that establishes terms-of-sale.

In the southern African context, the high proportion of subsistence farming in rural areas, and the complexities of land ownership under traditional land law regimes, can make large-scale acquisition of land somewhat more controversial. It has been suggested that a small-scale approach involving the contracting of small farmers to work as 'out-growers', dedicating a proportion of their land to growing a crop for guaranteed purchase by a processing company could be beneficial. Such an approach has the advantage of providing additional seasonal income for poor rural farmers, without dismantling their existing livelihoods. However, the lower intensity of land use entails a larger area of agricultural production for each processing plant, resulting in feedstock transport costs becoming potential obstacle to commercial viability.

❑ Sugar crops

In the case of permanent (as opposed to annual or semi-annual) crops such as sugarcane, different parts of the world have adopted different models. Various ownership models can be categorised as follows:

- cane is owned by the factory owner; fields are located adjacent to the factory;
- long-term agreements between factory owners and cane supply partners (farmers who own land adjacent to the factory and sell the cane directly to the factory);
- land rented from third parties; and
- cane bought from independent growers/suppliers (usually to supplement cane shortages).

When ownership is separated, it may be the case that cane growers are in principle free to sell the cane to whatever factory they choose, but usually in practice cane growers will have some type of agreement with a particular factory to supply sugarcane. This avoids transporting the cane to other factories located further away, as sugarcane growers must balance out higher price received from the cane with the additional transport costs. It also reduces the uncertainty in cane supply for the factory owner.

In much of Africa, large estates provide most of the sugarcane that sugar companies use, although small farmers or out-growers may also supply 10-20% of the cane processed. In other parts of the world, land is owned or rented by many small producers, as is often the case in the Caribbean countries, India, and Thailand. In India, there are in fact operations at many different scales, even within the cane supply for a given factory; small family farms, medium-size, and large-scale estates might all supply cane to the same factory based on simple contract terms.

Small farmers would generally be grouped in some type of association that provides technical support as well as establishing standard contracts and terms-of-scale. A small farmer might have a plot of only 5-10 hectares; a yield of 100 tonnes/ha implies a need for 1000-2000 small family farms to reach the minimum-scale. In some African countries, family farms are even smaller; in Tanzania, the average family farm is only 1 hectare, and they are grouped in farmers' associations. In Mauritius, one third of the cane is also harvested by small growers, and there is a "farmer service centre" that supports small cane growers in the mechanisation process.

The significant differences in the experiences of the world's two largest cane producers are instructive. In Brazil, production is dominated by large estates; the Brazilian experience suggests that the optimum-scale for cane processing into sugar and/or ethanol is between 1 and 2 million tonnes of cane (Leal, 2005). The Brazilian market is open, as prices are set by international markets and not by government regulations or through preferential markets. The Brazilian structure is oriented towards the world market, as Brazil is a major exporter and in fact is currently the most competitive producer in the world of sugar as well as ethanol.

The situation is quite different in India, where 60% to 70% of cane growers are small ones, and these are generally organised into cooperatives that may have sharing formulae for markets and proceeds. The cooperative sector also provides technical support to small farmers, e.g. by providing seeds, fertilizers and chemicals. Moreover, the government fixes sugar prices, so that growers are protected from the fluctuations in the world market. In fact, India has perhaps the most regulated cane industry in the world, but such regulations are also made more feasible by the fact that India produces predominantly for domestic consumption (Seebaluck et al, 2007). One might tentatively conclude that it is difficult to develop export markets without fairly large-scale agricultural operations.

❑ Woody sources of biomass

Woody biomass for products and bio-energy can be organised in one of three ways:

- large plots or plantations, operated by private corporations or government agencies;
- woodlots or tree nurseries; or
- common-property managed forests

The issue of property rights is complicated and is beyond the scope of the discussion here. However, it is important to note the distinction between "common property" and "open access" systems. Common property systems are characterised by clear rules as to who can use the forest resources, when they can use them, and under what conditions, whereas open access systems lack such a framework. The distinction was first clarified widely in the scientific literature in response to the "Tragedy of the Commons" (Hardin, 1960), in which open access and common property systems were assumed to be equivalent. It has been subsequently shown that there are a wide range of

institutions that can and have been used to manage common resources such as forests (Ostrom, 1990).

Large plots are more economical where mechanisation is required due to the high cost of the capital equipment involved. The large plots will supply factories that process either mainly for export or for some combination of export and domestic consumption. Woodlots or nurseries can fit well with community plans for multi-purpose resource strategies, and might include various services such as soil conservation, watershed maintenance, recreation, and other uses as well as marketable products like energy and timber. Environmental concerns about large plantations are placing them under increased scrutiny in developed and developing countries alike.

Another important distinction is, of course, intensive (more inputs) vs. extensive (more land) expansion for bio-energy production. The Brazilian model for eucalyptus plantations generally exemplifies the large-scale intensive approach, using high capacity central processing points fed by intensively farmed surrounding areas. Where intensive farming is accomplished with best practice techniques and where the land used does not have major ecosystem functions, then the overall result can be beneficial, as more sensitive land elsewhere can be relieved from the pressures of expansion. On the other hand, less intensive bio-energy practices on wider areas could allow the benefits to be more widely dispersed and the bio-energy production to be integrated with production of food, environmental services, recreation, housing materials, and other welfare-enhancing activities.

❑ Oil-bearing crops

The land use issues of concern for oil-bearing crops are similar to those of sugar crops. The main oil-bearing crop in the developing world today is oil palm. It has a high yield relative to other oil-bearing crops and is generally grown on large plantations. Other oil-bearing crops are more amenable to smaller-scale production, such as coconut oil and jatropha. Ownership is less likely to be highly correlated to economies of scale than is the case of sugarcane. The establishment of smaller-scale operations should thus be feasible, although there does not yet appear to be examples of small-scale operations that produce a significant quantity in aggregate, through cooperatives or other institutional mechanisms. Another factor that will impact the scale and ownership is the destination of the final products. Unrefined oils are more likely to be compatible with small-scale production and ownership. Larger-scale and consolidated ownership is more likely where export markets require homogenous commodities, i.e. trans-esterification into bio-diesel.

3.2 Harvesting, delivery and transport

Harvesting, delivery, and transport of biomass resources comprise key elements in the bio-energy production chain, and often determine the spatial extent of bio-energy markets. The two main types of transport and delivery are thus the transport to the processing facility or facilities and the transport to final markets. One distinction is between the case where harvesting and delivery results directly in marketable products vs. when biomass is being sent to a major facility for further processing and conversion. Another distinction arises where intermediate products (e.g. compacted biomass, unrefined fuels) are involved.

❑ Sugar crops

For centuries, sugarcane harvesting has been done manually by the so-called "cane cutters" and this still remains the case in Africa (except for parts of South Africa) and much of Asia. The cane is often burned before harvesting so as to remove the extraneous matter and leave only the stalks that contain the sucrose, which do not burn due to their moisture content. In OECD countries such as the U.S. and Australia, mechanisation occurred many decades ago. In Brazil and other South American countries, the increasing cost of labour and other socio-economic factors have contributed to increased mechanisation. Until the past two decades, there has not been any dramatic change in harvesting methods in developing countries due to the following factors:

- relatively low cost of manual harvesting, and the availability of labour;
- high costs of mechanical harvesters;
- low efficiency of mechanical harvesting for sugar production (e.g. high losses of 4-5% of sucrose, cane impurities, etc.); and
- difficulty for mechanical harvesters to deal with certain topographies (e.g. steep slope, rocky terrain).

Mechanisation had been occurring where labour costs have been rising, not only in Latin America, but also in South Africa and in some Asian countries. Another

major driving force has been environmental pressure to ban burning of cane along with the growing interest in using cane residues for cogeneration. Yet another factor has been the drive for modernisation. Increasing competition, reductions in preferential sugar markets, and emerging market opportunities are transforming the sugarcane sector from a primarily "family run business" into a modern agro-industrial complex, run by an increasingly professional labour force. This is particularly so in the case of Brazil and South Africa. This process is facilitated by computerisation, which is providing greater efficiency and management control at all levels.

In a market faced with environmental and social pressure and increasing competition, mechanisation offers additional advantages. For example, a harvester can replace 80 cutters and thus facilitate the whole harvesting process. The benefit to the enterprise's cost is not only the saving per tonne/cane cut but also in administration (e.g. preparation of contracts), health and safety, training, transport, etc. Furthermore, with increasing standards of living, fewer and fewer persons are willing to accept the hard physical and seasonal labour required for cutting cane. In countries such as India, the process will be slower. With more than 500 sugar factories a lot of people depend on manual harvesting of cane for their livelihood.

There are also mixed systems in practice in some southern African countries, in which a machine cuts the cane, but people would still be needed to collect and gather cane in the fields. As the cutting of the cane is the hardest part physically, this will ease considerably the task for workers and open up the labour force for women. The mixed system may be of special interest for bio-energy production, since the gathering of residues might be accomplished at the same time that cane is gathered. Field research suggests that mechanical gathering of residues can be complicated and would be aided by human assistance, since the machine parts sometimes become tangled due to the bulkiness of the residues (GEF 2005). The additional labour required for gathering residues, known as "cane trash," would partially compensate for some of the labour losses due to mechanisation of cutting (Macedo, 2005).

❑ Woody sources of biomass

There are more direct end-use markets for woody biomass and thus they will generally require less processing compared to agricultural sources. Transportation cost to final markets is an important element in feasibility and cost-effectiveness and the spatial extent of export markets will often be related. When production is for woodfuel and timber products, for example, land transportation costs will be significant, as the cost of transporting wood products 60 kilometres by land is about the same as transporting it 1000 kilometres by ship. Consequently, international export markets have tended to cluster near coasts. Liquid fuels have an obvious advantage in this regard. Not only are they less bulky, but where quantities are sufficient, pipelines can greatly reduce the costs of transport.

Local markets for woody biomass will undoubtedly be important in developing countries, particularly in southern Africa, for many years to come. Consequently, traditional biomass in the form of charcoal and firewood will be needed for households and small-scale enterprises. The local nature of traditional biomass markets also suggests that woody biomass will be more valued for local use compared to agricultural or plantation-based biomass, other things being equal. It will be important, of course, to improve the efficiency of traditional biomass use, such as with improved cookstoves.

Woody biomass is also available in large quantities as a residue from wood industries. This has been demonstrated in Sweden and other countries, where sawdust from sawmills and paper industries are used for energy. The waste products from pulp production, known as "black liquors" are also being used for biofuel production. This has environmental benefits, of using what would otherwise be a waste product for energy as well as socioeconomic benefits as payments from the energy industry are now greatly contributing to the survival of the sawing industry (Kåberger, 2005). Some African countries, including Ghana and Tanzania are beginning to use residues from timber mills to sell in compact form, thereby obtaining supplementary income.

3.3 Environmental impacts

Bioenergy is inherently land-intensive, meaning that the associated socioeconomic and environmental impacts are much more significant than those of other renewable energy systems. A comprehensive list is difficult to summarise in this brief review, but some key concerns relate to loss of ecosystem habitat, deforestation, loss of biodiversity, depletion of soil nutrients, and excessive use of water. In addition to

the provision of a renewable energy source, some positive environmental impacts might include restoration of degraded land, creation of complementary land use options, and provision of non-energy resources and materials. Some specific issues that arise in the case of sugar crops, woody biomass, and oil-bearing crops, are outlined below.

❑ Sugar crops

The environmental impacts of sugarcane have been analysed in considerable detail in the case of Brazil. When Brazil began its effort to expand sugarcane for ethanol production in the 1970s, the environmental impacts were quite significant, particularly the disposal of large streams of waste effluent from ethanol distilleries. Over the past thirty years, dramatic improvements have been achieved in technical efficiency and in the efficiency of key resource inputs (e.g. water). The case of water use is particularly interesting, since cane requires significant amounts of water during a key period in the growth cycle. Cane is rain-fed in Brazil, and furthermore, the amount of water that is recycled in the cane-ethanol processes is to the order of 90% (Macedo, 2005).

In other parts of the world where water is scarcer, sweet sorghum could provide a useful alternative, with its low water requirements, less than half of that needed for cane. Additionally, it has the ability to remain dormant during periods of drought, resuming growth upon the re-occurrence of favourable conditions (Bassam, 1998). This means there is a much greater likelihood of small-scale farmers with no access to irrigation raising a crop of sweet sorghum in dry conditions than sugarcane, or even of maize. This could potentially have strong socioeconomic benefits by increasing the productivity of small-scale farmers.

Sweet sorghum has low requirements for nitrogenous fertiliser, about 35-40% compared to sugarcane (Praj, 2005). This has economic benefits for the farmer, as the crop will require less investment in inputs, as well as possible environmental benefits from avoiding impacts of fertiliser run-off. Sweet sorghum has high potassium uptake, however, and is therefore highly depleting of this mineral (El Bassam, 1998).

❑ Woody biomass

Woody biomass is a major source of primary energy for the majority of the world's poor. In some African countries, over 95% of households depend on wood for cooking and heating. However it is generally industries that are responsible for deforestation, rather than households. Unsustainable extraction practices of forest and wood products industries are a major source of environmental degradation in many regions. The environmental impacts of wood fuel use by industries and households are well known, and include:

- health effects of indoor air pollution, which kills more women and children than tuberculosis and malaria (UNDP, 2004);
- contributing to deforestation, a major problem in some southern African countries; and
- soil degradation and erosion problems.

A common impact from the use of wood fuels relates to the opportunity cost of the time spent collecting wood. The gathering of wood can require several hours per day, sometimes preventing children from attending school, and women from improving their livelihood by engaging in other, possibly profitable enterprises.

However, the consumption of woody biomass as a household fuel need not be inherently unsustainable, although improvements in conversion efficiency and use are needed, especially in more densely populated regions. Improved charcoal and wood burning stoves have an important part to play in poor areas where modern energy services are unlikely to penetrate for many years. A number of studies have suggested that even traditional charcoal use can be sustained in regions that are not too densely populated. Analysis in the Lusaka region in Zambia showed that charcoal use had not exceeded the sustainability threshold (Chidumayo, 2002). However, an important question will be whether policy should aim towards providing "clean cooking fuels" through more efficient energy carriers, both non-renewable such as LPG, and renewable, such as ethanol gel fuel.

❑ Oil-bearing and other biomass crops

Jatropha trees yield oil that is highly suitable for use in raw form or for refinement into bio-diesel. This tree is reported to have strong environmental benefits when intercropped with other produce. It can be used as a hedge to prevent soil erosion, and can also have regenerative effects on the soil, being a nitrogen fixer (Openshaw, 2000).

Several oil bearing crops, currently used predominantly in food products, are strongly associated with severe environmental impacts. In particular, soya bean plantations are encroaching on

rainforests in Brazil, and the palm oil industry is a major cause of deforestation in Malaysia and Indonesia, threatening species such as the Sumatran tiger and the orangutan with extinction (Friends of the Earth, 2005). In order to preserve the credibility of bioenergy as an environmentally sustainable source of energy, particularly in the context of a possible future international trade in biofuels, such sustainability concerns will have to be addressed. Some form of social and environmental certification would seem to be desirable. The precise structure of such a scheme, whether it could be mandatory, or would have to remain voluntary, and how it could be linked to other existing social and environmental certification schemes, needs to be established.

One starchy crop that is quite important in the southern African context is cassava, a staple food crop in many parts of southern Africa. It could serve a dual purpose by providing food and energy. It could also be seen as a food reserve crop in case of food shortages. In Tanzania, farmers devote more than 10% of their land to cassava for this purpose. Cassava is productive on poor soil, resistant to drought and capable of achieving high yields (10 tonnes/hectare). It also has the advantage of being able to remain in the soil for long periods, and can be harvested only when required. This eliminates storage problems, making it an ideal back-up crop, for fuel or food.

❑ Industrial processing impacts: the case of vinasse

There are many further impacts from the industrial side of bioenergy processing. Stillage or *vinasse*, a by-product of ethanol production, presents a somewhat special case. It is produced in large volumes and is also potentially valuable input for further bioenergy production as well as for other uses such as fertiliser. Each litre of ethanol produced is accompanied by 10-15 litres of vinasse. This large volume of vinasse and its high BOD (Biological Oxygen Demand) and high COD (80,000 to 100,000 mg/l) poses a problem for its disposal.

The hazardous substances present in the vinasse generate a very high BOD, ranging from 30,000 to 40,000 mg/l and a low pH of 4-5, because of the organic acids, which are corrosive and require stainless steel or fibre glass to resist it. Vinasse contains unconverted sugars, non-fermented carbohydrates, dead yeast, and a variety of organic compounds, all of which contribute to the BOD (Cortez *et al*, 1998). The organic components in the vinasse can be used for biogas production through anaerobic digestion, a process in which methane is produced when microorganisms break down the components under conditions of low oxygen and low temperature (recall section 1.5).

One possibility of reducing its polluting effect is recycling it in the fermentation process. Vinasse may be partly used to dilute the sugarcane juice or molasses in the fermentation step. The juice or molasses need to have the Brix adjusted to allow proper yeast growth, a process that normally requires water to dilute it. One company (Alfa Laval) has developed a process called "Biostil" that uses vinasse to dilute the molasses prior to the fermentation step.

In Brazil, detailed and extensive studies and field testing have shown that vinasse is an excellent fertilizer and improves the physical, chemical and biological properties of the soil. It increases the pH, enhances the nutrient availability, improves the soil structure due to the addition of organic matter, increases the water retention capacity and improves the microorganisms' population.

3.4 Socio-economic impacts

Socio-economic impacts that are of primary interest generally include income generation, job creation, provision of new services, creation of new infrastructure, establishing opportunities for entrepreneurs, and stimulating innovative technical and institutional approaches. At the same time, large-scale projects have encountered controversy involving the acquisition of traditional land and competition with food crops.

The range and extent of socio-economic impacts of bioenergy use are greatly dependent on the scale and intensity. The Brazilian model exemplifies the large-scale intensive approach, using high capacity central processing plants fed by intensively farmed surrounding areas. The establishment of large estates can bring significant benefits to employees, such as health care, sanitation and improved infrastructure (Tomlinson, 2005). Indeed, the large-scale crop enterprises are more economically efficient. However, the question remains whether or not they can be modified to further improve local livelihoods.

In the southern African context, the high proportion of subsistence farming amongst livelihoods in rural

areas, and the complexities of land ownership under traditional land law regimes, has made such large-scale acquisition of land somewhat more controversial. It has been suggested that a smaller-scale approach may be more appropriate, possibly involving the contracting of small-scale farmers to work as 'outgrowers', dedicating a proportion of their land to growing a crop for guaranteed purchase by a processing company. Such an approach has the advantage of providing additional seasonal income for poor rural farmers, without dismantling the structure of their existing livelihoods, which may be vital to their survival. However, the lower intensity of land use entails a larger area of agricultural production for each processing plant, resulting in feedstock transport costs becoming a serious obstacle to commercial viability.

A decentralised approach could also help to reduce feedstock transport costs by reducing the weight of the cargo—in other words—by decentralising more of the production process through the setting up of small-scale factories. This would create another important benefit for the rural poor—access to clean, domestic fuel—with resultant benefits to health from reduction of indoor air pollution. The economic viability of such small-scale distilleries has not been proved, and concerns have been expressed about the dangers of alcohol abuse. It is nevertheless an area worthy of some further investigation.

Seasonal employment can pose social problems in industries such as sugarcane in southern Africa. The sudden influx of migrant seasonal workers into regions to which they have no attachment has been reported to have negative effects on community cohesion, causing ethnic tension and disintegration of traditional structures of authority. Migrant workers sometimes establish unauthorised settlements and they are unwilling to leave at the end of the season, ultimately increasing overall unemployment levels and pressure on land for subsistence farming. Due to the sometimes drunken and promiscuous behaviour of migrant workers, it has also been observed that HIV infection rates can be higher around sugarcane plantations (Cornland et al, 2001; FAO, 1995).

A major area of concern for critics of biofuels is the possibility that bioenergy crops could replace land for food crops. Another advantage of sweet sorghum is that in addition to producing sugary stems suitable for ethanol production, many varieties also produce edible grains, which can be ground to make 'mealie meal', a staple food in many parts of southern Africa. This has the attraction of providing potentially a double benefit – subsistence food and a cash income – allowing the farmer the chance to rise out of poverty, without losing self-sufficiency.

3.5 Sustainability criteria

There has been considerable effort during the past few years aimed at the development of sustainability criteria for biomass and biofuels, both within regions and in the context of international trade. In Europe, a recent analysis shows that 15-17% of expected primary energy requirements in the EU-25 in 2030 could be met through bioenergy, even with the application of rather stringent sustainability criteria. The expansion would be facilitated by increased availability of significant quantities of waste residues, the increasing productivity of agricultural biomass sources, and the increased amount of land available for dedicated energy plantations (EEA, 2006).

