Industrial Biotechnology and Biomass Utilisation

Prospects and Challenges for the Developing World

STOCKHOLM ENVIRONMENT INSTITUTE

UNITED NATIONS
INDUSTRIAL DEVELOPMENT ORGANIZATION

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Preface

UNIDO, as the United Nations' specialized agency on industrial development in developing countries, has a particular interest in the impact of industrial biotechnology on its clients. The cleaner industrial processes that biotechnology can support are important in all key industrial sectors, including food, textiles, leather, wood and energy. Cleaner industrial processes through the application of biotechnology also help to reduce negative environmental impacts that might otherwise occur. Through international cooperation and technology transfer, industrial biotechnology has a valuable role in supporting the International Conventions, particularly the Stockholm Convention on Persistent Organic Pollutants (UNEP-POPs), the U.N. Convention to Combat Desertification (UNCCD), and the U.N. Framework Convention on Climate Change (UNFCCC).

An Expert Group Meeting on "Industrial Biotechnology and Biomass Utilisation: Prospects and Challenges for the Developing World" was convened at UNIDO's headquarters, Vienna, Austria in December 2005. The Meeting included presentations and discussions on potential key focal areas for UNIDO's support to developing country policy makers on industrial biotechnology applications. Its objective was to analyse relevant policy and technology issues and initiate follow up actions intended to fill information gaps and generate awareness at the government and industrial levels.

This report is a follow-up to that meeting, with the intention of supporting ideas for the creation and/or deployment of technology platforms and policy frameworks for biomass conversion and industrial development. The report is divided into three parts. Part I provides an overview and background on the emerging bio-economy, with emphasis on the role of agricultural biomass resources for industrial biotechnology and renewable energy in supporting sustainable development and economic competitiveness. Part II provides nine papers that illustrate representative issues related to resource use, conversion options, and the development of new product markets. Part III provides documentation from the workshop, including summaries of presentations and information on the workshop participants.

A full review of broad and complex issues such as these is beyond the scope of this brief report; the focus here is on some of the key technology and policy issues related to the choice of feedstocks and technology conversion platforms for bioenergy and industrial biotechnology in developing countries. The examples and case studies used are intended to illustrate the way in which the bio-economy derives its value from a broad array of biomass resources, including various agricultural and industrial residues, municipal waste, forest plantations, natural forests, and agricultural crops. The heterogeneity of biomass along with the many potential conversion paths and market applications has wide-ranging economic and environmental implications.

The introduction and expansion of biotechnologies within the different industrial sectors can only be achieved when the institutional setting in a given country includes the appropriate policies, socio-economic frameworks and legal mechanisms. UNIDO's private sector development initiatives—including investment, technology acquisition and adaptation programmes—aim to ensure that such aspects are considered at local, regional and global levels. In short, industrial biotechnology and bioenergy are at the heart of UNIDO's programmes to promote clean and sustainable industrial development in developing countries.

PART ONE

Overview of Issue Adressed

1 Introduction to the Industrial Bio-economy

With the continued pace of world economic growth, sustainable socio-economic development will depend upon a secure supply of raw material inputs for agriculture, industry, energy, and related sectors. Today's heavy reliance on non-renewable resources—especially fossil fuels and various minerals—is increasingly constrained by economic, political, and environmental factors. The reliance on non-renewable resources is accompanied by a heavy reliance on chemical and thermo-chemical processes; the role of biological processes in the global economy is small but is growing fast. There are initiatives from both public and private sector interests that support the supply of more of our industrial product and energy needs through biological processes and/or biomass resources.

The bio-based economy can be loosely defined as consisting of those sectors that derive a majority of their market value from biological processes and/or products derived from natural materials, as opposed to products and processes associated with non-renewable resources and/or purely chemical processes. The industrial portion of the bio-economy is somewhat distinct from agricultural, forestry and other sectors, in that raw materials are used to make industrial feedstocks or products, or to drive industrial processes.

Sustainable feedstock supply is one of the key issues for the transition towards the bio-based economy. Therefore the resource base needs to be identified from the perspective of supply and demand. The exploitable biomass is of highly heterogeneous origins, either derived from specially grown crops or from crop residues of food and feed production, forestry residues and marine crops. Municipal waste, manure and animal products also need to be considered as potential resources for bio-based products and services.

The strategic importance of the bio-economy is linked to those areas in which bio-based products and processes can substitute for fossil or mineral-based products and/or chemical processes. Since the overwhelming majority of industrial products and processes are currently based on non-renewable resources and minerals, such substitution has considerable potential to make various industry sectors more sustainable in the long-run, while also reducing environmental impacts in the near-term, especially in reducing GHG emissions and land disposal requirements. Various aspects of the industrial bio-economy are reviewed in this report, including feedstocks, conversion options, products, and market development.

The use of bio-based renewable resources holds great potential value for industries in many sectors, including energy, organic chemicals, polymers, fabrics and health-care products. In general, a bio-based economy offers many benefits and opportunities:

- new areas of economic growth and development for the many regions that have plentiful biomass resources;
- creation of new innovative business sectors and entrepreneurial skills;
- improved energy security, by reducing dependence on non-renewable resources;
- enhance economic and environmental linkages between the agricultural sector and a more prosperous and sustainable industrial sector;
- reduction of greenhouse gas emissions;
- improved health by reducing exposure to harmful substances through substitution of natural bio-based materials for chemical and synthetic materials;
- job creation and rural development.

At the same time, there are many issues that need to be addressed in order to avoid negative impacts and facilitate a smoother transition to a bio-based economy, such as:

- how to manage competition of land used as raw material for industry with other land uses, especially in relation to food and animal feed;
- bioethical issues, where genetically modified crops are used or proposed;
- potential loss of biodiversity through large-scale and/or contract farming;
- equitable treatment of farmers in their interaction with bio-based companies;
- expanded research and development efforts, including potential integration of fossil fuel and bio-based approaches;
- improving transportation and delivery systems, e.g. for raw materials, delivery to/from processing facilities, and final product distribution and use.

The sections below address some key opportunities and challenges for the developing world in the emerging bio-economy, with an emphasis on energy and industry applications; consequently, the discussion includes various resources, feedstocks, and conversion options. Sustainability of the bio-based economy requires attention to key environmental criteria, some of which are outlined below. International policy issues related to climate change, technology transfer, financing, investment and international trade are briefly reviewed in relation to biomass resource development and environmental impacts. Case studies and examples are provided to illustrate both