It is worth reiterating that in the context of bioenergy projects, there are no "one size fits all" solutions (ESMAP, 2005). Socio-economic and environmental impacts must be assessed for every new bioenergy project in the context of the pre-existing ecological, cultural, agro-industrial and land use systems that are specific to the area under consideration. However, it is possible to devise a 'check list' of sustainability criteria most likely to be relevant to a bioenergy project. The following are among the key criteria, as identified by Smeets et al (2005) in their case studies of Ukraine and Brazil:

- land use patterns: deforestation, competition with food, protection of natural habitats;
- socioeconomic: child labour, minimum wages, employment, health care, education; and
- environmental: soil erosion, fresh water use, fertilisers pollution, agricultural chemicals.

Smeets et al (2004) assess the costs of applying these criteria both in a 'loose' and 'strict' fashion, the latter set sometimes being defined as not merely minimising negative impacts, but making positive improvements, most notably in the provision of health care and education services. It is worthwhile considering whether the concept of sustainability in bioenergy projects or programmes should mandate simply that conditions measured according to these criteria should not be negatively impacted; or whether in fact true sustainability should entail positive improvement of

conditions. At the same time it is important to recognise that bioenergy in some cases will replace fossil fuels, and as such the costs and benefits must be compared to those of the fossil fuels being replaced.

Sustainability criteria for bioenergy will inevitably have to address certain core criteria, which will differ considerably in different regions and for different crops. The core criteria would likely cover the following areas (WWF, 2006):

- land use and land ownership, including food security;
- maintenance of biodiversity;
- reduction and minimisation of greenhouse gas emission;
- soil erosion and degradation;
- water use and contamination; and
- socio-economic impacts.

The criteria would also have to be applied at varying levels: local, regional, national, and international (i.e. particularly in relation to trade). Undoubtedly there will be conflicts across the scales, and consequently a governance system or perhaps an environmental regime would have to be somewhat flexible, but also capable of maintaining fairly high standards.

Regional and Global Markets for Biofuels

This section provides an overview of regional and global markets, focusing on liquid biofuels—bioethanol and biodiesel in particular—since these have the greatest significance in terms of international trade in the near-term. A historical overview is provided, followed by some discussion of key regional markets and a brief consideration of global market prospects. Biogas is a cost-effective and important option in many developing countries, but is unlikely to have much relevance in terms of international trade. Although not addressed here, in the longer-term, there may be significant potential for trade in other liquid fuels such as methanol and various second-generation biofuels.

Production and consumption of bio-ethanol is dominated by Brazil and U.S.A, though interest is growing in many countries around the world. After 30 years of running a bio-ethanol programme, Brazil initiated a bio-diesel programme in 2005. Legislation proposed in the U.S. in early 2007 calls for a twelve-fold increase in biofuels by 2030, amounting to 60 billion gallons or about 227 billion litres (Harkin, 2007). U.S. production is destined almost exclusively for domestic markets, while Brazil is a major exporter as well as domestic consumer. There is also some production and trade in synthetic ethanol, derived from coal and natural gas in countries such as Saudi Arabia and South Africa. Production and use of bio-diesel is dominated by Germany. While there is not yet significant trade in bio-diesel outside Europe, it is growing quickly. Much of the discussion in the following sections focuses on bioethanol, although some of the same principles may apply to biodiesel too.

4.1 Historical overview

Biofuels have been around for over a hundred years, and bio-ethanol in particular saw significant use in the early part of the twentieth century. Before the era of cheap oil and during times of conflict such as World War II, biofuels have been recognised as a valuable domestic alternative to imported oil. The resurgence of interest in biofuels in recent years is in part for similar reasons of energy security, but now the added issues of rural development and climate mitigation make the case for biofuels even more compelling. An interesting historical note is that the Model T introduced by Henry Ford during 1908-1926 could run on either petrol or ethanol. Consequently, the dual-fuel vehicles introduced in recent years are simply a somewhat more sophisticated re-introduction of a capability that was already available at the dawn of the auto age!

❑ Ethanol

Ethanol fuel played a key role in the first four decades of the 20th Century. By the mid-1920s ethanol was widely blended with gasoline in many industrial countries. In the Scandinavian countries, a 10-20% blend was common, produced mostly from paper mill waste. In most of continental Europe ethanol was obtained from surplus grapes, potatoes, wheat, etc. In Australia, Brazil, and many other sugarcane producing countries, ethanol was produced from cane juice and molasses (Rosillo-Calle & Walter, 2006).

After World War II, few countries showed any interest in ethanol as there was plentiful cheap oil around. In the 1970s, after the oil shock, many countries began to again consider the ethanol fuel option, notably Brazil. During most of the 1990s the low price of oil again had a negative effect on ethanol fuel programmes, with many schemes being either abandoned or scaled down significantly. The past several years have witnessed a growing interest in ethanol fuel as a substitute to petrol in the transportation sector on a global-scale. This is due to a combination of factors, ranging from environmental and social benefits to climate mitigation and energy security.

There are three broad market categories for ethanol—fuel, industrial, and potable—with the largest volume market today being for fuel. In fact, since 1975, the market share of fuel ethanol (of all ethanol) has increased from about 5% to over 75%, due mainly to its use in Brazil and the U.S. (FO Lichts, 2006). The industrial market is generally associated with chemical and pharmaceutical industries that require ethanol as a feedstock for fine chemicals and various products. The industrial market generally has greater purity requirements than fuel alcohol, since it is directed to specialised production processes rather than

combustion as a fuel. The potable market includes distilled spirits and liquors. However, surplus wine alcohol is sometimes re-directed to other markets, such as is the case in some Caribbean countries, which re-process the wine alcohol for export to the U.S. under special trading arrangements. Ethanol can also be processed into ETBE (ethyl-tertio-butyl-ether) by reaction with isobutylene, a refinery by-product. Such re-processing is popular in the EU, due to the fuel standards adopted by the automobile industry in EU markets, and the preferences of oil distributors in the EU for ETBE rather than bio-ethanol as a final product for blending (EUObserver, 2005).

Not all ethanol is bio-based. Synthetic fuels—both diesel and ethanol—can be produced from coal or natural gas through the Fischer-Tropsch process, as is common in South Africa. Synthetic ethanol is often used in the industrial market, due to the specific purity requirements. Synthetic ethanol is chemically identical to bio-ethanol, and market data is not necessarily reported separately (Table 5 gives total ethanol production). Although synthetic ethanol production is generally not cost-competitive with bio-ethanol, the higher levels of purity required can acquire a price premium for certain applications. Production in South Africa was initially a result of the political isolation against the apartheid regime in the 1970s. Trade sanctions required greater reliance on domestic energy sources where feasible, and South Africa has plentiful supplies of coal. Having all the infrastructure in place, South Africa has continued for many years now, after apartheid, with its synthetic production. The process for gas-to-liquids is analogous to the production of second-generation biofuels in the future via gasification of biomass.

As illustrated in Table 5, world ethanol production has increased significantly in recent years. The two largest producers—Brazil and USA—have generally been responsible for 60-70% of world ethanol production. All ethanol produced in Brazil is bio-ethanol, as is nearly all ethanol produced in the U.S. Synthetic ethanol is produced in a number of European countries as well as in Middle Eastern countries, South Africa, and some Asian countries. Due to fuel quality issues and ongoing negotiations with oil companies, most ethanol produced in the EU is either synthetic or is bio-ethanol that is processed into ETBE (EurObserv'ER, 2006). In a few EU countries such as Sweden, ethanol is blended directly rather than using ETBE. Sweden is also one of the few countries to run a significant fleet of E100 vehicles; much of the bus fleet runs on ethanol, using specially-designed engines.

❑ Biodiesel

The process of trans-esterification for making bio-diesel has been known for well over a hundred years, although bio-diesel, as it has come to be known, emerged only in the past twenty years, in terms of the use of refined vegetable oils on a large-scale.

Table 5: Ethanol production[1] by country or region (billion litres)

	2000	2001	2002	2003	2004	2005	Global share, 2000	Global share, 2005	Annual average change
Brazil	10.6	11.5	12.6	14.7	14.7	16.1	33%	34%	8.6%
U.S.A.	7.6	8.1	9.6	12.1	14.3	16.2	24%	34%	16.4%
other Americas	1.0	1.0	1.0	1.0	1.0	1.1	3%	2%	0.8%
EU	2.4	2.6	2.5	2.5	2.5	2.7	8%	6%	2.5%
other Europe[2]	3.7	4.0	4.0	4.0	4.0	4.2	12%	9%	2.6%
Africa	0.5	0.5	0.5	0.5	0.6	0.6	2%	1%	3.6%
China	3.0	3.1	3.2	3.4	3.7	3.8	9%	8%	5.1%
India	1.7	1.8	1.8	1.9	1.7	1.7	5%	4%	-0.2%
other Asia[2]	1.2	1.2	1.2	1.4	1.3	1.3	4%	3%	0.8%
World	**31.7**	**33.7**	**36.5**	**41.5**	**43.6**	**47.6**			**8.5%**

NOTES:
[1]All figures include bio-ethanol and synthetic ethanol; about 85-90% of the total world ethanol market is bio-ethanol; about 75% of the total world ethanol market is for fuel; Some ethanol is processed into ETBE for blending, particularly in the EU.
[2]*Other Europe includes Russia and republics; other Asia includes Pacific/Oceania*
Source: F.O.Licht's, 2006.

Rudolf Diesel first demonstrated his breakthrough engine design in 1893, and it was powered by peanut oil. He believed that the utilisation of a biomass fuel represented the future for his engine. In 1911, he said "The diesel engine can be fed with vegetable oils and would help considerably in the development of agriculture of the countries which use it." The emergence of cheap fossil fuels, however, encouraged the diesel engine manufacturers to alter their engines to utilise the lower viscosity petroleum diesel.

Research into the use of trans-esterified sunflower oil and refining it to diesel fuel standard was initiated in South Africa in 1979. By 1983 the process to produce fuel quality engine-tested bio-diesel was completed and published internationally (SAE, 1983). An Austrian Company, Gaskoks, obtained the technology from the South African Agricultural Engineers, put up the first pilot plant for bio-diesel in November 1987 and the erection of the first industrial bio-diesel plant in April 1989, with a capacity of processing 30,000 tons of rapeseed as feedstock per annum. Throughout the 1990s, plants were opened in many European countries, especially in the Czech Republic, France, Germany, and Italy.

Globally, production of bio-diesel is concentrated in a few countries, with Germany and France accounting for nearly 60% of production and consumption, as shown in Table 6. Global production has been increasing at a tremendous pace, with most of the growth in the EU as a result of fairly generous tax benefits and subsidies. From 2000 to 2005, biodiesel production increased globally four-fold, from under 1 billion litres to nearly 4 billion litres. Production in Germany alone increased more than five-fold over the same period.

4.2 Biofuels in Brazil

The rapid development of ethanol production capability in Brazil took place only after the creation of the Brazilian Alcohol Program, known as PROALCOOL, in 1975, with the purpose of producing anhydrous ethanol for blending with gasoline. After the second oil shock in 1979, the government decided to expand production to include hydrated ethanol to be used as neat fuel in modified engines. Sugarcane production has increased several-fold during the past three decades, up to over 380 Mt in the 2004/2005 harvest. In the past five years alone, production has increased by over 50% (recall Table 5).

The continued expansion of the sugarcane industry in Brazil, particularly in the last decade, has been the result of various factors, ranging from high demand for sugar and ethanol both in the domestic and international market to continuous improvements in productivity. Such improvements include the whole chain system, ranging from better varieties, soil management, pest and disease control, transportation, technical improvement in conversion, to end use.

With dozens of new industrial units in different stages of construction, ethanol production capacity is set to expand considerably in the coming years. Brazil has the capacity—land, technical know-how and even finance—to expand its ethanol production capacity 8-10-fold in the next 20-30 years. The implications of such an expansion are being evaluated at the

Table 6: Biodiesel production by country or region (million litres)

	2000	2001	2002	2003	2004	2005	Global share, 2000	Global share, 2005	Annual average change
Germany	250	315	511	813	1176	1897	26%	45%	50.0%
France	373	364	416	406	395	559	40%	13%	8.4%
Italy	89	160	239	310	364	450	9%	11%	38.4%
other EU	112	128	130	181	330	713	12%	17%	44.8%
EU Total	**813**	**912**	**1210**	**1630**	**2265**	**3618**	**86%**	**86%**	**34.8%**
U.S.A.	8	19	57	76	95	284	1%	7%	106.4%
other	125	190	256	284	273	307	13%	7%	19.7%
World	**945**	**1121**	**1523**	**1989**	**2633**	**4209**			**34.8%**

NOTES: other EU includes EU-25 starting in 2004 and 2005
Sources - estimated based on: Eurobserver, 2006; National Biodiesel Board, 2006.

University of Campinas, one of Brazil's premier research universities (Cortez, 2006).

With the lowest cost production in the world, Brazil has become the largest exporter of ethanol. The main priority in Brazil has thus far nevertheless been to supply the domestic market. Alcohol is used as an octane booster blended with gasoline, alone as "neat" fuel, and in flex-fuel vehicles, and also as a chemical feedstock and other industrial applications. The flex-fuel vehicles, introduced in 2003-2004 run on any combination of gasoline and alcohol.

❑ Sugarcane burning

The burning of sugarcane fields has been a major issue in Brazil for some years as well as in many other sugarcane producing countries. The cane is burned to kill pests and remove extraneous matter, making it much faster for manual cutting of the cane. Although the overall cycle of cane production is CO_2 neutral, the emissions emanating from sugarcane burning is still a significant economic and environmental issue, particularly in the State of Sao Paulo, Brazil, not only because it is the largest producer of cane, but also because it is most densely populated. Some of the negative impacts of sugarcane burning are:

- loss of sucrose: unburned cane can have as much as 20% higher productivity;
- loss of nutrients: 10-20 ton/ha of dry matter are lost in the process of burning; and
- smoke and danger from fire is a nuisance and hazard for neighbouring residents.

❑ Sugarcane harvesting

Mechanical harvesting is partly dictated by the legislative pressure to ban the practice of burning, although new factors are emerging. There are two camps: the first camp consists of those who promote manual harvesting, mainly because of social considerations, as it is a large source of employment. In some areas of the State of Sao Paulo for example, the competitive pressures for sugarcane are intense. This is because industrialisation and services are becoming increasing important and thus there is pressure on land and wages for alternative uses. Similarly, in areas around Piracicaba, a major sugarcane area, pressure on land and wages is forcing cane growers to move to other areas as it is becoming uneconomic to grow cane (UDOP, 2005). This forest camp includes mainly trade unions, academics and government officials. The second camp promotes mechanisation fairly agressively and is more representative of the corporate interests of the sugarcane, ethanol and related industrial sectors.

Until recently, there has not been any dramatic change in harvesting methods mostly due to the following reasons:

- relatively low cost of manual harvesting (availability of labour);
- high costs of harvesters; and
- low efficiency of mechanical harvesting (e.g. sucrose losses 4-5%, cane impurities).

However, in recent years this situation has began to change, particularly in the State of Sao Paulo, due to a combination of factors of which harvesting costs and environmental pressures play a major role. Increasing cost of labour in some areas is becoming acute according to sugarcane growers. However, this is more complex than what it seems at first instance. For example, sugarcane cutters usually receive a salary that is as much as 3 times higher than other workers doing similar jobs (e.g. in the agro-forestry sector). This difference in wages is caused by social reasons, younger workers do not want to work as cane cutters since it is extremely hard and short-term work that is associated with poor education and low status. Emerging opportunities in other sectors can offer jobs with better working conditions.

Environmental pressure is increasing due to social concerns about the effects of burning. There is new legislation that bans burning near urban areas, motorways, roads, etc. For example, in Sao Paulo State by 2006, 30% of the cane would have to be harvested whole in areas where mechanisation is possible. This will reach 100% by 2021, and by 2031 all sugarcane would have to be harvested whole (green), mechanically or otherwise. Currently, the average for Brazil is 25% mechanical and 75% manual harvesting and in Sao Paulo State 35% is harvested mechanically (Gazeta Mercantil, 2005). The consensus is that manual harvesting will gradually be replaced by mechanical harvesting. In fact, new expansion of sugarcane takes place only where the topography and soil conditions are suitable for mechanised harvesting.

❑ Expansion of land under cane

Brazil has enormous potential for increasing ethanol production, due to the high productivity of sugarcane, as it does not require as much land as for other crops. There is about 62 million ha (Mha) cultivated for all crops in Brazil and cane is grown on about 5.7 Mha.

In the short-run it is estimated that domestic ethanol fuel demand will grow about 9% a year for the next 5 years (Oliveira, 2005). In 2013, the domestic demand could reach 25 B/l, while exports could reach 6 billion litres (Nastari, 2005). However, such large expansion could have serious land use impacts.

There is considerable domestic and international concern with the possible opening of the *Cerrado,*[2] a large region that is the biologically richest savannah in the world. There is a perception of negative effects due to multinational agro-industrial corporations growing crops such as soybean, which is much more land-intensive than sugarcane. EMBRAPA[3] has identified over 90 Mha suitable for sugarcane cultivation, although there is considerable disagreement as to the suitability of this area[4]. Some proposals have suggested that ethanol fuel from the Cerrado must meet internationally agreed environmental and socially sustainable development criteria. Purchasers of ethanol fuel should also be willing to pay a price premium to make such a policy more attractive.

❑ Biodiesel in Brazil

A Brazilian programme for biodiesel has been initiated, with similar objectives to those of the bio-ethanol programme. However, the approach will be different, in that small farmers are expected to provide feedstocks for the industrial producers of biodiesel. A regulatory instrument will be used to enforce the social and environmental profile, known as "The Social Fuel Seal," which will be awarded by the Ministry of Agrarian Development, as a condition for industrial producers of biodiesel to obtain tax benefits and credits. In order to receive the Seal, an industrial producer must purchase feedstock from family farmers, enter into a legally binding agreement with them to establish specific income levels, and guarantee technical assistance and training (PNPB, 2005).

Unlike the large-scale approach used in the case of ethanol from sugarcane, the benefits of building a new industry could be better distributed. Economies of scale are somewhat different for biodiesel, and so a different approach may be useful. However, it is not clear whether the small-scale approach will ultimately prove to be economical in the global market. Government legislation will provide security for the market demand. A blend of 2% (B2) will be mandatory for all diesel fuel as of 2008, while 5% (B5) will be mandatory starting in 2013 (MDA, 2005). There are support schemes for research and development, in addition to the support for implementation, via the tax credits associated with the Social Fuel Seal. There is growing criticism within the business community of the conditions imposed by government, which seems more concerned with social development rather than energy at competitive price. They argue that the conditions attached to biodiesel production, particularly in the Northeast, will make biodiesel uncompetitive.

4.3 EU bio-energy policies and programmes

EU policies on biofuels are relevant with respect to international trade, as it is recognised that a rapid increase in biofuels within the EU cannot be achieved without imports. Biomass and bio-energy are promoted through a variety of programmes and policies within the EU, and is widely recognised that bio-energy will be among the major renewable energy sources in the near-term. Recent policies and strategies address liquid biofuels, solid biomass and biogas. The sector coverage includes heat and power production, transport, and direct uses in households and businesses. A biomass action plan was released by the EC in late 2005 and a biofuels strategy in early 2006 (EC, 2005; EC, 2006).

In 2001, the EC launched its policy to promote biofuels for transport, the motivation for which includes several dimensions:

- to reduce greenhouse gas emissions;
- to reduce the environmental impact of transport;
- to increase the security of supply;
- to stimulate technological innovation; and
- to promote agricultural diversification.

The policy was to be market-based, but would include indicative (i.e. non-binding) targets and financial incentives in order to maintain progress. The targets

[2] The Cerrado is an area of 204 Mha (agricultural land 137 Mha, cattle ranching 35 Mha; forest & plantations 12 Mha) of which about 90 Mha of land is potentially available for other crops. However, there is considerable disagreement even about what land the "cerrado" actually covers.

[3] Empresa Brasileira de Pesquisa Agropecuaria (Brazilian Agricultural Research Organization)

[4] It is not clear what classification criteria EMBRAPA has used; in any case, only a small fraction could eventually be planted with sugarcane, due to various factors, including: soil quality, water availability, domestic opposition, and topographic limitations. Topography is a major factor since the tendency is to plant cane only in areas where mechanisation is possible.

were to be based on the percentage of biofuels in the transport market, which was only 0.6% in 2002.

The EU Directive on biofuels came into force in May 2003, under which Member States were expected to ensure a minimum 2% share for biofuels by 31 December 2005 and 5.75% by December 2010 (EC, 2003a). Only Sweden with 2.2% and Germany with 3.8% exceeded the 2% target in 2005 (EC, 2006). Sweden accomplished this mainly through bio-ethanol, while Germany relied on bio-diesel. The biofuels component within the overall roadmap for renewable energy has been revised somewhat in light of the slow progress by Member States. A more recent policy document acknowledges that the 2010 targets will be difficult to meet, but nevertheless proposes a target of 10% for 2020, with the assumption that policy instruments must be made more effective (EC, 2006). The integrated energy-climate package that was put forth by the Commission also retains biofuels as a major component of strategies aimed at the goals of energy security, competitiveness, and sustainability (EC, 2007).

In conjunction with the biofuels directive, and other renewable energy directives and policies, legislation was developed to allow exemptions in the taxation of energy sources (EC, 2003b). The Directive allows Member States to apply exemptions or reductions in the level of taxation on renewable energy sources, including solar, wind, tidal, geothermal, biomass, and waste. These tax concessions are considered state aids, which may not be implemented without prior EC Commission authorisation, in order to avoid undue distortion of competition and over-compensation.

A third component of the EU biofuel legislation relates to fuel quality. In 2003, the environmental specifications for market fuels were amended to establish specifications for gasoline and diesel. The previous Fuel Quality Directive was thus amended, and applies to biofuels as well as to petrol and diesel (EC, 2003c). The European Committee for Standardization (CEN) has set limits on biodiesel blending to no more than a 5 percent share by volume for technical reasons. This strict technical requirement represents an obstacle to achieving the targets set in the Biofuels Use Directive. Consequently, it is proposed that the Fuel Quality Directive be revised again in order to remove such technical barrier, as well as to address related issues that may constrain the use of biofuels.

The EU currently has a special aid programme for energy crops grown on non-set-aside land, i.e. land that is not already within the 10% of land that farmers are requested to set aside under the EU Common Agricultural Policy (CAP). The energy crops can receive a premium of Euro 45 per hectare, within a maximum guaranteed area of 1.5 million hectares. In 2005, an estimated 0.5 million hectares received the energy crop payment. The generous support mechanisms available for bio-diesel have resulted in twenty of the twenty-five Member States of the EU producing biofuels, as of the end of 2005 (EURobserver, 2006).

EU biofuels production is generally not cost-competitive, mainly because of high-priced feedstock, which is rapeseed in the case of biodiesel and sugar beet, corn, or wheat in the case of bioethanol. In spite of recent sugar sector reforms, the EU internal sugar prices are expected to remain substantially above international market prices, and consequently sugar beet will continue to be an expensive feedstock. With recent significant increases in world oil prices, biofuels have become more competitive, particularly biodiesel. EU-produced bioethanol is still not cost-competitive, and imported bio-ethanol will generally be cheaper than EU-bioethanol, particularly that imported from Brazil, which is cost-competitive at current oil prices. However, since most EU countries continue to charge customs duties based on the higher agricultural tariffs, even lo-cost Brazilian ethanol can become more expensive.

In early 2006, the EC released a biofuels strategy, in which the overall aims of the biofuels initiatives were reviewed, progress was assessed, and specific implementation issues were addressed in terms of meeting future targets (EC, 2006). It was recognized that only about half of the target for 2010 could be met through production within the EU, and the remainder would need to be met through imports.

The EU biofuels policy currently relies on an assumption that the heavily-subsidised cultivation of rapeseed will meet its biodiesel targets. However, this is a very large assumption. Already some 3 million hectares of agricultural land across the EU, an area roughly the size of Belgium, results in 10 Mt of rapeseed. Only 20% of this is ultimately used for biodiesel as opposed to food oil. Therefore, another area, about the size of Belgium, would have to be cultivated with rapeseed in order to meet the targets.

Rapeseed tires the land, and requires expensive crop rotation and fossil-based fertilisers. Growing rapeseed also has an opportunity cost of preventing farmers from growing more environment-friendly, less intensive, and often more profitable produce such as cereals or organic root vegetables. Under these circumstances, the supply of rapeseed oil is unlikely to be able to meet the demand.

There is an obvious conflict between the stated policy of the EU to promote imported biofuels as well as internally-produced fuels, and the fact that most countries have not extended tariff exemptions to imported bioethanol. The failure of the Doha Round to produce significant trade reforms has been attributed by developing countries to the unwillingness of the EU and the USA to reduce protections for their agricultural sectors. Consequently, there will be a continuing struggle between agricultural policy, which has been firmly entrenched in the EU for several decades, and renewable energy policy, which is relatively new—now that it has reached a significant-scale—by comparison.

4.4 Biofuels in other countries/ regions

A number of other regions are significant producers of biofuels, or could become significant producers in the near-term. Countries with large domestic markets (USA, China, and India) are unlikely to become exporters. Other regions could become major exporters in the future, particularly southern Africa and some parts of Southeast Asia. Smaller African producers such as Malawi are discussed in section 5 along with other summary case studies. The situation in the U.S., China, and India is briefly mentioned below, since these countries could be major producers, but also potentially major importers in the future, depending on market developments.

❑ U.S.A.

Ethanol is produced mainly from corn in the U.S., and domestic producers receive a subsidy of $0.52/ gallon ($0.14/litre). Partly, as a result of such support schemes and the recent rise in oil prices, USA production exceeded Brazilian production for the first time in 2005. Ethanol is sold in most states as an octane enhancer or oxygenated blended with gasoline, and in the Midwest there are also E85 or ethanol-only vehicles, including buses.

Bio-diesel production has also been increasing significantly due to the generous tax credits provided by legislation enacted during 2004-2005. The tax credit is $0.50/gallon ($0.13/litre) of biodiesel made from waste grease or used cooking oil and ($0.26/litre) for biodiesel. If the fuel is used in a mixture, the credit is 1 cent per percentage point of agribiodiesel used or 1/2 cent per percentage point of waste-grease biodiesel. For small biodiesel producers (i.e. production capacity of less than 60 million gallons annually), an additional $0.10 ($0.03/litre) tax credit is provided for each gallon of biodiesel produced by small producers. This tax credit is capped after the first 15 million gallons produced annually (US-DOE, 2004).

In September of 2005, Minnesota became the first state to require that all diesel fuel sold in that state contains part biodiesel. The Minnesota law requires at least 2% biodiesel (B2) in all diesel fuel sold. In March 2006, Washington State became the second state to pass a 2% biodiesel mandate, with a start-date set for December 1, 2008 (WA, 2006).

❑ China

Although China cannot be regarded today as a major player in biofuels, this could change dramatically in the near future. China is potentially a hugely untapped vehicle market. In 2004 there were only 27 million privately owned vehicles, most of them concentrated in large cities (Brown, 2004), which is very low by western standards. The Chinese automobile use has been growing faster than in any other country and during the past 5-6 years, automobile use has nearly doubled. If this trend continues, the size of the Chinese automobile industry will have significant implications for fuel demand, and some of this demand may very well be met through biofuels.

❑ India

With the growing mobility of India's increasing population, demand for crude oil long ago surpassed domestic production. Diesel demand is much higher than petrol, due to the significant amount of freight transported by road. Bio-diesel production offers the possibility for fuel produced from renewable sources to sustain the growing demand. Some oil-bearing crops such as jatropha, can be grown on degraded land, that are not well-suited for traditional agricultural crops. Over 65 million hectares of land has been declared "wasteland" in India, and another 174 million hectares are close to being called wasteland, and this may present an excellent opportunity for energy crops like Jatropha.

In April 2003, the National Committee on Development of Biofuel recommended a major multi-dimensional programme to replace 20% of India's diesel consumption. The National Planning Commission has involved the Ministries of Petroleum, Rural Development, Poverty Alleviation and the Environmental Ministry and others, in the working of the National Committee. One objective is to blend petro-diesel with a planned 13 million ton of bio-diesel by 2013, produced mainly from non-edible jatropha oil and a smaller part from pongomia. For this, eleven millions ha of presently unused lands are to be cultivated with jatropha. One of the difficulties is lack of experience with large-scale production of jatropha, compounded by its low productivity in terms of fuel produced per hectare.

There is a key socio-economic and environmental question related to how the Indian biodiesel programme will be implemented. The crucial issue is whether privatisation of wastelands can rehabilitate these lands and generate gainful employment for the poor in the process (Sharma, 2005). It is clear that the programme will generate wide investor interest, due to the financial incentives available. Consequently, the productivity of the wastelands is likely to improve considerably in the process. What is not at all clear is what will happen to those persons who rely on the public wastelands for their livelihoods. A related question is whether poor farmers will be able to participate in this programme on equal terms with large corporations. Consequently, the programme remains somewhat controversial with respect to privatisation and the institutions that will govern land tenure.

4.5 International trade in biofuels

Biomass markets already exist in Brazil, Canada and Nordic countries. Trade between countries is already settled, for example, Sweden imports biomass from Finland and Russia. The bioenergy trade that is currently in action is not controlled by any text or institution. However, the biomass energy challenge will fail if biomass resources are not conserved. Today, most direct drivers of degradation in ecosystems remain constant or are growing in intensity in most ecosystems (Millenium Ecosystem Assessment). The question is how to deal with interactive issues involving land availability and improved productivities and rural livelihood, natural resource conservation and biodiversity, poverty reduction and modernized energy supply.

International bioenergy trade is growing rapidly, particularly for co-firing (wood chips, and pellets), CHP (wood chips), and liquid biofuels for transport (bioethanol and biodiesel). The potential for international biotrade is quite huge, and this was recognised by the International Energy Agency (IEA) Bioenergy Program, when it decided to set a new research task (Task 40) to specifically address issues related to bioenergy trade.

The case of bio-ethanol is of particular interest for developing countries, as it is different from other biofuels and from biomass resources in general in several respects. First, the opportunity to export a value-added product such as ethanol, rather than raw biomass is important for developing countries. Second, there are many significant potential producers of bio-ethanol. Any of the more than 100 countries that grow sugarcane could enter the market fairly easily in the absence of protectionist measures. Third, the most economical biomass source or feedstock, sugarcane, is found almost exclusively in the developing world. Fourth, unlike biomass or wood products, ethanol markets are impacted significantly by trade barriers and tariffs. While many small sugarcane–producing developing countries are potential producers, both sugar and ethanol are protected products in most markets. Preferential prices for sugar have been a disincentive for developing countries to switch to bio-ethanol from sugar, since they can obtain more money from the subsidised sugar exports.

The sugarcane sector is at a crossroad. For decades, this industry has both benefited and suffered, as it is one of the most distorted international commodities in the world. In spite of some market openings and reductions in subsidies, preferential markets for sugar remain in place and in several different forms. Some countries have benefited while others have paid a high price. Pressures from the WTO means that markets are gradually being liberalized, again for the benefit of some and to detriment of others. The recent agreement by the EU to cut the internal price of sugar by 36%, forcing greater domestic and international competition, is a good example, greeted with a sense of relief by some (low-cost) producers and outrage by those (high-cost) producers that have been greatly dependent on supported prices.

Some projections suggest that ethanol trade will increase by a factor of 3-4 by 2010 (Rosillo-Calle &

Walter, 2006). Between 2010 and 2015, trade is expected to more than double (Lichts, 2006). More significantly, the number of exporting countries/regions will increase significantly, with countries other than Brazil and U.S.A. making up about 30% of the total, compared to less than 5% in 2005. Exports are increasing as a growing number of countries are developing ethanol fuel policies and programmes, due to several driving forces:

- progress on climate change: implementation of Kyoto and further post-Kyoto decisions;
- clearer long-term policy in U.S.A. in favour of alternative transport fuels;
- improving attitude of the automobile industry toward alternative fuels;
- technological progress, including cellulose-based ethanol; and
- interest in supporting rural development in developing and developed countries alike.

International trade of fuel ethanol also faces some specific barriers, including:

- tariff and non-tariff trade barriers;
- in most countries ethanol fuel programs have been aimed at the domestic rather than the external market. International trade requires a change in mentality;
- new investments in infrastructure and adaptations to new programmes; and
- direct domestic production subsidies to ethanol fuel actually hinder longer-term market development because of market risk perceptions in light of political uncertainty of future support schemes.

Recent trends indicate that it would be possible to create sizeable production and consumption centres outside the USA and Brazil, i.e. EU, China, India, Japan, Thailand, and southern Africa. If a goal, such as 10% blending is used, future scenarios suggest that multiple regional markets could emarge by 2025 (Johnson, 2002). It is relatively easy and cheap to transport ethanol by ship, as for oil, where the transport cost is generally between 1-2 US ¢/litre. Currently, between 3 and 4 billion litres of ethanol is traded annually, with Brazil and the USA being the main exporters, and Japan and EU the main importers. The EU and Japan could continue to be the major importers in the future, given the interest in creating renewable fuels markets based on environmental and energy security reasons, and the low availability of cost-effective domestic production. Howeve, in the case of the EU the strong agricultural lobby is pushing for domestic production rather than imports.

Fulton (2005) has studied the potential large-scale ethanol production from sugarcane up to 2050, estimated at 633 B/l/yr (14.5 EJ/yr or about 20% of the estimated projected world gasoline demand in 2050). This scenario considers only a maximum of 10% of the cropland area to be used for sugarcane (excluding Brazil). Brazil accounts for nearly half of the total ethanol production in this scenario. It is estimated that 3,460 new industrial plants would have to be built up to 2050, of which 1,720 will be in Brazil; the cumulative associated investment is estimated at US $215 billion. This appears to be an optimistic scenario in terms of a total market size equal to 20% of gasoline demand. On the other hand, the estimated amount of cropland required may in fact be less, given the historical improvement in yields and the possibility to focus production on the most high-yielding regions and the varieties best-suited to those regions.

Policies and Programmes in Selected SADC Countries

This section provides an overview of country or regional case studies on bioenergy policies and programmes. The case studies include particular biomass or bio-energy programmes as well as general policies and strategies related to bio-energy and other renewable energy sources. The emphasis is on the energy services to be delivered, and the opportunities for advancing biomass options alongside the creation of livelihoods and market development regionally and globally. Specific demonstration projects are not reviewed or discussed here, except in the context of policies and programmes to which they were connected. A particular focus is placed again on biofuels, and particularly on bio-ethanol, due to the long experience with sugarcane in the SADC region, and the impact of recent competitive pressures that have increased economic incentives for sugar producers to diversify into bio-energy.

5.1 Overview of policies and programmes in Tanzania

Tanzania is blessed with abundant energy resources in its different forms, biomass, solar, wind, hydro, etc. With exception of biomass, most of the other renewable energy resources remain unexplored. Biomass fuels (firewood, charcoal and farm residues) are the dominant energy sources, accounting for more than 90 percent of total energy consumed and 98 percent of the total energy used in the rural household sector. The overwhelming dependence on woodfuel for energy, and clearing land for agriculture and commercial logging are greatly contributing to environmental degradation, such as high deforestation and soil erosion.

More than 90 percent of the 35 million people in the country do not have access to electricity. About 80 percent of the population live in rural areas. Only one percent of the rural population is connected to the electricity grid, so that the overwhelming majority of Tanzanians depend on woodfuel as their main source of energy. It is anticipated that, due to lack of affordable alternatives, this trend is unlikely to change in the foreseeable future, unless there are serious efforts taken both at the national and local levels.

In the recent National Energy Policy, which was approved by the Cabinet in February 2003, the Government is focusing on new approaches that will have an impact on rural transformation. Among these is the establishment of an institutional framework that would mobilise, co-ordinate, facilitate, monitor and evaluate private and public initiatives in rural and renewable energy. The Ministry of Energy and Minerals is in the process of developing a national strategy, which encompasses an entirely new approach to provide of modern energy to Tanzania's rural population. In the new approach, a Rural Energy Agency (REA) and Rural Energy Fund (REF) will be established with clear roles and functions.

The strategic focus of the REA and REF will include, among other things, the provision of energy services for productive applications in rural areas to stimulate economic development, and rural growth in line with major government policies in most sectors, and to provide modern energy sectorsto key rural service, particularly health, education, water, and communication.

Manyenergy projects and programmes have been initiated in Tanzania (i.e. tree planting, improved stoves, biogas, solar technologies, improved charcoal making kilns, etc.) for various purposes, including combating deforestation, improving energy services, substitution of imported petroleum fuels, and health improvement. Efforts made so far have not had much success in facilitating large-scale adoption of modern energy technologies in rural areas.

Inefficient technologies dominate production and use of biomass, and women and children are the main suppliers of biomass energy as they do most of the wood-gathering. Tanzania urgently needs to modernize its traditional uses of biomass for energy, but this faces many challenges ranging from lack of capital to cultural practices. Following are some of the problems identified through studies and field observations, as the main causes of the low adoption of modern energy technologies in rural areas:

Technical constraints

- low quality and inefficient energy technologies;

- inadequate training opportunities, facilities and infrastructure;
- limited capacities for operation and maintenance; and
- non-availability of reliable data for energy planning.

Economic/financial limitations

- use of non-commercial fuels reduces economic benefits of technology adoption;
- low degree of involvement of commercial sector, due to unfavourable policy environment for private sector to operate as effective promoters of energy technologies;
- low commercialisation of renewable technologies and market potential poorly understood; and
- lack of financing schemes.

Government/policy

- low priority and inadequate commitment and no major government biomass programmes;
- priority centralised energy, which provide services to less than 10% of the population;
- top-down approaches have been used, which failed to consult and involve those who would be directly affected; and
- lack of appropriate institutional framework to provide consistent and quality services.

Social and cultural limitations

- majority of people are poor and lack resources and education;
- project/programme developers have poor understanding of the socio-cultural issues of the targeted community; and
- communities tend to differ widely, depending on the level of development, leadership, etc. and frequently energy options need to be specifically targeted.

A number of strategies have been discussed in terms of overcoming the above difficulties, and expanding the market for modern efficient energy systems.

Technology issues

- technical assistance programmes should be initiated;
- technology should reflect resources available and needs of people;
- technologies should be socially relevant and economically viable;
- training of local persons in production, installation and maintenance of energy systems; and
- R&D results should be brought to the benefits of users and producers.

Energy planning issues

- formulate energy strategy within the framework of sustainable integrated development;
- give priority to developmental needs of the community;
- encourage sustainable management of locally available energy resources; and
- undertake market studies.

Financing issues

- provision of low-interest loans and tax incentives;
- incentives to create and promote SMEs;
- scale-up efforts to mobilise adequate financial resources;
- local financial institutions educated on energy's role in socio-economic development; and
- financial assistance programmes should be initiated.

Capacity-building and networking

- serious consideration should be given to incorporate energy and related issues in the curriculum of formal education course at all level of learning;
- collection, dissemination and exchange information - mainly through electronic means;
- facilitate networking among relevant institutions; and
- ensure that material is accessible in a form that is easy to understand by users.

Overall, concerted efforts in formulating and implementing rural energy strategies are required in order to facilitate improved and sustainable energy services to the majority of the population. Such strategy will result in a positive contribution to the overall rural socio-economic development and energy sector needs of the country. These initiatives will simultaneously accelerate the development and greater use of modern rural energy technologies for improved energy services for the majority of the rural people. To achieve this, a new thrust in the development of modern energy technologies has to be initiated to consolidate whatever achievements has been made so far, to remove constraints and problems for facilitating accelerated adoption of modern rural energy technologies on a large-scale.

5.2 Bioenergy options and energy policies in Zambia

The Zambian Government's Energy Policy is divided

into 5 main sectors: (1) petroleum, (2) woodfuel, (3) electricity, (4) coal, and (5) new and renewable sources of energy, including energy conservation and substitutions. In addition, energy pricing is incorporated as a cross-cutting element within all the sectors. The main policy objective is to promote optimum supply and utilisation of energy, especially indigenous forms, to facilitate the socio-economic development of the country and maintenance of a safe and healthy environment.

The government aims to support and promote new and renewable energy sources through systems and components adaptation, manufacture and documentation, and dissemination of information, and establishment of a specialised agency on renewables. The agency would be expected to:

- carry out R&D;
- provide evaluation, certification and monitoring of technologies to ensure that they conform to quality, safety, health and environmental standards; and
- training in development and application of renewable and efficiency technologies.

The Government is reviewing its energy policy to take into account new developments that have occurred in the energy sector. For example, the revised national energy policy recognises the need to use ethanol and biodiesel as transport fuels. A policy on ensuring availability of data on market demand, resources and applicability of renewable energy technologies includes the following:

- a study on the feasibility of growing energy crops (ethanol and biodiesel) and their economic use as transport fuels;
- policies and standards on the replacement of lead as octane enhancers; and
- policies and standards on the use of biodiesel as a transport fuel.

Zambia imports all its petroleum products, which account for 10% of the country's foreign exchange expenditure and 14% of the national energy requirement. The business-as-usual policy option in the petroleum sector is to continue with the current state of operation, under which the INDENI refinery remains the sole importer of crude and there is no blending with biofuels. The other option would be to introduce ethanol and biodiesel for blending with gasoline and diesel, and the resulting blends can be distributed independently or through the oil marketing companies (OMCs). If this option is considered, three implementation models would be assessed:

1) INDENI maintains its monopoly status, as the sole responsible agent for blending, including the following elements:
   - INDENI buys ethanol from producers and blends with petrol and sells to OMCs;
   - INDENI invests in equipment to process bio-diesel from jatropha and sells to OMCs; and
   - Farmers and out grower schemes sell jatropha and sweet sorghum to INDENI and ethanol producers, respectively.
2) An open but regulated market, allowing for various companies undertaking localised blending of petrol and diesel with biofuels; and
3) An open and deregulated market, where OMCs are allowed to buy petrol and diesel from any competitive market and blend it with biofuels.

Successful implementation of a biofuels programme will require political will, smart subsidies or support schemes, and an integrated approach to the implementation of the programme. There will be a need to incorporate the biofuels programme in poverty reduction strategies. The regulators also need to develop standards on biofuels and the upper limit in blending. The Zambia Government has been learning lessons from other countries such as Brazil as to how to encourage development of the local ethanol industries.

A feasibility study on the Luena farming block in northern Luapula Province examined the potential for bioenergy from a new sugar factory and distillery. The study included technical, economic, financial, social, and environmental assessments for ethanol production and cogeneration of electricity. The study concluded that markets for joint production of sugar, ethanol and cogenerated electricity were economically feasible and socially beneficial under certain conditions: consistent policy support, a mandate for blending with petrol, access to the electricity grid, a renewable motor fuels credit amounting to about 5 US cents/litre, and private investment for some of the infrastructure required (Cornland et al, 2001). A scenario based on ethanol-only (i.e. no production of sugar) would not be economically feasible due to the lack of sufficient demand and also the opportunity cost of the foregone sugar production.

The draft National Energy Policy includes a policy discussion on biofuels, under which the Ministry of Energy has, for the first time, established a Working

group comprised of key stakeholders to develop a National Biofuel Strategy. Biofuels have the potential to play a significant role in the economic development of Zambia. However, for this to succeed the government has to take a leading role by creating an enabling environment that is conducive to investment.

5.3 The Malawi ethanol programme

Malawi began looking at ethanol in the 1970s for the same reasons that Brazil did: to address rising oil prices, save foreign exchange, and develop a domestic resource. Public-private partnerships and market coordination (for blending, distribution, transportation, etc.) were critical to establishing the ethanol programme in Malawi. The first ethanol plant was commissioned in Northern Malawi in 1982, and was managed by ETHCO Ltd. (ethanol company of Malawi). The plant has operated continuously since 1982, with annual production varying between 10 and 20 million litres. The price of ethanol was pegged to that of petrol, plus an incentive of 5% or more, depending on the volume of ethanol blended. Since irrigation water is available from Lake Malawi, ETHCO was not susceptible to climate-induced interruptions (World Bank, 2005).

The company faced some difficulties in supply of molasses—the feedstock for ethanol production. ETHCO was owned separately from the adjacent Dwangwa sugar factory, resulting in the need for price negotiations, additional costs, and increased uncertainty in feedstock supply. This factor along with spare plant capacity and the desire to maintain blending targets, prompted ETHCO to secure additional molasses supply (as much as 40%) from the Sucoma sugar factory, located several hundred kilometers to the South. Ironically, use of diesel trucks to transport molasses from Sucoma reduced the otherwise positive environmental and economic benefits of ethanol substitution.

Another ethanol plant was commissioned in South Malawi in June 2004, which partially alleviated the need to ship the molasses north. It has a capacity of 60,000 litres per day and can produce approximately 14 million litres of ethanol per year. This plant alleviated the need to transport molasses from the sugar factory in the South. The plant process uses continuous fermentation to produce 8% alcohol in the wash, and uses tray column distillation and molecular sieve dehydration as separation. The plant built in 2004 gives a much higher quality of ethanol and is 99.8% pure. The ethanol is sold locally to petroleum companies for blending with petrol. A small fraction is also exported to South Africa and Europe for the cosmetic and pharmaceutical industry. The expanded capacity for ethanol production in Malawi has resulted in insufficient domestic supply of molasses to operate both factories, and Malawi has had to import molasses from Mozambique and Zambia. Corn (maize) is being considered as a supplementary feedstock for ethanol production that can be made available domestically.

Locally, the ethanol is blended with petrol, at a blending rate of 10%, although the blending rate has been much higher when the supply allows it. Rates as high as 24% have been reported, which is nearly as high as the blending rates used in Brazil (Chanje 1998). Blending is not compulsory in Malawi, but 95% of the gasoline consumed today is blended with ethanol. There is a high demand from foreign countries for Malawi ethanol exports, especially from South Africa and the Netherlands, but also from France and Tanzania. Supply has not been sufficient to meet the demand for exports, suggesting options for future expansion.

One of the main problems in Malawi has been the complaints that arise from the communities living around the ethanol plants because of the smell from the effluent, which is known as stillage. Some of it is used to reduce dust on roadways, and in some cases it can be used as fertiliser, but the lack of implementing such alternatives in Malawi means that stillage disposal remains a major concern. When the first plant was built, it was planned that the stillage waste from ethanol production was to be turned into biogas, using an anaerobic digester funded mainly by the Dutch government. However, lack of training and standardized operational procedures resulted in the plant being shut down without ever having operated for more than a few days at a time (Chanje 1998). Efforts aimed at more productive use of stillage through biogas plants could provide major benefits to nearby communities in the form of gas for direct use or for electricity production or even transport.

5.4 The cogeneration programme in Mauritius

During the past two decades, a series of plans and reforms were undertaken in the sugar industry in Mauritius in order to address key issues with regard

to rationalisation and modernisation of the sector. A special focus of many of the policy measures was to promote bagasse cogeneration, and the resulting programme has been quite successful. The programme was facilitated through legislation, financial incentives, and technical support.

The Sugar Industry Efficiency Act formulated in 1988, contained incentives and measures for the various stakeholders, including the millers, miller-planters, large planters, and the many employees in the sugar sector. Measures for land conversion restrictions were also included. The measures for promoting bagasse energy were as follows (Seebaluck, 2007):

- introduction of performance-linked rebates on export duty payable by millers for bagasse saved and sold for firm electrical power generation[5];
- exemption from the payment of income tax for 75% of the proceeds from the sale of bagasse by a miller to another one for the purpose of generating firm electrical power;
- exemption from the payment of income tax for 60% of the proceeds from the sale of firm electrical power by a miller to the public utility body; and
- increase in the initial allowance from 50% to 80% for machinery or plant used for energy saving or treatment of fly ash.

The Bagasse Energy Development Programme (BEDP) was set up by the Government with the assistance of the World Bank in consultation with concerned stakeholders. The objective was to develop a strategy to optimize the use of bagasse, including:

- displace the heavy investments to be effected by the national utility company;
- reduce dependence on petroleum products and diversify its energy base;
- improve the viability of the sugar industry through modernisation and rehabilitation;
- allow savings in foreign exchange by decreasing import of petroleum products; and
- contribute to GHG mitigation.

The plan was to erect two firm power plants annexed to the sugar factories, one at Union St Aubin sugar factory (southern part of the country) and the other at Belle Vue sugar factory (northern part of the country), each having an installed capacity of 22 MW. All the bagasse generated from the sugar factory would be used to generate high pressure steam, which would subsequently be sent to condensing-extraction turbo alternator for cogeneration of electricity to the national grid, after satisfying factory processing needs. Additional plans, including rehabilitation of some existing plants, restrictions on intermittent power production due to its inefficient mode of operation, and adoption of the process of satellite factories supplying excess bagasse to the neighboring power plant.

The bagasse would be burnt during the crop season, and any surplus from its own or satellite factories would be stored for use during the intercrop. The firm power plant would burn coal as an alternative fuel during the intercrop, since it can be burnt in the same boiler house. Use of coal during the intercrop would help in diversifying the energy base of the country and also because it was cheaply and largely available from supplying countries that are less exposed to political risks and instability. It was also intended to compact bagasse and use additional cane field residues as a supplementary boiler fuel.

A Sugar Energy Development Loan (SEDP) amounting to US $15 million was negotiated by the Government to facilitate the implementation of the BEDP. The loan was mainly for projects pertaining to enhance bagasse savings in the cluster of factories. An additional grant of US $3.3 million was made available from the Global Environment Facility (GEF) of the World Bank to conduct projects and studies in relation to the BEDP.

Some problems arose in the initial stages of the programme. Only 40% of the SEDP loan was initially disbursed for investment in bagasse saving in the satellite factories, due to the slow progress in one of the firm power plants, which was connected to a factory that had a low crushing capacity of 130 TCH, and hence, had to rely largely on bagasse from satellite factories. The satellite factories determined that the price of bagasse should be calculated on the basis of the equivalent coal price, which deteriorated the financial viability of the project. It was also determined

[5] Firm power is defined as power available at any time during a commitment period, even under adverse conditions. In Mauritius, firm power associated with cogeneration plants at sugar mills is based on bagasse during the harvest season, and generally requires coal-fired boilers for use in the non-harvest season. A 'continuous' power plant in Mauritius in this context generally refers to bagasse cogeneration plants that run only during the harvest season. In some cases, stored bagasse along with the use of cane trash can extend the operation of the plant on biomass sources beyond the harvest season, thereby also reducing the use of coal.

that the firm power plant project would have a reasonable rate on return on investment with a capacity of 30 MW instead of 22 MW.

Tax-free incentives for bagasse electricity and modernisation of sugar equipment were raised through the Finance Acts of 1992 and 1993, which also extended the performance-linked rebates on export duty to firm power producers who carried out energy savings of their own bagasse and also to millers selling bagasse to continuous power producers. Part of the capital expenditure incurred in the installation of efficient equipment used to enhance bagasse saving and hence, further energy generation was also entitled to refund of export duty. Export duty was abolished altogether in 1994 and as per a Memorandum of Agreement with the Government, the sugar companies had to segregate growing and milling activities and further set up public milling companies. This led to the creation of a Sugar Investment Trust (SIT) where 20% of the equity shares of the milling companies were sold to planters and millers. In 1995, the tax on milling companies was brought down to 15%, through the Income Tax Act.

Centralisation was important for reducing the cost of production in cane milling through the closure of low capacity crushing mills and their integration in bigger capacity adjoining mills. Higher crushing capacity at the sugar factories made available more bagasse on a single site and thus ensured the running of more efficient boilers. In 1997, a policy was issued with guidelines and conditions for the closure of mills. Particular emphasis was laid for the need to link the closure of mills with cogeneration of bagasse energy.

The Ministry of Energy conducted a study to interpret the clauses of the draft purchase agreement and was helped by the World Bank in working out the principles and guidelines. An in-depth analysis of the price setting mechanism used as cost basis for a diesel plant of 22 MW capacity, as proposed by the CEB, was conducted to arrive at the avoided cost for the firm power plant, both economically and financially. The appropriate prices for bagasse (Rs. 1.59/kWh) and coal (Rs 1.43/kWh) were subsequently recommended. The prices for continuous plants that came into operation later were partially indexed to oil prices. The electricity price of the firm power plants in Mauritius varies according to the plant set-up, and ranges from approximately 20% above to 20% below the recommended prices. The electricity prices are indexed to the coal price, cost of living indices in Mauritius and foreign exchange rate fluctuations.

A Sugar Sector Strategic Plan (SSSP) was developed for 2001-2005, which considered a number of reforms, mainly at the factory level, which included:

- centralisation whereby placing a high priority on electricity generation in the centralisation process;
- adoption of energy conservation devices to improve steam consumption with the aim of increasing export to the national grid;
- adoption of continuous processes and automation to improve sugar recovery efficiency; and
- production of value-added products in the form of special sugars in the strategy of diversification within sugar.

As of 2005, independent power production from sugar factories accounted for over a third of installed capacity in Mauritius (Table 7). The transformation in the sector thus occurred over a period of about twenty years. The success achieved on bagasse energy cogeneration in Mauritius can be replicated in almost all of the cane producing countries in the southern African continent. There is a wide spectrum of opportunities, which can encourage integration of sugar and energy production. On the technical front,

Table 7: Overview of plant capacities in Mauritius

Central Electricity Board			Independent Power Producers		
Conventional plants	Plant capacity/MW		Thermal (bagasse/coal)	Plant capacity/MW	
	installed	effective		installed	effective
Hydro	59.4	54.2	Firm producers	136.3	121.0
Thermal	348.5	290.0	Continuous producers	100.2	84.7
TOTAL	**407.9**	**344.2**	**TOTAL**	**236.5**	**205.7**

(Source:CSO, 2005)

many sugar factories in southern Africa use diffusion technology, which is less energy intensive than milling. There would be less power consumption at the front end of the sugar factory, thereby enhancing co-generation. The experience in Mauritius suggests that consistency and comprehensiveness in policy implementation is actually more important than the technical features, which are well-documented and commercially mature.

The advantages are enormous in the context of southern African countries. There is reduced dependence on petroleum products and improved reliability in power supply through diversification of electric power sources. Implementation of cogeneration will also bring additional revenue to the sugarcane industry which is facing threats of price and quota reduction in preferential markets in the context of trade liberalisation. Cogeneration is a climate friendly technology that can attract GEF funding as well as financing schemes, such as, Activities Implemented Jointly and the Prototype Carbon Fund. Most of the cane producing countries in the African continent could benefit from such funding or schemes.

However, the path of power sector reform can be difficult. There are difficult socio-economic conditions prevailing in most of these countries. Power generation is usually undertaken by the national utility as a monopolistic activity, whereas the issue of renewable energy/bagasse is more profitable if undertaken by Independent Power Producers. This entails that a proper Government policy should be defined to promote this type of investment. The access to finance by IPP is another difficulty that needs to be overcome.

5.5 Farming for Livelihoods in Southern Africa (FELISA)

Biofuels hold enormous potential for the southern African agriculture and for the economies of the region in general. In terms of liquid biofuels for making bio-diesel, palm oil offers an attractive option due to its high yields, while jatropha could be another useful alternative due to its ability to grow in poorer soils along with the fact that it is non-edible and thereby does not create a conflict with food production.

FELISA (Farming for Energy for better Livelihoods in Southern Africa) is a new initiative in Tanzania that

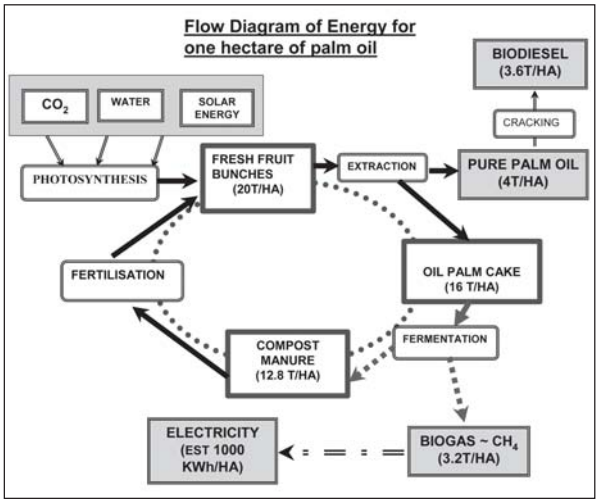


Figure 11: Production of various products from palm oil

intends to produce biodiesel, biogas and compost from palm oil, and to a lesser extent, from sunflowers and jatropha. Palm oil has the highest yield among oil-bearing crops. It is native to Africa but today the overwhelming majority of its production is based in Asia. Many different products and services are obtained from palm oil production, some of which are indicated in Figure 11.

Integrated production of biofuels can be promoted based on a multi-use and multi-system platform that includes appropriate incorporation of supply and demand constraints. The options within a management strategy would include:

- management of oil seed plantations, such as palm oil plantation;
- production of vegetable oils;
- production of bio-diesel;
- production of bio-gas for electricity, cooking or other uses; and
- ongoing research on applications and uses of bio-fuels.

Farming for energy can contribute significantly to Africa's economic development in a way that is financially, economically, socially and environmentally sustainable. However, a number of issues need to be addressed to establish biofuels on a larger-scale in Africa:

- evaluation of the potential of different agro-ecological zones and different crops;
- identification and development of high-yielding varieties;
- promote involvement of the private sector in production;
- ensuring remunerative price for the farmers on a

long-term basis; and
- setting up processing plants in major oilseed growing areas.

A biofuels strategy for southern Africa needs to take into consideration many different conditions, constraints, and priorities, including agronomic, technical, socioeconomic, and environmental aspects. A regional strategy will also require coordination among key producing regions, potential distribution companies, and related infrastructure needs. As with many countries or regions engaging in biofuels development, public-private partnerships will be important to provide both the proper incentives and also the appropriate oversight.

5.6 Small-scale ethanol production in Zambia

Due to lack of modern energy resources in most parts of Zambia, many people have come to rely on traditional energy resources such as fire wood and charcoal to meet both their domestic and industrial needs. Home-based industries operated by women depend heavily on biomass as their major source of energy (AFREPREN, 2004). These home industries such as bakeries, pottery, fish smocking and oil processing are the ones which provide income for the families. Most of the institutions such as school, hospitals and prison in rural community also depend on wood fuel for cooking and heating water.

The technology used in the homes and institutions have health effects, especially on women and children, who spend long time in the poorly ventilated kitchens where soot and smoke oil affect the respiratory system and eyes. The hard work also strains the back muscles of women, creating difficulties during child delivery. Charcoal and firewood are the cheapest and easily accessible sources of energy for the poor, and can be purchased in small quantities. The annual increase for charcoal consumption in Zambia's urban households was estimated at 4% or 24150 tones of charcoal (Chaposa, 2002)

In an effort to conserve the environment and to promote the efficient use of wood fuel and charcoal, work has been done to promote the use of efficient cookstoves. However, due to technical and procedural constraints, these programs have generally not been effective. In many cases, cookstoves were manufactured and disseminated without involving women and women's groups, resulting in rejection of the technology. Improvements have been made, but the dissemination is slow due to the ease of obtaining charcoal and its relatively low price. Substitution of ethanol gelfuel for charcoal and fuelwood in cooking could help to address a number of problems and issues, including the following:
- reduce health and environmental impacts of smoke, especially on women and children;
- provide jobs for farmers and rural dwellers;
- reduce the amount of time needed by women for gathering fuel and cooking, which would in turn create more time for income-generating activities that might also utilise renewable energy sources;
- improve air quality in urban areas; and
- create a new market for renewable energy.

At the national level, Zambia plans to replace the blending lead in petrol with ethanol that will also create a market for ethanol, which can be made from sugarcane, sweet sorghum and other crops. If ethanol is also used for cooking and lighting to replace charcoal, firewood and kerosene, it will broaden the local markets, especially since transport uses of petrol in rural areas are extremely low. There is also a possibility to create export markets to the EU and other regions. Additional national benefits could accrue through credits obtained from the Clean Development Mechanism (CDM). The additional investment in Zambia will result not only in GHG emission saving projects, but also in new economic opportunities and livelihoods for the biomass growers and the associated industries.

Sugarcane and sweet sorghum will generally offer the most efficient feedstock options. Sugarcane has the highest overall efficiency, but it requires a fairly large scale and high upfront investment costs. Growing cane, which is a perennial crop, is also a major commitment, due to the long time frame for establishing initial production. Sweet sorghum is easier to grow on a smaller-scale, has low cultivation costs, and is more accessible than sugarcane for small-scale farmers who may not have significant technical expertise. Sweet sorghum matures fairly quickly (120 days), whereas cane requires a year or more. The price/liter of ethanol produced from sweet sorghum will generally be less than the price from production of cane (Woods, 2001).

An initial program could begin with small-scale farmers growing sweet sorghum. The following are some potential initial activities:

Table 8: Production using sweet sorghum vs. sugarcane

Properties	Sugarcane	Sweet Sorghum
Crop cycle	11-13 months	3.5-4 months
Yield per ha	70 -100 tonnes	17-22 tonnes x twice/year = 34 - 44 tonnes
Sugar content	11-13%	9-11%
Ethanol yield	68-74 litres/tonne	45-55 litres/tonne
Water requirement		65-70% of cane
Fertilizer requirement		35-40% of cane
Bagasse availability	30% of cane	28-30% of sweet sorghum

Source: (Yamba, 2004)

- conduct survey and identification of women charcoal producers;
- develop technical specification, source and place order for the plant;
- identify and train farmers in sweet sorghum cultivation;
- supply sorghum seeds to farmers;
- install ethanol plant;
- train operators;
- conduct ethanol stove testing and identify local producers; and
- conduct training for management of public institutions and farms on ethanol.

Considering the fact that the technologies and operations are new to Zambia, there will be a need initially to seek external assistance in the following areas:

- develop criteria on the selection of growing sites and plant locations;
- plant design, using the most cost-effective processes of ethanol production;
- develop technical specification of ethanol plant;
- develop plant technical specifications, maintenance and operational standards;
- train the management of the ethanol plant in factory operation and business skills; and
- develop a strategy of scaling up the ethanol plant and draw up a business plan based on the experience gained to entice the private sector to invest in the expansion programme.

The goal would be to make the village ethanol projects self-sustaining through the revenues generated, the livelihoods created and maintained, and the higher productivity of rural dwellers engaged in biomass production. Since the government is promoting the use of ethanol as a domestic fuel, and there is currently no local production of ethanol, the village ethanol projects will complement the supply of ethanol from larger plants and provide some greater stability to the overall markets for biofuels.

Strategic Issues and Priorities

In evaluating alternative strategies for developing biomass and bioenergy, it is necessary to consider some key issues at various scales—local, regional, national, and global—in order to set priorities. This section identifies and elaborates some key issues that need to be resolved with respect to the evolution of new markets for bioenergy in southern Africa and the associated implications for sustainable development in the region.

6.1 Household and small industry use of traditional biomass

Traditional biomass, mainly charcoal and firewood, remains a key energy source in Africa, in households and in small-scale enterprises and institutions. The utilisation of fuelwood and charcoal for cooking creates indoor air pollution that strongly affects the health of women and children. Furthermore, collecting wood raises several social problems. Women in least developed countries may spend more than one-third of their productive life collecting and transporting wood. The need for additional help from children may prevent them from going to school.

Major efforts have been aimed at replacing traditional biomass usage with improved cookstoves that utilise biomass more efficiently and reduce indoor air pollution. Whilst improved cook stoves are more efficient than the traditional three-stone fireplace, overemphasis on improved cookstoves can lock people in a technology that is only marginally better. Where more efficient fuels and cooking equipment are close to being economically feasible, policies and incentives for switching might be considered.

Cost-benefit analysis of improved stove programmes is difficult, for the same reasons that analysis of household energy in developing countries is difficult in general—because there is a great deal of informal economic activity and non-priced labour involved in the household sector. Furthermore, even with improved cook stoves, indoor air pollution levels remain many times above the maximum levels recommended by the World Health Organisation (WHO).

There is a need to take household energy services delivery efforts beyond the improvement of cookstoves to services that result in "significant" impacts, whilst of course expanding improved cookstoves programs where transitions can be clearly shown to be a long way off. Modern biomass energy including ethanol, gel fuel, biomass-based electricity, and other options present opportunities to provide basic energy services as well as contribute to "fuelling" industrial processes.

One of the few renewable energy alternatives for household cooking that can be economically competitive in the near-term is ethanol or ethanol gelfuel, the latter being a safer alternative to liquid fuel. It also offers the possibility for developing small-scale, village-based industries in rural areas. Some preliminary studies have suggested that gelfuel could be made in significant quantities in sub-Saharan Africa—about 30 billion litres—and from a variety of feedstocks, including cane, sweet sorghum, cassava, and sweet potatoes (Utria, 2004). Whether or not sufficient demand could arise to create such a large market is unclear, however, as it would require improvements in both the cost differential of gelfuel cooking, and in the income of the population in the region, given higher purchase costs compared to wood and charcoal.

6.2 Role of mechanisation

One of the advantages of bioenergy in developing countries is the large number of jobs created, which are significantly higher when harvesting of biomass is manual. At the same time, the manual harvesting of some energy crops is extremely physically demanding. In the case of sugarcane, it also leads to the practice of burning before harvest in order to remove debris, while leaving the green parts that contain the sucrose. Due to the low or even negative (as a result of high unemployment) cost of labour, we can expect manual harvesting of biomass to be the norm in most sub-Saharan African countries in the near-term, assuming that there are no laws or regulations against it.

With the increase of standards of living, it is very hard to find local people willing to cut sugarcane and other crops manually. It is therefore believed that all

the countries, as they get richer, will have more and more difficulties to find local people willing to cut sugarcane and other densely planted energy crops. One illustration of this trend is in Brazil, where an increasing share of sugarcane is cut mechanically.

The solution to this problem could be half-mechanization. It consists in mechanical aid for harvesting. A machine is used for cutting the crop but people are still needed to collect and gather the crop in the fields. As the cutting of the cane is the hardest part, it will considerably ease the task for workers, but at the same time, fewer jobs will disappear and when they do it will be more gradual. This solution will also allow limiting the capital costs. This method was successfully used in Brazil as a transition from manual to mechanized harvesting.

Mechanisation was showed to be crucial in the global study of bioenergy potential at Utrecht University, which estimated biomass potential in 2050 (Smeets et al, 2004). This study takes into account the competition with food as well as the preservation of natural ecosystems. In the most favourable scenario, bioenergy production would be 4 times as much as total energy consumption! Much of this potential is in fact located in sub-Saharan Africa. This potential could be achieved if the best available techniques are used everywhere. Indeed, today, the productivity in Africa is very low (around 1ton/ha/year), whereas productivity in France or the United States reaches 10 ton/ha/year. It is therefore above all a matter of technology and productivity for a very high bioenergy potential to be reached. Transportation costs are not expected to break down international trade of biomass. Indeed, transportation costs generally account for less than 10% of the total cost of bioenergy, and in the case of liquid biofuels less than 5%, which is comparable to that of petroleum fuels.

6.3 Regional markets vs. international markets

Creating an international market for a relatively new set of commodities poses a number of challenges, especially in an underdeveloped region such as southern Africa. In the near-term, it may be preferable to concentrate on national and regional (SADC) markets, where the benefits of substituting a domestic resource can be obtained without having to compete head-to-head with international companies and/or sell through large traders or distributors. The lack of experience and infrastructure are important barriers, while the comparative advantages include the low cost of labour and the excellent growing conditions for various energy crops. It is also possible that the export and local markets could develop together, with some potential cross-subsidisation due to the larger-scale associated with export markets.

Alternatively, developing national and regional markets can be seen as a logical step in the development of international export markets, indeed, several phases exist in bioenergy use and market development:

- local use of forest and agricultural residues;
- assuring proper waste treatment, processing of residues, and energy efficiency;
- infrastructure development;
- national market development through supportive policies and incentives;
- regional biomass markets, medium-to-large-scale utilisation, transport logistics;
- increasing scale, followed by decreasing costs; and
- global commodity market.

It may be premature to consider a global commodity market for bioenergy products from Africa, since the early stages of market development have not been completed. Policymakers may place highest priority on energy accessibility in the near-term rather than bioenergy export as this will be more appropriate to emerging economies that lack infrastructure. There is also concern that Brazil and others will have monopolies on some markets and will set international standards and prices.

On the other hand, large markets would be needed to attract foreign investment, which is urgently needed in the region. Other than South Africa, the markets for biofuels and bioenergy will be too small to attract much investment. Since the risks are perceived as high in many respects, investors will require a risk premium and the prospect of large payoffs. Dependence on national markets alone may result in no market at all, as there is a certain threshold of demand required before investment will flow. The determination of such thresholds would be a useful type of policy analysis that would support decisions about regional development and investment incentives.

An alternative that lies somewhat between the two options is to develop a super-regional market in southern Africa, which would require an accelerated lowering of traded barriers in the region and a commitment to infrastructure development and much

greater economic coordination policies. Once this market develops, a new and potential element could enter in the form of region-to-region trade agreements, e.g. with the European Union. The idea would then be for the EU to provide financial support and market access to poorer developing countries that can produce biofuels cheaper than in the EU and more sustainably, due to the better energy balance and lower degree of mechanisation.

6.4 Implementation strategies

Implementation of successful bioenergy strategies in developing countries is not dependent on technology or financing alone, but often on the intersection of the two in combination with social and institutional factors. Three essential components can be identified: (1) adaptive R&D (especially for conversion technologies); (2) good assessments of emerging business opportunities; and (3) support for the emerging modern bio-energy industry in seizing these opportunities (identifying key financial and social institutions, development of business plans, etc). A further aspect is the key role of the agricultural sector. It is not possible to have a modern biofuels sector without a modern agricultural sector, i.e. high and sustained agricultural productivity.

It is also important to co-ordinate with other development initiatives (e.g. commercial forestry, agro-forestry, commercial cropping to produce concentrated high-volume residues such as sugar, tea, coffee). Also the mobilisation of key potential stakeholders, such as, smallholders interested in agroforestry, or farm forestry, equipment manufacturers, and independent power producers.

In comparison to other renewables, bioenergy strategies are more tailored to the capabilities and needs of the local population. While this presents special challenges, it also offers tremendous opportunities to design and implement energy systems that promote sustainable livelihoods. It is important to keep in mind that in order for bioenergy to have a long-term future, it is not enough to reach a large-scale or high technical efficiency—it must be able to provide what the consumer wants, and this requires modernisation and restructuring of bioenergy systems in accordance with market demands.

Bioenergy industries that are derived from historically non-energy industries, such as sugarcane, often lag behind other industrial sectors, when it comes to innovation and introduction of new technologies. The reasons are many and complex, including the price fluctuations of commodity markets that results in tight profit margins, fragmentation of various sectors, differences in agronomy practices, differences in productivity, know-how, and cultural differences. Following is a summary of the main findings of a survey on such issues (Kochergin et al, 2003):

- R&D has often been marginalised due to falling prices, fragmentation, and existence of many small producers concerned with everyday survival;
- poor cooperation among international R&D centres, partly since many are located in developing countries that cannot afford scientific exchanges;
- intensifying competition requires innovation, investment in new technologies to improve productivity and cost-cutting by companies;
- environmental sustainability issues must be taken on board by industry in order to gain international acceptance and set common standards;
- longer-term plans for R&D are needed; and
- better methods are needed to identify and prioritise land suited for energy crops.

Concerns over land use conflicts are perhaps the most important element to be addressed via stakeholder interaction and dialogue. The multi-dimensional issues involved require a systematic thinking and holistic perspective, tackling the issues of increasing environmental and social pressures associated with development of bioenergy sources. Sustainability indicators, economic modelling, and productivity benchmarks are needed to assess environmental, economic, and technical progress and impacts over time.

Recommendations

This section summarises some recommendations for scientific analysis and research, policy analysis and research priorities, training and capacity-building, demonstration projects, and programme development.

7.1 Scientific analysis and research

One of the major difficulties facing bioenergy development, particularly in developing countries, is poor understanding of fundamental issues dealing with agronomy and end use technologies. Considerably more long term reliable data on all aspects of biomass production and uses are still required, as lack of such data hampers energy planning for the production and use of biomass for energy. Programmes to tackle this breakdown in the biomass system will require detailed information on the consumption and supply of biomass, i.e. annual yield and growing stock of biomass resources.

It is surprising that despite the overwhelming importance of biomass energy in developing countries, policy makers and energy analysts do not pay much attention to planning for management of biomass production, distribution and use. This is largely caused by lack of financial and human resources for adequate data collection and analysis, and because of the informal nature of traditional bioenergy. Lack of good statistical long-term data and an integrated approach, methods and tools, requires urgent attention in order to provide reliable data for sound decision-making.

For example, in the case of bioethanol a broad range of critical scientific, technological environmental and social issues are arising as a result of its rapid expansion that needs to be addressed, including:

- wider, technical, socioeconomic and environmental implications;
- the role of sugarcane as the most feasible feedstock for ethanol, combined with the need to modernize and diversify this industry;
- emerging technological alternatives [i.e. new crops, fuels (hydrogen), and engine technologies];
- synergy of sugarcane-sugar-ethanol systems and use of by-products; and
- assessment of the wider sustainability issues related to ethanol fuel industries.

In the case of biodiesel, more research is needed on specific oil-bearing plants in Africa. For example, whereas there are plentiful amounts of data available in Europe on rapeseed, and in the US on soybean, there is very little data available internationally on jatropha oil, which is among the most promising crops, due to its ability to grow on marginal lands. Interest in jatropha has increased in recent years with many countries and in particularly in Africa, but little agronomic information exists. In order to gather better data about such plants, it would be helpful to set up an information-sharing network. The importance of gathering data whose dissemination is not limited by commercial sensitivities must be emphasised, while a multi-stakeholder approach is important for reliability and credibility.

7.2 Policy analysis/research

There are many questions that need to be pursued with respect to economic policy, organisational issues, and the type of databases that are needed. The relation between policy analysis and bioenergy development strategies might be assessed based on issues such as:

- long-term sustainability of biofuels from oil bearing plants;
- role of North-South and South-South partnerships;
- detailed environmental impacts of key tropical crops such as palm oil;
- fuel vs. food: what are the potential conflicts and synergies; and
- development of biofuel industries should be integrated with related policy areas, such as environment, transport and health. A holistic approach is required.

A key policy question is whether a biofuels development strategy should focus on local demand or the international market. The options that are most economic will evolve alongside the different stages of development, as the national economy becomes more integrated with world prices and benefits more from international investment.

7.3 Training/capacity building

Among the skills needing development, the following can be highlighted:

- what technologies are available given local conditions;
- where and how to get financing;
- how to bring local communities on board;
- how to improve the ability to negotiate at international meetings, so that local knowledge should not get drowned out by international agendas;
- how to incentivise technology transfer/ development;
- empowerment of marginalised groups, e.g. minorities, women; and
- building the capacity of the donors to "listen to the people"

In addition, it should be recognised that growing energy crops will not necessarily compete with food. There can be synergies or conflicts, and it is necessary to conduct careful analysis of local conditions before reaching any conclusions.

7.4 Demonstration projects

Demonstration projects on locally available biomass sources are important for identifying priority areas of research, but often suffer from lack of financial and human resources. There is often difficulty in performing detailed studies on bioenergy feedstocks that have special local significance, since there is a tendency for bioenergy research to focus on crops that are used in OECD countries. For example, demonstration projects for the invasive plant *Lantana camara*[6] should receive higher priority in East Africa. Government attempts to organise removal programmes were unsuccessful, however, the potential use of the collected crops for energy created an economic incentive, which greatly encouraged people to participate in collecting the plant. The crop can be gasified or converted into pellets.

Also highlighted isthe case of *Chromolaena odorata*[7], the most prevalent invasive plant in eastern southern Africa. It also happens to have a high hydrocarbon content and is therefore ideal as an energy crop. Such plants offer economic alternative energy uses that should receive higher priority. The general point is that effective biomass demonstrations projects need to be designed around local environmental and socioeconomic conditions.

7.5 Programme development

Some key issues related to programme development were identified:

- short term/long term: it should be established whether a programme is intended as a transition to a more efficient technology, or whether it is intended to be developed in the long term;
- "software/hardware": software was defined as setting up the social networks to make programmes successful, hardware as the more physical process of putting projects on the ground. Both are important; and
- programme on commonly used subsistence crops such as cassava

Governments need to take the lead in the development of institutions for biomass development. It is only when a strong institutional framework is in place that investors will take interest. One idea is that a Department of Biomass should exist in every African country, given the importance of this resource. The reason why it probably does not exist now is that access to modern energy is incorrectly interpreted primarily as access to electricity and hence biomass is not given the appropriate priority in energy planning. If an international market is to develop, project guidelines and a certification system that is supported by international bodies are also needed.

[6] It is a widespread species in East Africa occurring mainly at the forest edges

[7] It is considered the most aggressive invasive species of the indigenous sub-tropical areas.

References

- Batidzirai, B., Faaij, A. P.C., and Smeets, E., *Biomass and Bioenergy Supply from Mozambique*, Energy for Sustainable Development, Volume X No. 1, March 2006.
- Berndes, G., 2002, *Bioenergy and Water - the implications of largescale bioenergy production for water use and supply*, Global Environmental Change 12, 253-271.
- Bradley, P., and Dewees, P., 1993, *Indigenous Woodlands, Agricultural Production and Household Economy in The Communal Areas*, in: Bradley, P. N. & McNamara, K. (eds.) *Living with trees: policies for forestry management in Zimbabwe*, World Bank, Washington, D.C. pp. 63-137.
- Brammer, J.G., Lauerb, M., and Bridgwater, A.V., 2006, *Opportunities for biomass-derived 'bio-oil' in European heat and power markets*, Energy Policy 34, 2871–2880.
- Briggs, M., 2004, *Widescale Biodiesel Production from Algae*, UNH Biodiesel Group, Available at: www.unh.edu/p2/biodiesel/article_alge.html.
- Brown, W., 2004, *Automakers Find China Ripe for New Technology*, Washington Post, Available at: www.washingtonpost.com
- Chanje, A., 1999, *Comments on the production of ethanol in Malawi*, Technical memorandum provided by ETHCO to the Stockholm Environment Institute, November.
- Chaposa, 2002, *Charcoal Potential of Southern Africa (Chaposa)*, Final consolidated report to EC DG-Research under contract ERBIC18CT980278.
- Chidumayo, E.N., 2002, *Charcoal Potential of Southern Africa: Zambia Country Study*, Report to EC DG-Research under contract ERBIC18CT980278.
- Cornland, D., Johnson, F., Yamba, F., Chidumayo, E., Morales, M., Kalumiana, O., Mtonga-Chidumayo, S., 2001, *Sugarcane Resources for Sustainable Development: A Case Study in Luena*, Zambia, ISBN: 91 88714 71 3
- Cortez, L., Griffin, M., Scaramucci, J.A., Scandiffio, M.A.G., Braunbeck, O.A., 1998, *Considerations on the worldwide use of bioethanol as a contribution for sustainability*, Management of Environmental Quality: An International Journal, Vol. 14, No. 4.
- CSO, 2005, Central Statistics Office, Mauritius, Digest of Energy and Water Statistics
- DFID, 1999, Department for International Development, *Sustainable Livelihoods Guidance Sheets*, UK, Available at: http://www.livelihoods.org/
- EC (2003b), Directive 2003/96/EC18
- EC (2003c) Directive 2003/17/EC of the European Parliament and of the Council of 3 March 2003 amending Directive 98/70/EC relating to the quality of petrol and diesel fuels
- EC, 2006, An EU Strategy for Biofuels {SEC(2006) 142} European Commission, Brussels, 8.2.2006, 34 final.
- EC, 2006, Renewable Energy Road-Map, *Renewable Energies in the 21st Century: Building a more sustainable future*, [COM (2006) 848 Final, SEC (2006) 1719]
- EC, 2006a. *Biomass Action Plan*, European Commission, DG-TREN, March 2006.
- EC, 2006b. *An EU Strategy for Biofuels*, COM(2006) 34 final, Communication from the Commission, Brussels, 8.2.2006.
- EC, 2007, *Communication from the Commission to the European Council and the European Parliament - An Energy Policy for Europe* {SEC(2007) 12}/* COM/2007/0001 final */
- EEA, 2006, *How Much Bioenergy can Europe Produce without Harming the Environment?*, Copenhagen, EEA Report No 7/2006. ISBN 92–9167–849-X
- EL Bassam, N., 1998, *Energy Plant Species- Their Use and Impact on Environment and Development*, James and James, London.
- ESMAP, 2005, *Advancing Bioenergy for Sustainable Development: Roles for Policymakers and Entrepreneurs*, Report prepared by Stockholm Environment Institute (SEI) for the World Bank Energy Management Assistance Programme, ESMAP report 300/05, April.
- EurObserv'ER, 2005, *Observatoire des énergies renouvelables*, Renewables Barometer, June 2005, n° 159.
- EurObserv'ER, 2006, Observatoire des énergies renouvelables, *Le baromètre des biocarburants*" (Biofuels Barometer), May 2006, n° 167
- FAO, 1995, *The Effects of HIV/AIDS on Farming Systems in Eastern Africa*, FAO Farm Management and Production Economics Service, Available at: http://www.fao.org/docrep/v4710e/V4710E00.htm#Contents
- FAOSTAT, 2005, Food and Agriculture Organisation Statistical Database, http://faostat.fao.org.
- FO LICHT, 2004, *World Ethanol and Biofuels Report*, Vol.2, No.17
- FO LICHT, 2006, *World Ethanol - The Outlook Until 2015,* FO Licht, London, UK
- Friends of the Earth, 2005, *The Oil for Ape Scandal* Available at: http://www.palmoilorg.uk last accessed on 27/10/05
- Fulton, L., 2004, *Biofuels for Transport- An International Perspective*, IEA
- FULTON, L., 2005, *Recent Biofuels Assessments and Two New Scenarios*, IEA Seminar Assessing the Biofuels Option, Paris, Available at: http://

www.unfoundation.org/features/biofuels.asp

- Gazeta Mercantil, 2005, Newsletter, 2-3 April p. B12, Available at: www.gazetamercantil.com.br/
- GEF, 2005, *Biomass Power Generation: Sugar Cane Bagasse and Trash*, Global Environment Facility, GEF/UNDP/CTC project BRA/96/G31.
- Goldemberg, J., and Coelho, S. T., 2003, *Renewable Energy - Traditional Biomass vs. Modern Biomass*, Energy Policy 32 (6), pp. 711-714.
- Green Star Products Press Release, 2006, *Green Star Products Signs Contract to Build 90 Biodiesel Reactors*, last accesses on 13/11/2006, Available at: www.greenstarusa.com/
- Hamelinck, C.N., Suurs, R.A.A., and Faaij, A.P.C., 2003, *International Bioenergy Transport Costs and Energy Balance*, Copernicus Institute, Utrecht University, Netherlands, NWS-E-2003-26, ISBN 90-393-3508-7.
- Hardin, G., 1968, *The Tragedy of the Commons*, Science 13, December: Vol. 162. no. 3859, pp. 1243 – 1248.
- Harkin, T., 2007, *Renewable Fuels Act of 2007 – draft version*, http://Harkin.senate.gov.
- IEA, 2005, *World Energy Outlook*, International Energy Agency, www.iea.org.
- International Energy Agency (EIA), 2001, *Potential for Economic GHG Reduction in Coal-fired Power Generation*, IEA, Paris
- Johnson, F., and Matsika, E., 2006, *Bio-energy Trade and Regional Development: the case of bio-ethanol in southern Africa*, Energy for Sustainable Development, Volume X No. 1, March 2006
- Johnson, F.X., 2002, *Bio-Energy from Sugarcane for Sustainable Development and Climate Mitigation: Options, Impacts and Strategies for International Cooperation*, Twelfth European Biomass Conference: Biomass for Energy, Industry and Climate Protection, Amsterdam, the Netherlands, June 2002, James & James, London
- Kåberger, T., 2005, *Analysis of Multi-Product Biomass Systems and Options*, Presentation at Stockholm Environment Institute Conference on Biomass and Sustainable Livelihoods
- Karekezi, S., Lata, K., Coelho, S.T., 2004, *Traditional Biomass Energy: Improving its Use and Moving to Modern Energy Use*, Thematic Background Paper, International Conference for Renewable Energies, Bonn, May.
- Kartha, S., and Larson, E.D., 2000, *Bioenergy Primer: Modernised Biomass Energy for Sustainable Development,* United Nations Development Programme.
- Knothe, Gerhard 2001, *Historical Perspectives on Vegetable Oil-Based Diesel Fuels,* Inform, 12, 1103-1107, Available at: http://www.biodiesel.org/
- Kochergin, V., Purchase, B., and Rhoten, C., 2003, *Research and Development in the Sugar Industry: Status and Future Trends. Summary of a Survey*, International Sugar Journal 105, March:137-41.
- Leach, G., and Johnson, F., 1999, *Modern Bioenergy – an overview of its prospects and potential*, Renewable Energy for Development, Vol. 12, No. 4, December.
- Leach, G., and Mearns, R., 1988, *Beyond the Woodfuel crisis: People, Land, and Trees in Africa*, Earthscan, London.
- Leal, M.R.L.V., 2006, *Techno-Economic Characterisation of Ethanol Production in Brazil*, Report commissioned by Stockholm Environment Institute (SEI), Stockholm, Sweden, January.
- Lichts, F.O., 2006, *Ethanol market statistics*, World Ethanol and Biofuels Report, 27 January.
- Macedo, I.C., 2005, *Sugar Cane's Energy – Twelve Studies on Brazilian Sugar Cane Agribusiness and its Sustainability*, UNICA, Brazil.
- MDA, 2005, *Federal Law 11.097*, Ministry of Agrarian Development, Brazil.
- Moreira, M., and Goldemberg, J., 1999, *The Alcohol Program*, Energy Policy, 27, 229-245
- Moreira, R., 2006, *Global Biomass Energy Potential*, Mitigation and Adaptation Strategies for Global Change, Vol. 11, Number 2: 313-333, March.
- Nastari, P., 2005, Ethanol: the Global Overview, *Ethanol – the Smart Way Forward*, 2005 International Ethanol Conference, Queensland Government, May, Brisbane, Australia.
- NBB, 2006, *National Biodiesel Board*, www.nbb.org.
- NZT, 2006, *NZ firm makes bio-diesel from sewage in world first,* New Zealand Herald, last accesses on 5/12/06, Available at: www.nzherald.co.nz
- Oliveira, Hr., 2005, *The Brazilian Experience*, IEA Seminar Assessing the Biofuels Option, Paris, June, Available at: http://www.unfoundation.org/features/biofuels.asp
- Openshaw, K., 2000, *A Review of Jatropha Curcas: an Oil Plant of Unfulfilled Promise,* Biomass and Bioenergy. 19: 1-15
- Ostrom, E., 1990, *Governing the Commons: The Evolution of Institutions for Collective Action*, Cambridge University Press, London, UK.
- PNPB, 2005, *National Biodiesel Production Programme (PNPB)*, http://www.biodiesel.gov.br.
- Rosillo-Calle, F., 2002, *Global Overview of Ethanol fuel*, in Proc. 12th European Conf. & Technology Exhibition on Biomass for Energy, Industry and Climate Protection, James & James, London
- Rosillo-Calle, F., ~~et al~~, 2004, *Sugarcane - A Worldwide Feedstock for Ethanol Production*, 2nd World Biomass Conference, Rome, 10-14 May, James and James, London, Vol. 2 pp.1906-1909
- Rosillo-Calle, F., ~~et al~~, 2006, Biomass ~~Energy~~ Handbook ~~J&J~~, London
- Rosillo-Calle, F. Walter, A., 2006, *A Global Perspective of Ethanol Fuel*, for Sustainable Development, Vol. X, No. 1, March
- SADC, 2004, *Regional Indicative Strategic Development Plan (RISDP)*, Southern African Development Community, www.sadc.int.

- SADC, 2005, *Strategy for biofuels in SADC*, Southern African Development Community, October, www.sadc.int.
- SAE, 1983, Technical Paper series no. 831356, SAE International Off Highway Meeting, Milwaukee, Wisconsin, USA, 1983.
- Scoones, I., 1998, *Sustainable Rural Livelihoods: A Framework for Analysis*, IDS Working Paper 72, Brighton, UK
- Seebaluck, V., Mohee, R., Sobhanbabu, P.R.K., Rosillo-Calle, F., Leal, R.L.V., and Johnson, F.X., 2007, *Thematic Report on Industry, Cane Resources Network for Southern Africa (CARENSA)*, European Commission report under contract ICA-4-2001-10103, February.
- Sharma, S., 2005, *Privatisation of wastelands in India for Biofuels Production*, Presented at Workshop on Biomass, Livelihoods and International Trade, April 2005.
- Smeets, E., Faaij, A., and Lewandowski, I., 2004, *A Quickscan of Global Bio-energy Potentials to 2050: An Analysis of the Regional Availability of Biomass Resources for Export in Relation to the Uunderlying Factors*, Copernicus Institute Report NWS-E-2004-109, Utrecht, Netherlands.
- Smeets, E., Faaij, A., Lewandowski, I., 2005, *The Impact of Sustainability Criteria on the Costs and Potentials of Bioenergy Production*, Copernicus Institute, Available at: http://www.fairbiotrade.org/
- Steenblik, R., 2005, *Liberalisation of Trade in Renewable-Energy Products and Associated Goods: Charcoal, Solar Photovoltaic Systems, and Wind Pumps and Turbines*, OECD Trade and Environment Working Paper No. 2005-07, Organisation for Economic Cooperation and Development, Paris.
- Sydkraft, 2001, *Värnamo Demonstration Plant for Biofuel-fired Combined Heat and Power Generation Based on Pressurised Gasification*, Berlings Skogs, Trelleborg, Sweden
- Tomlinson, D., 2005, *Future Prospects of Bio-Energy Utilization in the South African Sugar Industry*, Illovo Sugar Ltd, SEI Workshop on Biomass, Sustainable Livelihoods and International Trade Workshop, 29-30 April 2005
- UDOP, 2005, União dos Produtores de Bioenergia Available at : www.udop.com.br/versao_impressao.php
- UN, 2005, *Energy Statistics Yearbook 2002*, Department of Economic and Social Affairs, Statistics Division, United Nations, New York.
- UNCTAD, 2005, Trade Statistics, www.unctad.org.
- UNDP, 2004, *World Energy Assessment*, United Nations Development Programme, New York, ISBN: 92-1-126167-8, www.undp.org/energy.
- UNICA – União da Agroindústria Canavieira de São Paulo, 2004; 2005, Açúcar e álcool do Brasil Commodities da Energia e do Meio Ambiente Commodities da Energia e do Meio Ambiente Açúcar e álcool do Brasil, São Paulo, Brazil, Available at: http://www.portalunica.com.br
- UNICAMP, 2005, *Estudo sobre as possibilidades e impactos da produção de grandes quantidades de etanol visando à substituição parcial de gasolina no mundo*, Universidade Estadual de Campinas Núcleo Interdisciplinar de Planejamento Energético Fundação de Desenvolvimento da Unicamp, RELATÓRIO FINAL, Dezembro de 2005.
- US-DOE, 2004, *Alternative Fuels Data Center*, U.S. Department of Energy, Energy Efficiency and Renewable Energy Division, http://www.eere.energy.gov/afdc/.
- US-DOE/EIA, 2005, International Energy Outlook 2005, Report # DOE/EIA-0484(2005), US Department of Energy, Washington, DC, July.
- Utria, B., 2004, *Ethanol and Gelfuel: Clean Renewable Cooking Fuels for Poverty Alleviation in Africa*", Energy for Sustainable Development, Vol. VIII No. 3, September, pp. 107-114.
- van Dam, J.E.G., de Klerk-Engels, B., Struik, P.C., and Rabbinge, R., 2005, *Securing Renewable Resources Supplies for Changing Market Demands in a Biobased Economy*" Industrial Crops and Products 21 (2005), 129-144.
- WA, 2006, *Washington State Senate Bill 6508,* http://www.leg.wa.gov/
- Walter, A., et al, 2000, New Technologies for Modern Biomass Energy Carriers, in: Industrial Uses of Biomass Energy - The Example of Brazil, F. Rosillo-Calle, S. Bajay & H Rothman (ed.) Taylor & Francis, London, pp. 200-253
- Washington State, 2005, *Developing Minimum Renewable Fuel Content Requirements and Fuel Quality Standards in an Alternative Fuels Market,* Legislation SB 6508 - 2005-06, Available at: http://apps.leg.wa.gov/billinfo/summary.aspx?bill=6508
- WEC, 1999, *The Challenge of Rural Energy Poverty in Developing Countries*, World Energy Council, London, October.
- Woods, J., 2001, *The Potential for Energy Production Using Sweet Sorghum in Southern Africa*," Energy for Sustainable Development, Vol. V No. 1, March, pp. 31-38.
- World Bank, 2005, "World Development Indicators," http://web.worldbank.org.
- World Resources Institute (WRI), 2005, *World Resources Institute Earth Trends*, http://earthtrends.wri.org/.
- WWF, 2006, *Sustainability Standards for Bioenergy*, World Wide Fund for Nature, WWF Germany, Frankfurt, November.
- Yamba, D., Matsika, E., 2004, Policies and Regulations Related to Implementation of Sugarcane Co-products Projects within Southern Africa, CARENSA, Durban

ANNEX I
Summary of Workshop Deliberations and Events

This section summarises the workshop on "Biomass, Sustainable Livelihoods, and International Trade," that was held in London, at the end of April 2005. Also described are some additional events that were organised in conjunction with the workshop, including two study visits and a special seminar. The focus, objectives, and participant profiles are included here, as well as brief summaries concerning the working groups that were developed. The results of discussions and some key issues that emerged from the presentations have been incorporated into this report.

Thematic focus

The broad thematic focus of the workshop was in the conflicts and synergies that arise between local and global economic development objectives, with respect to biomass and bio-energy markets. Local development objectives are represented in this case by the notion of sustainable livelihoods, while global economic development is represented by expansion of international trade. Consequently, the more specific focus of the workshop is the relative contribution of biomass and bio-energy to sustainable development goals through domestic vs. international markets.

Economists might frame the tension between domestic and international markets as being somewhat analogous to the choice between development strategies based on import substitution vs. export-led development. However, in this workshop, an interdisciplinary approach was taken in which the issues are viewed as the intersection of technical, economic, political, social, and environmental aspects. Furthermore, the emphasis is on policies and institutions rather than on specific technical solutions or economic approaches.

The case of bio-ethanol from sugarcane is given considerable attention for a number of reasons. Sugarcane is currently the world's most significant energy crop, due to its high productivity. Second, for climatic reasons, it is grown predominantly in developing countries, which allows for South-South cooperation and technology transfer. Third, as an agro-industry, it offers significant opportunities to create rural livelihoods and facilitate rural development. Fourth, it addresses a number of environmental issues, including lead phase-out and GHG reduction. Fifth, oil dependency in southern African countries consumes hard currency and limits local development benefits. Finally, there are emerging opportunities for international trade in bio-ethanol, due to the EU biofuels strategy and increasing demand for renewables.

However, it is important to note that the choice of particular bio-energy feedstocks (e.g. sugarcane), and the choice of final products (e.g. ethanol) in market strategies depends crucially on local and regional conditions. Furthermore, even in regions where the conditions are favourable for sugarcane, it may not necessarily be appropriate or desirable, depending on the development objectives and the socio-economic and environmental context.

Geographical focus

The primary geographical focus of the workshop was southern Africa. The region of southern Africa not only has significant biomass potential, but also has set ambitious goals for improving economic integration, political cooperation, and development of its natural resource base in a sustainable manner, mainly through the Southern African Development Community (SADC). The economic and political integration within SADC, along with international cooperation on issues at the environment-development nexus, are among the important drivers for larger-scale biomass production, and along with the coordination of national markets and policies, would facilitate expanded international trade by improving the region's overall economic competitiveness in bio-energy markets.

In terms of international cooperation, the relationship between the EU and southern Africa has special significance for several reasons. First, the strong economic and development cooperation ties between the EU member states and the countries of the region provide an institutional basis for evaluating programmes and policies at both national and regional levels. Second, several EU countries are world leaders in biomass and bio-energy research and development and implementation. Third, the expanded demand for

biomass and biofuels is expected to be met to a significant extent by imports, which could be potentially supplied from the SADC region. Finally, there are useful opportunities for technology transfer between the EU and southern Africa, especially in light of biofuels and bio-energy projects, policies and programmes recently initiated by the European Commission.

The process of economic integration in SADC could potentially both facilitate—and benefit from—the expanded production of modern biomass and biofuels. The domestic benefits will include health improvements, reduced regional emissions, and creation of rural livelihoods. The macroeconomic impacts include foreign exchange savings and reduced dependence on imported sources of energy. There is also significant potential for greenhouse gas (GHG) emission reductions from expanded use of modern bio-energy, with the latter potentially earning credits under the Kyoto Clean Development Mechanism (CDM).

Objectives

The primary aim of the workshop was to exchange information and share experiences in the development of biomass resources and bio-energy markets sources, with an emphasis on the resulting impacts on rural livelihoods and sustainable development in southern Africa. A related aim is to examine developments in biomass and bio-energy within the EU, and the opportunities for technology transfer and for international trade. In terms of technology transfer, there is a need for more detailed assessments of how best-practice technologies for biomass preparation or conversion that are available in the EU might be adapted for use in southern Africa. With respect to international trade, liquid biofuels have special appeal in terms of future EU imports from southern Africa.

Another aim of the workshop was to consider the formation of a network, or connections among existing networks, for comparing and evaluating local experiences with biomass and bio-energy. Unlike the EU or OECD countries, the availability of consistent data and comparable analyses is lower in southern Africa as well as in many small and poor developing countries around the world. Such a network is effectively a North-South-South network, through the participation from representatives of major biomass producers such as Brazil and India, in cooperation with partners from the EU and southern Africa.

Workshop participants and programme

There were thirty-nine participants, who came from several EU countries and southern African countries, as well as several international experts. About half of the participants were from developing countries, mainly in southern Africa. Participants came from research institutes, consulting organisations, universities, NGOs, government, international organisations, and private industry, as shown in Table A-1. The full list of participants is provided in Annex II.

The programme included presentations, discussions, and working group sessions, as given in Annex III. The presentations included some short (5-10 minutes) informal presentations as well as formal presentations that were longer (20-30 minute).

❑ Study visits

There were two study visits, each lasting 2-3 hours, and amounted to a full day after accounting for transportation time. The purpose of the study visits

Table A-1: Type of affiliation and region/location for workshop participants

Type/location	EU	Other OECD	Africa	Other DC	TOTAL
Research Institutes	4	1	3	1	9
University	6	1	3	1	11
Consulting	3		2		5
Governmental or International Organisation	2	1	2		5
NGOs	1		3	1	5
Private Industry	1		3		4
TOTAL	17	3	16	3	39

was to consider some of the issues relating to biomass and livelihoods in the UK context, and draw some comparisons with the situation for bio-energy development in Southern Africa and elsewhere. The study visits were also designed to place biomass and bio-energy within the context of renewable energy and sustainable development strategies, drawing on the example of the UK.

The first study visit was to Beaufort Court – a zero emission facility that incorporates many different elements and types of renewable energy and energy efficiency into its buildings and facilities, which include working offices (Annex IV). On an annual basis, the site generates more energy than it consumes, with sales to the grid, compensating for those periods of the year when wind and sun is insufficient for heating needs.

The main bio-energy element was the miscanthus planted on the grounds for biomass production. A boiler using the miscanthus provides approximately 160 MW of heat, about 100 MW of which will be available for sale to industries or district heating facilities. Additional information on the site is given in Annex IV.

Other renewable energy components at Beaufort Court included solar thermal for water heating, passive measures for energy storage, a windmill, and a number of efficiency measures. The aesthetics and social impacts appeared overall to be quite positive. One participant remarked that the sound of the windmill above their head was drowned out by the sound of the nearby motorway!

The second study visit was to Friars Court, a working farm, multi-purpose farm encompassing 575 acres (233 ha) and located in central England. In addition to the crops grown (wheat and barley), the farm has livestock, a conservation area, a nature trail, a restaurant and catering facility, a beautiful terrace and garden where weddings and other events can be held, and 25 acres of short-rotation crops (SRC), for which willow was chosen. A more detailed description of the establishment of the SRC plantation is found in Annex V. A biomass boiler generates heat using the harvested biomass, which generates a surplus that is also sold for use in construction and as fuel for neighbouring areas.

Perhaps the most interesting aspect of the visit was the fact that the farmer in the UK faces many of the same issues and challenges faced by farmers in developing countries, although of course, only in a relative sense, given the huge disparity in incomes. A main example was the need that arose to diversify the use of the land and sources of income in the face of competition and the fluctuating prices of agricultural commodities. Furthermore, multiple uses of biomass are not only recognised as important, but improvements come somewhat naturally to farmers who know the land, underlining the important role for farmers in the future bio-economy.

The farmer at Briars Court also had to deal with inconsistent signals from government policy at the same time deal with the unpredictable market, just as farmers all around the world do at the time of globalisation and shifting policies. In this case, the SRC plantation initially received support for experimenting with production of biomass for fuel, but the support was later modified with rather short notice (Willmer, 2005). In spite of this, the farmer adapted to the changed circumstances by finding other markets for the willow, such as for crafts. In the same way, albeit in the face of more dire circumstances, farmers in Africa have to adapt to changing conditions, but at the same time try to take advantage of their skills in harnessing biomass resources effectively.

❑ Seminar on energy for sustainable development

A special half-day seminar on the broad theme of "Energy for Sustainable Development: Past Experiences and Future Challenges" was held in memory of the passing of Gerry Leach, a well-known biomass/development researcher from the UK, who had worked for many years together with African colleagues on woodfuels and bio-energy systems, incorporating local institutions into the analysis and discussion. A keynote presentation was made by Youba Sokona, Executive Secretary of the Sahara and Sahel Observatory (OSS). Five panellists, representing international research and policy organisations, provided responses to the address and to questions from the audience. The detailed programme is given in Annex VI.

❑ Working groups

In addition to the general workshop discussions, three working groups were formed for more detailed discussion of biomass resource development. It was decided that the groups should be based on different

types or classes of feedstocks. Three categories of feedstock were chosen for the working groups: (1) sugar crops, (2) woody biomass, (3) oil-bearing crops (and other crops).

The working groups were asked to address five aspects relating to priorities for future analyses, implementation, and research:

- scientific analysis/research;
- policy analysis/research;
- training/capacity building;
- programme development; and
- demonstration projects.

The categories are not intended to be representative of the overall biomass resources, nor are they separated on the basis of agronomic characteristics. They merely form categories that are somewhat homogenous in terms of production methods, and are interesting in terms of near-term markets as well as current uses and availability. Production of liquid biofuels for the international market warrants a focus on sugar crops—sugarcane and sweet sorghum—for bio-ethanol, and various oil-bearing crops for bio-diesel. Sugar crops are preferred over starch crops such as maize or wheat, as they are much more efficient.

Woody biomass is by far the most important category for households in Africa, and this will certainly continue to be the case in the near-term, even if there are significant advances in modern bio-energy in the next 5-10 years. In addition to the role of woody biomass for traditional uses in households, the use of woody biomass for bio-energy is important for small-scale businesses that have no access to modern energy services.

ANNEX II
List of Participants

Participant	Organisation	Position	Country
Avis, Jonathan	Environmental Change Institute	Research Analyst	UK
Ballard-Tremeer, Grant	Eco Ltd	Director	UK
Brown, Gareth	Imperial College- ICCEPT	Research Fellow	UK
Cherni, Judith	Imperial College		UK
Chilembo, Edith	Energy and Environmental Concerns for Zambia (EECZ)	Chairperson	Zambia
Estrin, Alexander	Imperial College-ICCEPT	PhD Student	UK
Faaij, Andre	Copernicus Institute - Utrecht University, Department of Science, Technology and Society	Associate Professor, Coordinator Energy Supply & System	The Netherlands
Fulton, Lew	IEA	Transport Energy Specialist	US/France
Fylaktos, Nestor	IC	PhD Student;	UK
Hachileka, Excellent	IUCN	Country Programme Coordinator	Zambia
Hektor, Bo	HPP		Sweden
Hongo, Hamimu	FELISA Co. Ltd.	Director	Tanzania
Hughes, Nicholas	Imperial College	MSc Student	UK
Jamieson, Max	Imperial College	MSc Student	UK
Johnson, Francis	SEI, Climate and Energy Programme	Research Fellow	Sweden
Jolly, Lindsay	ISO Sugar Organisation	Senior Economist	UK
Kgathi, Donald Letsholo	Harry Oppenheimer Okavango Research Centre, University of Botswana	Senior Research Fellow	Botswana
Kåberger, Tomas	International Institute for Industrial Environmental Economics, IIIEE Lund University	Associate Professor	Sweden
Magalhaes, Paulo Graziano	Faculty of Agricultural Engineering, Brazil	Professor	Brazil
Matinga, Margaret Njirambo	Eco Ltd.	Junior Consultant	Malawi
Mbolela, Ngosa	Zambian Department of Energy	Project Officer	Zambia
Morales, Maria	SEI, Climate and Energy Programme	Research Fellow	Sweden
Mphundukwa, James	PressCane Ltd.	Technical Operations Manager	Malawi
Ng Wing Tin, Marion	SEI, Climate and Energy Programme	Intern	France Sweden
Nilsson, Solveig	SEI, Climate and Energy Programme	Administrative Assistant	Sweden
Peksa, Malgorzata	ETA Renewable Energies	International Projects Manager	Italy
Read, Peter	Massey University	Senior Lecturer	New Zealand
Rosillo Calle, Frank	Imperial College - ICCEPT	Research fellow	UK
Sekhwela, Mogodisheng B.M.	University of Botswana	Assistant Director Research Quality Management	Botswana

Participant	Organisation	Position	Country
Sharma, Sudhirendar	The Ecological Foundation		India
Silveira, Semida	Sustainable Energy Expert	~~PhD Student~~	Brazil/ Sweden
Sobhanbabu, P.R.K.	Winrock International India	Senior Programme Officer (Energy and Environment)	India
Sokona, Youba	Sahara and Sahel Observatory (OSS)	Executive Secretary	Mali/Tunisia
Songela, Francis	Tanzania Traditional Energy Development and Environment Organisation (TaTEDO)	Biomass Energy Coordinator	Tanzania
Swai, Mary E.	Tanzania Traditionnal Energy Development and Environmental Organisation (TaTEDO)	Environment Energy Expert	Tanzania
Tomlinson, Denis	Illovo Sugar Ltd.	Corporate Affairs Development Manager	South Africa
Watson, Helen K.	University of KwaZulu-Natal	Senior Lecturer	South Africa
Vikram, Seebaluck	University of Mauritius	PhD Candidate, Lecturer	Mauritius
Woods, Jeremy	Imperial College - ICCEPT	Research Fellow	UK

ANNEX III
Workshop Programme

Day One - Friday 29 April

08:30 – 09:30 Registration, Coffee, Informal discussions

09:30 – 11:15 Welcome, Introductions, Overview

11:15 – 13:00 Reports and Information from Recent Events, Networks, Initiatives

- World Bank Energy Week & IEA Task 40 Sustainable Bio-Trade Workshop – *Andre Faiij, Copernicus Institute, University of Utrecht, Netherlands*
- Abrupt Climate Change (ACC) Meeting and the Importance of a Carbon Life-cycle Approach – *Peter Read, Massey University, New Zealand*
- Biomass, CDM, and the Nordic Initiative (April 2005-Copenhagen World Bank Donors Meeting) – *Semida Silveira, Swedish National Energy Administration*
- Renewable Energy Partnerships for Poverty Eradication in Africa – *M. Morales, SEI*
- Cane Resources Network for Southern Africa (CARENSA) – *Francis X. Johnson, SEI*

13:00 – 14:15 Lunch

14:15 – 16:00 International Cooperation, Biomass Resources, Bio-Trade

- Sustainable Bio-trade: Global Analysis of Potentials – *Andre Faiij, Copernicus Institute, University of Utrecht, Netherlands*
- Global Village Energy Partnership (GVEP) – *Dick Jones, GVEP Secretariat, DFID*
- Multi-product Biomass Systems – *Tomas Kåberger, Lund University, Sweden*
- Biomass Potential from Sugarcane Production in Brazil – *Paolo Graziano Magalhaes, University of Campinas, Brazil*
- Ethanol Production and Markets – *Frank Rosillo-Calle, Imperial College*

16:00 – 16:15 Coffee Break

16:15 – 17:45 Sustainable Livelihoods, Rural Energy, and Biomass Policies in Africa

- Experiences from SPARKNET – a Knowledge Network for Africa – *Margaret Matinga, Eco Ltd., Malawi*
- Experiences from the Household Energy Development Network (HEDON) – *Grant Ballard-Tremeer, Ecoharmony, UK*
- Farming for Livelihoods in Southern Africa (FELISA) – *Hamimu Hongo, FELISA, Ltd., Tanzania*
- Biomass Successes and Failures in West Africa – *Youba Sokona, OSS, Tunisia*
- Overview of Energy Policies and Programmes in Tanzania – *Francis Songela and Mary Swai, Tatedo, Tanzania*
- Bioenergy Options and Energy Policies for Zambia – *Ngosa Mbolela, Zambia*

17:45 – 18:00 Wrapping-up and Summary

Day Two - Saturday 30 April

08:30 – 09:30 Registration, Coffee, Informal discussions

09:30 – 11:00 Biomass, Bioenergy and Biofuels: Policies and Potentials

- Zambian Government Policy Position on Biofuels and Renewable Energy – *Ngosa Y. Mbolela, Department of Energy, Zambia*
- Overview of Bioenergy Policies and Programmes in Tanzania – *Francis Songela and Mary Swai, Tatedo, Tanzania*
- The Ethanol Programme and Experiences from Ethanol Production and Utilisation in Malawi – *James Mphundukwa, Presscane, Malawi*
- Biomass Potential from Sugarcane Production in Brazil – *Paolo Graziano Magalhaes, University of Campinas, Brazil*
- Ethanol Production and Markets – *Frank Rosillo-Calle, Imperial College*

11:00 – 11:15 Coffee Break

11:15 – 12:30 Biomass and Biofuels issues-scale and impacts: global, regional, local

- Agronomics of Sugarcane and Sweet Sorghum inSsouthern Africa – *Helen Watson, South Africa*
- Land use and Ownership Issues in Biofuels Production – *Sudhirendar Sharma, India*
- Community Based Natural Resource Management – *Donald L. Kgathi, Botswana*
- Small-scale Production and Sustainable Livelihoods – *Edith Chilembo, Zambia*
- Industry Perspectives – *Denis Tomlinson, ILLOVO*

12:30 – 12:45 Goals and Structure for Working Groups

12:45 – 14:15 Lunch and Working Group I Meetings

14:15 – 15:00 Reports from Working Group I Sessions

15:00 – 15:15 Goals and Structure for Working Groups II

15:15 – 16:00 Working Group Sessions

16:00 – 16:15 Coffee Break

16:15 – 17:00 Reports from Working Group Sessions

17:00 – 17:30 Wrap-up and Conclusions

ANNEX IV
Beaufort Court – Zero Emissions Building

Source: *http://www.beaufortcourt.com*

An integrated renewable energy strategy

It is intended that all energy used by Beaufort Court be provided by renewable sources located on the site. These are: a wind turbine providing electricity, a photovoltaic/thermal solar array providing both electricity and hot water for heating, a ground water borehole providing cooling and a biomass crop providing heat (and maybe, in the future, combined heat and electricity).

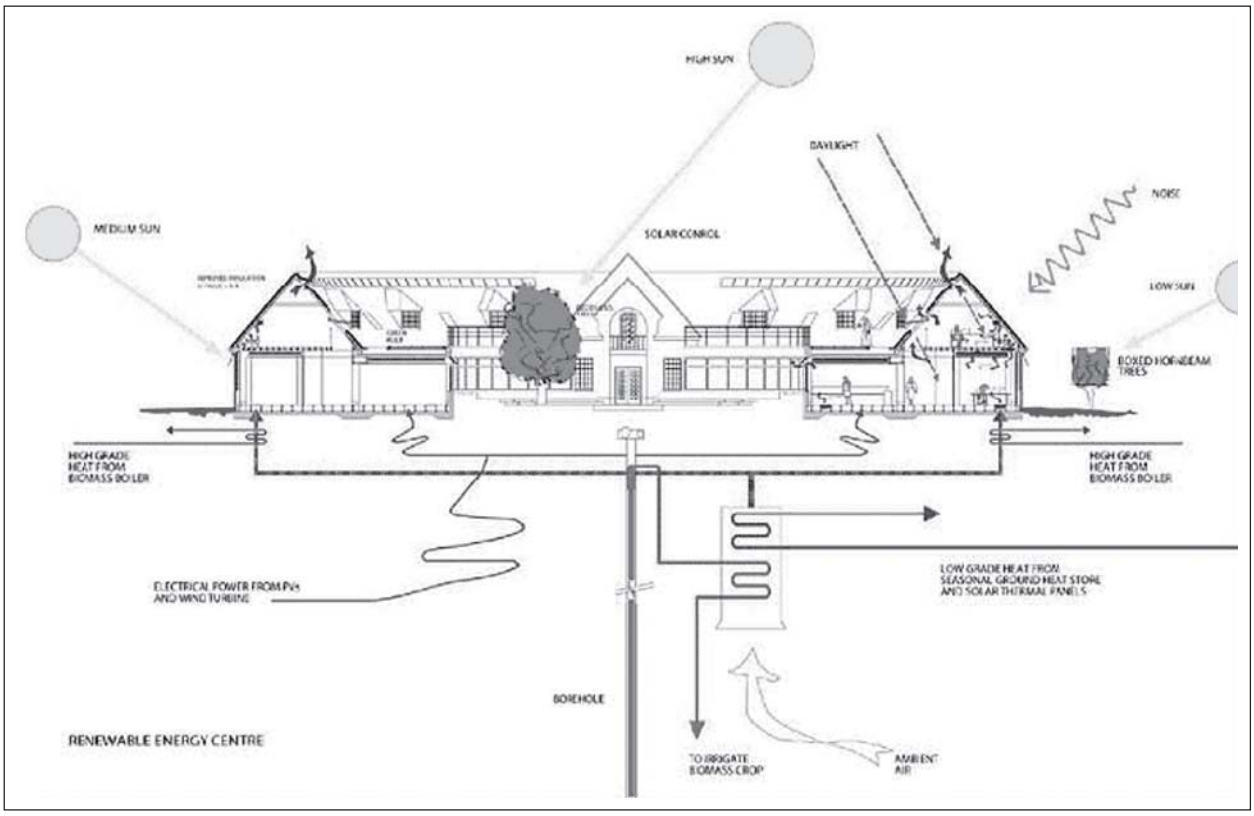
The biomass installation will not be installed later, therefore, in the meantime, its heat contribution is provided from natural gas. Even so, it is expected that the buildings will be carbon neutral with export of electricity compensating for the use of fossil based gas supply. An underground seasonal heat store allows heat generated in summer to be used in winter. Detailed information on the various energy sources is given below.

❑ Biomass

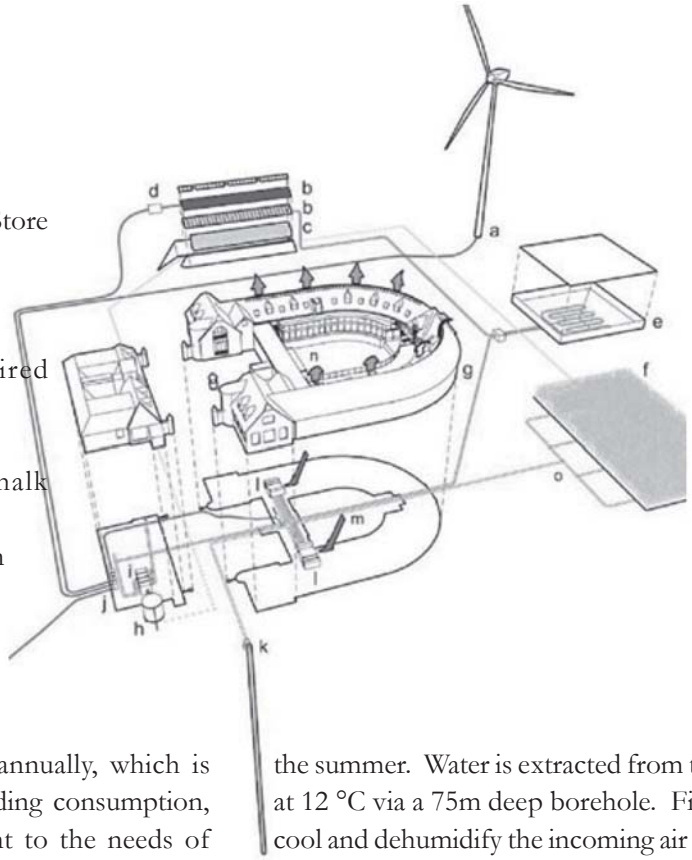
The buildings' heating needs will primarily be met by a biomass boiler fuelled by the energy crop miscanthus, or 'Elephant Grass', 5 hectares of which have been planted adjacent to the site. The crop is harvested annually in the late winter with conventional harvesting equipment and stored as bales until needed. The bales are shredded before being fed into the biomass boiler. The field is expected to yield 60 oven-dried-tonnes per year with a calorific value of 17GJ/tonne. The 100 kWh biomass boiler is provided by Talbott's Heating. It is 80% to 85% efficient and can modulate down to 25% of full load. The shredded bales are fed into the boiler by a mechanical screw auger. Biomass is carbon neutral as the CO_2 emitted during combustion is balanced by the CO_2 absorbed by the crop, which is coppiced on short rotation. The emissions from the boiler comply with the Clean Air Act. The boiler is expected to be installed for operation later.

❑ The wind turbine

The 225 kWh wind turbine has a hub height of 36 m and a rotor diameter of 29 m and is a Vestas V29 model previously in operation in the Netherlands. The turbine is connected to the buildings' electrical distribution network and to the national grid. It is



a. 225kWh Wind Turbine
b. Hybrid PVT Array
c. Crop Store
d. PVT Invertors
e. 1400 m2 Underground Heat Store
f. Biomass Crop (miscanthus)
g. Office Building
h. Crop Shredder
i. Biomass Boiler & Gas Fired Backup Boilers
j. El. Import/Export Meters
k. 75m Deep Borehole in Chalk Aquifer
l. 2No. Air Handling Installation
m. Fresh Air
n. Exhaust Air
o. Irrigation



expected to generate 250 MW annually, which is greater than the anticipated building consumption, and the excess power (equivalent to the needs of around 40 homes) will be exported to the grid.

❑ Ground water cooling

Ground water is used to cool the buildings during the summer. Water is extracted from the local aquifer at 12 °C via a 75m deep borehole. First, it is used to cool and dehumidify the incoming air to the buildings in the Air Handling Units. The water is then circulated at 15 °C through chilled beams (finned tubes) at high level in the offices. Finally, the water is used to irrigate the energy crop.

PVT array

The 170 m2 solar array comprises 54 m2 of PVT panels and 116 m2 of solar thermal panels. The PVT panels consist of a photovoltaic element, which converts light into electricity, and a copper heat exchanger on the back to capture the remaining solar energy. The panels have been developed by ECN in the Netherlands, incorporating Shell Solar PV elements and Zen Solar thermal elements. They produce electricity and hot water. The solar thermal panels are identical to the PVT panels, but without the photovoltaic element.

Seasonal underground heat store

The underground heat store is a 1400 m3 body of water that stores the heat generated by the PVT and solar thermal panels for use in the buildings during the colder months. The top of the store is insulated with a floating lid of 500 mm expanded polystyrene, but the sides are uninsulated. As long as the ground around the store is kept dry, it will act as an insulator and additional thermal mass, increasing the capacity of the store. The high specific heat capacity of water (4.2kJ/kg °C) makes it a good choice for storing heat.

During the summer there will be little or no demand for heat in the building, so the heat generated by the PVT array will stored in the heat store. In autumn, some of the solar heat generated will be used directly in the buildings and the excess will be added to the heat store. The temperature of the water in the store will gradually rise over the summer and early autumn. During the winter the solar heat generated will be less than the building's heat load, and heat will be extracted from the heat store to heat the incoming air to the building. The temperature of the water in the store will drop as the heat is extracted. Some heat will also be lost to the surroundings. This is estimated to be about 50% of the total heat put into the store over the summer. The relatively low-grade heat from the store can be used to preheat the incoming air to the building, as the outside air will be at a lower temperature than the water.

❑ Wealth creation and life changes

Beaufort Court is located in a relatively affluent part of the United Kingdom. However, the relocation of an expanding company to Kings Langley will provide opportunities for work and provide alternative career possibilities outside the magnet of London, obviating the need to commute. The new facilities will assist RES in expanding their operations worldwide and the creation of wealth inherent in this expansion. The main local social benefit will be the provision of an efficient and stimulating workplace. However, the decision to operate the new head office as a visitors' centre and information resource, allowing those of all levels of interest to learn about the technologies and issues involved in creating low and zero net energy work settings, provides an invaluable national facility.

❑ Clean and green

Bringing back to life a derelict building rather than building new is a considerable benefit in terms of land utilisation, use of resources and improving the amenity of the area. The construction work was undertaken on the basis of minimising waste, and using materials and components with low embodied energy from readily available resources.

The site is self-sufficient in energy. In order to minimise the need for energy, a judicious combination of active systems (mechanical ventilation, artificial cooling, heating and lighting, building management systems) and passive systems (solar heating, natural ventilation and lighting, solar shading, a well insulated building envelope incorporating thermal mass) was developed. A building management system (BMS) controls and optimises all the energy systems, including opening and closing the rooflights.

The buildings are exposed to considerable external noise: from passing trains to the West and the motorway to the South. To cut out the disturbance from noise inside the buildings, the outward facing facades had to be sealed. This, together with the relatively high levels of heat generated by modern office use, requires the building to be artificially cooled in summer months. The cooling source is water drawn from aquifers located in the chalk below the building. This strategy avoids the heavy energy consumption and potential polluting effects of refrigeration plant normally used for air conditioning. The cool water is used to drop the temperature of air being fed into the building and is circulated through convectors within the office space, cooling the air within it.

Heat is supplied from the biomass boiler (or gas boiler until such time till the biomass plant is installed) and from the PVT array, either direct or via the seasonal ground heat store. Hot water from these sources is used in a similar way, as the chilled water for cooling. Electricity is generated from the PVT array and the wind turbine.

Windows can be opened in facades and roofs facing away, or sheltered from the motorway and the railway, to ventilate the building in temperate conditions. Exposed windows are shaded from the sun by fixed glass or aluminium screens and by deciduous tree planting, thereby reducing unwanted solar gains and the need for cooling. The building is well insulated and sealed.

❑ Estimated energy use and supply

Predicted energy use and energy supply is shown in the table below. The current monitoring programme will show whether these predictions are born out in reality.

Table A-2: Predicted energy use and energy supply

	Electrical	Space heating
Building annual loads (2500m^2 building gross area)	115 MW	85 MW
PV/T direct contribution (with 48 m2 of PV)	3.2 MW	15 MW
Heat collected into storage		24 MW
Pumping load/heat lost from storage	-4.5 MW	-12 MW
Wind turbine	250 MW	
Miscanthus: peak expected production (60odt/year)		160 MW
Net contribution	248.7 MW	187 MW
Potential electrical export	133.7 MW	
Potential surplus miscanthus for heat export		102 MW

ANNEX V
Information on Friars Court Farm

Source: *Friars Court information brochure (Clanfield, Oxon. OX18 2SU)*

The short-rotation crop (SRC) plantation, which surrounds the 'Scrape' was first established in 1992, and it has grown over a three year planting program to its current size of 25 acres. This was done in conjunction with a project started by the Department of Trade & Industry, as it wanted to find out if willows could be grown as an alternative, economically viable crop for use as a bio-fuel.

But why willow? Because willow trees grow at a tremendous rate, especially in damp wetland soil, while cutting them back, only stimulates their growth further. The entire 25 acres was hand-planted using small 10 cm long willows rods, 4,000 to the acre - a total of over 100,000 trees! After a year the trees produced two or three shoots and grown up to 2 metres high. At this stage they are cut back to ground level – this is known as coppicing.

Coppicing stimulates the tree to produce more side shoots (up to ten) and three years later, when the trees have reached a height of about 5½ metres, harvesting can begin. This can be done either by hand or machine. Once harvested the trees produce more shoots and the cycle is repeated after another three years. Current research indicates that this can be done for up to 30 years!

The primary reason for growing the trees was so that the wood could be chipped. Some of the potential uses for these chips are as follow:

By spreading them on a garden they act as an effective barrier against weeds. As they decompose, nutrients are released back into the soil.

Mixed with manure the chips can be used as a very good peat substitute (chicken manure has been used as it is virtually odourless).

The wood chips can also be burnt, thus generating heat. Central heating systems and industries that require a lot of hot water could find this an effective alternative to existing oil-fuelled boilers.

When burnt in a controlled environment, it is possible to separate and clean the exhaust gases, which are in themselves flammable. These are ignited and burnt in boilers, which in turn could power electricity generators. There are currently plans to build a wood-fuelled power station at Cricklade near Swindon, Wilts.

Although the primary reason for growing the trees on the farm was for use in the energy market, it was soon apparent that the equipment required to burn the wood would not be perfected in time for the trees' first harvest. Therefore it was necessary to find a new market.

Friars Court had for a long time been approached by a number of organisations, such as schools, who wanted small amounts of willow for weaving. From this a new business idea was formed. Friars Court is now home to three craftsmen, who use the willow grown on the farm for garden and restorative weave work.

Two of the craftsmen use willow rods, between one and three years old, to make living ornamental structures and hurdles, whilst the other uses it for 'Spiling' which is a form of riverbank stabilisation to help prevent erosion. Examples of their willow work can be seen in the gardens at Friars Court.

ANNEX VI
Seminar Programme

Energy and Sustainable Development: Past Lessons & Future Challenges

Imperial College, London - Thursday 28 April 2005, 11:00-14:00

A Seminar in remembrance of Gerald A. Leach (1933-2004)

Co-organised by:
Imperial College Centre for Energy Policy and Technology (ICCEPT)
International Institute for Environment and Development (IIED)
Stockholm Environment Institute (SEI)

In the 1970s, the traditional energy-economic paradigm was being questioned, due to concerns over high oil prices, energy security, and the environmental impacts attributable to fossil fuels and nuclear power. While the North was focused on its energy crises, oil-importing developing countries were facing their own crises. Higher energy prices, population growth, and exploitation of natural resources exacerbated extreme poverty, threatened fragile political institutions, and constrained future options for growth and development.

The role of energy in relation to environment and development has evolved considerably since the 1970s. Climate change emerged in the 1980s as a major challenge for policy-makers grappling with how to reconcile the aspirations of the South for economic development with the unsustainable energy paradigm that had fuelled rapid economic growth in the North. The social and environmental impacts of increasing energy consumption pose a threat to human health and ecological systems, even as two billion persons lack access to the modern energy services that help to create livelihoods, generate growth, and reduce poverty.

This seminar will explore some of the basic synergies and conflicts between the role of energy services in poverty reduction and the social and environmental consequences of energy consumption. What is the role of energy in sustainable development and what are the key institutional changes needed to facilitate the global transition to a sustainable energy future? The emphasis in the seminar will be on the EU and sub-Saharan Africa, although the themes and questions will naturally be broad in nature.

11:00 – 11:30 Welcome and Introductions

- Francis X. Johnson, *Research Fellow, Energy and Climate Programme, SEI-HQ (Stockholm)*
- Matthew Leach, *Imperial College Centre for Energy Policy and Technology (ICCEPT)*
- Camilla Toulmin, *Director, International Institute for Environment & Development (IIED)*
- Johan Kuylenstierna, *Director, SEI-York*

11:30 – 12:00 Keynote Address

Youba Sokona, *Executive Secretary, Sahara and Sahel Observatory (OSS), Tunisia*

12:00 – 12:30 Panellists' Response

Moderator: Andrew Barnett, The Policy Practice Limited (Brighton, UK)

- Andrew Simms, *Director, Policy Analysis & Climate Change, New Economics Foundation (UK)*
- Margaret Njirambo Matinga, *Consultant, Eco Ltd, (Malawi)*
- Ritu Kumar, *Director, European Office, The Energy Research Institute (TERI, India)*
- Mayer Hillman, *The Policy Institute (UK)*
- Peter Davies, *Energy Group, Department for International Development (DFID, UK)*

12:30 – 13:00 Refreshments (light lunch)

13:00 – 13:45 Roundtable Discussion with Panellists

13:45 – 13:55 Summary Remarks – Andrew Barnett

13:55 – 14:00 Closing – Francis X. Johnson and Matthew Leach

ANNEX VII
International Networks and Partnerships

There is a widespread belief that active international partnerships among many different stakeholders—including NGOs, SMEs, donors, university research groups, multilateral institutions, and civil society—can help to address energy and development goals. A brief overview is provided below for several North-South networks and partnerships, established in recent years that were aimed at cooperation between EU and African partners, on research and policy issues related to bio-energy, rural development and livelihoods.

The so-called "Type II partnerships" that grew out of the WSSD—such as the Global Village Energy Partnership (GVEP)—are not reviewed here, since they are not specific to the EU and Africa and since information on them is readily available through their own websites.

HEDON: Household Energy Network

HEDON is a grassroots organisation of over 600 household energy practitioners, the majority of whom are based in the South. Established in 1992, this currently 100% voluntary and 'free' network has grown rapidly, and now brings together many key stakeholders in household energy to create a powerful tool for change.

HEDON is a user-driven network that is fully determined by the users themselves—it is up to the users to decide on what information to post and how to edit it. So, not only can users of HEDON access up-to-date information on worldwide news, names of specialists, key documents, and links to other organisations and websites, but just as importantly, users can inform others about their work, their successes and failures, and any other information deemed relevant. Thus, the whole network is greater than the sum of individual efforts, given that single work can reach all users, and the time and money are not wasted.

To achieve this exchange of knowledge, HEDON offers its users a number of key outlets for interaction and exchange, including a library and knowledge base. The library allows users to post and retrieve documents of high relevance to household energy, offering an unparalleled exchange of key research and knowledge assets. The knowledge base uses an address book that allows personal webpages to be automatically created for all users and organisations. Users can quickly learn about other users, search for needed expertise, and develop a contact base. The HEDON knowledge base also contains critical 'how-to' documents, an introduction to household energy, an overview of household energy and health, and information on tools, technologies and techniques, all of which can be posted and edited by all. This ensures not only the provision of up-to-date knowledge, but the opportunity for discussion and debate.

One important area of network development for the future is the creation of special interest groups, which would link HEDON with specific communities of practice, allowing people to share ideas both through specialist websites and through linkages to other household energy sectors. Benefits would include the strengthening of existing links and infrastructure for wide dissemination of key messages from specialist communities to the wider community (including the non-online knowledge), as well as the creation of a reliable technical toolbox usable by anyone with only limited computer knowledge. SIGs are likely to include topics such as, clean indoor air, carbon and cookstoves (CDM), scaling up of household energy programmes, and alcohol-based fuels or biodiesel. Other thematic, regional, or language groups would also be encouraged.

Website: www.hedon.info

LAMNET: Latin America Thematic Network on Bioenergy

The Latin America Thematic Network on Bioenergy (LAMNET) was funded during 2001-2004 by the European Commission DG-Research, under the programme on 'Confirming the International Role of Community Research'. The main objective of LAMNET was to establish a trans-national forum for the promotion of sustainable use of biomass in Latin America and other emerging economies. A global network of 48 institutions (knowledge centres and SMEs) from 24 countries worldwide was set up to assess regionally adapted bioenergy applications. Regional centres were based in Mexico and Brazil.

In order to promote the sustainable use of biomass in Latin America and other emerging countries the objective was to establish a network of Knowledge Centres (universities and R&D institutes) and SMEs in EU and Latin America countries, as well as in other developing countries. Additionally, the project has a steering committee consisting of members from the EU, Latin America, China and several African countries.

The main focus of the project is thereby, the identification of technological objectives and the development of policy options to promote decentralised biomass production and energy generation. The following six key **Thematic Priorities** were identified:

- Analysis of the energy policy framework for biomass and bioenergy
- Assessment of energy demand, prices, rural development, and roles of key actors
- Assessment of present and potential biomass resources
- Technical and financial analysis of available conversion technologies and systems
- Development of policy options for the promotion of bioenergy
- Identification of training, technical cooperation, and demonstration projects

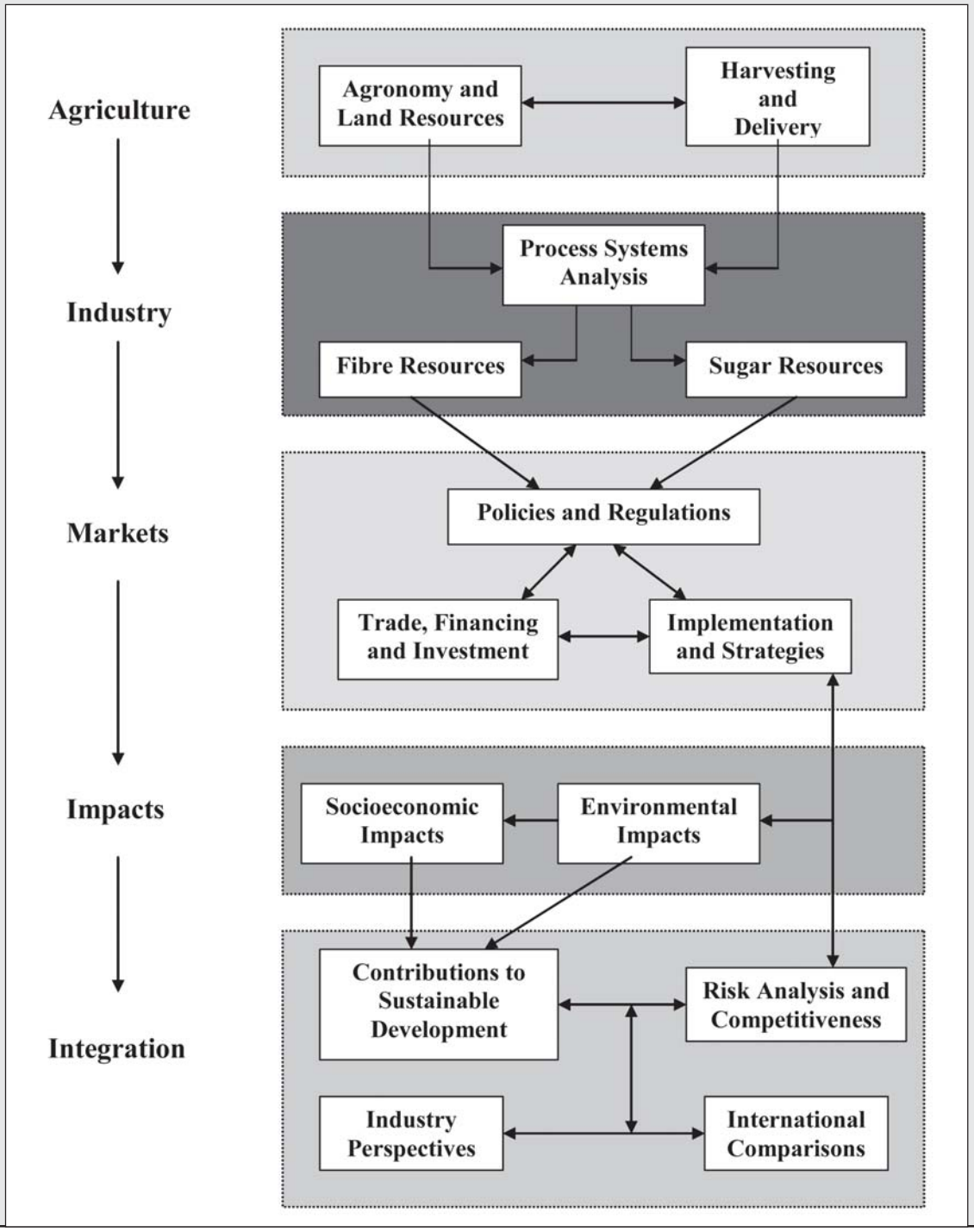
The efficient dissemination of the results of this project was based on a periodical newsletter and a website. Additionally, the focus of this project is to establish a shared data-base on a regional Latin American and other countries with emerging economies, to allow for enhanced comparability and long-term accessibility of the results. Several workshops and seminars were organized, and the proceedings are available on the website. Several members of the network also participated in the Renewable Energy Partnerships for Africa Support Action in 2004-2005.

Website: http://www.bioenergy-lamnet.org/

CARENSA: Cane Resources Network for Southern Africa

The Cane Resources Network for Southern Africa (CARENSA) was supported by EC DG-Research as a Thematic Research Network during 2001-2005. CARENSA aimed to critically assess the role of bio-energy from sugarcane and related crops in promoting sustainable development and improving global competitiveness in the region of Southern Africa. The network is structured on the principles of North-South-South cooperation, with partners in four EU countries, four African countries, and Brazil and India. Three international organisations also participate, to create linkages with the international community on issues at the intersection of environment and development. The network brings together five institutional or thematic phases that are critical to the goal of harnessing cane resources for sustainable development in Southern Africa, and the project components were designed around these five phases (as shown in the figure below).

Website: www.carensa.net



SPARKNET: Sustainable Energy Policy Research Knowledge Network

The Sustainable Energy Policy Research Knowledge Network (SPARKNET) was supported by the EC DG-Research International Cooperation Programme from 2002-2005. It focuses on energy issues affecting low income rural households in eastern and southern Africa. SPARKNET aimed to gather and disseminate up-to-date knowledge, relevant for the energy situation of the seven SPARKNET member countries of eastern and southern Africa, as well as with EU policy makers and researchers. SPARKNET was established as an interdisciplinary interactive network and core members of SPARKNET included policy makers, research institutions, universities, technology experts and NGOs, representing low income communities and end-users.

Core members of the network assemble information, according to pre-defined formats covering the household energy situation in their countries, from existing literature and from their expert knowledge and experiences. Some non-African partners provided knowledge on selected issues of health, gender and forestry, which cut across the energy sector in all the participating countries. The knowledge gathered is peer reviewed, firstly in-country and then by other expert participants, before final editing and publishing on the SPARKNET webpage.

SPARKNET participants also prepared scenario analyses that assessed the energy-poverty situation and its various impacts, attempting to answer the question "What will the household energy scenario in southern and eastern Africa be like in the next 10 to 15 years?" The outlooks assessed business-as-usual scenarios, economic prosperity and regional co-operation situations as well as worst case scenarios. These scenario preparations were followed by internet-based conferences to discuss the scenarios and possible strategies for a way forward. Network members then developed policy recommendations for their respective countries and thematic issues. Again, an internet-based conference was held to discuss the implications of suggested policies and strategies. Each of the two internet based conferences, (discussing scenarios and policy actions) attracted over 170 participants from around the world including Europe, Asia and across Africa. Knowledge products of SPARKNET include internet-based conference proceedings, country reports, thematic briefings on health, gender and forestry, bibliographies, organisation, project and funding profiles.

A key achievement of SPARKNET has been the availability of information that can be used by policy makers and researchers and also by partner countries. It also helps in exchange of knowledge and networking for informing about changes in policies and actions that can contribute in helping the region for better energy situations. The network has played a key role in building capacity for knowledge generation among southern and eastern African energy experts, and hence facilitating South-South as well as South-North knowledge flows to counter-balance the traditional North-South knowledge flow. Conferences conducted in the past has helped to expose gaps in expertise in various countries, particularly in moving from policy making to sustainable action, as well as about the failures in linking energy poverty with other socio-economic issues such as health and gender.

SPARKNET participants felt that SPARKNET activities were of high value and have expressed need for continuity and to further incorporate policy makers from government and possibly multilateral and bilateral partners. In addition, non-members have expressed interest to become future core members whilst other regions have expressed the need for similar initiatives in their respective regions.

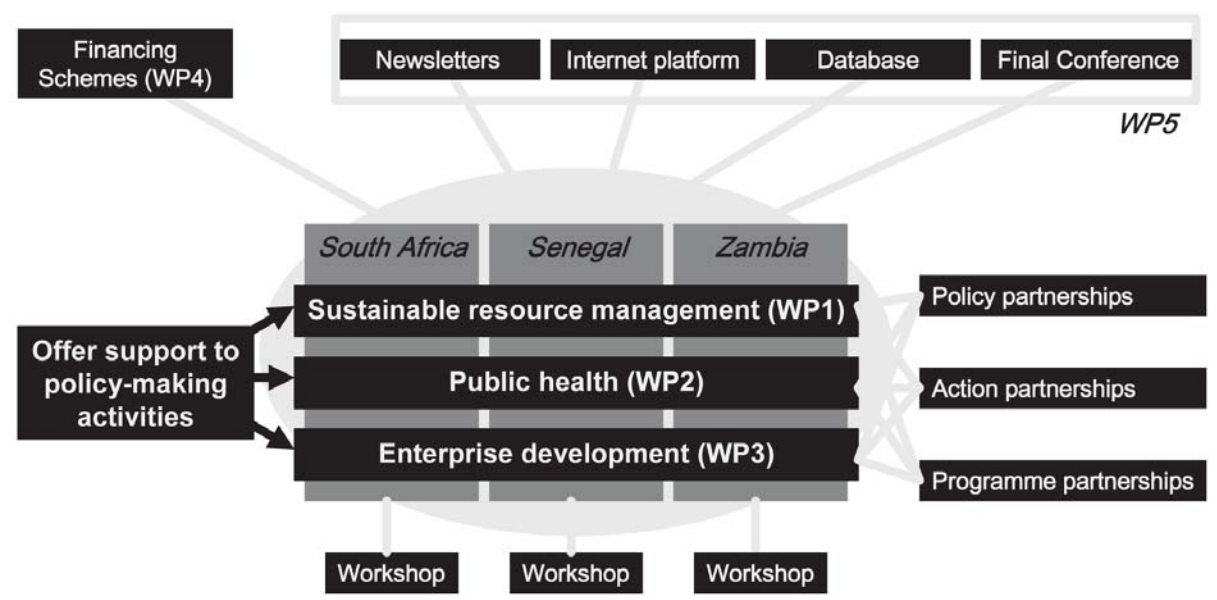
Website: www.sparknet.info

Renewable Energy Partnerships for Africa

This support action created international partnerships for promoting the role of renewable energy in poverty reduction, and supporting policy makers in the areas of renewable energy and sustainable resource management, public health and enterprise development. The mobilisation of partnerships in Africa involves:

- Identifying partners
- Bringing them together in partnership structures
- Supporting and contributing to their financing efforts
- Facilitating their set-up and operation

There are three types of partnership to be built: Policy Partnerships, Programme Partnerships and Action Partnerships. Policy Partnerships include progressive energy policy initiatives linked to various research activities and stakeholder networking. Programme partnerships initiate and support training and capacity-building. Action Partnerships lay the foundations for concrete demonstration or pilot projects. The three partner countries in Africa were South Africa, Senegal, and Zambia. Three thematic areas were addressed in providing support to policy-making: sustainable resource management, public health, and enterprise development. There was a particular emphasis on biomass resources in supporting energy for development. An outline of the work programme is shown in the figure below.



Website: http://www.partners4africa.org

COMPETE: Competence Platform on Energy Crop and Agroforestry Systems for Arid and Semi-arid Ecosystems in Africa

A new EC-funded Coordination Action with 48 partners from around the world will follow up on the biomass resources issues addressed in Partners for Africa and in the three aforementioned networks (LAMNET, CARENSA and SPARKNET). The new Action has many of the same partners and has similar objectives, but focuses on arid and semi-arid regions of Africa. It is entitled "Competence Platform on Energy Crop and Agroforestry Systems for Arid and Semi-arid Ecosystems in Africa (COMPETE)."

Website: http://www.compete-bioafrica.net/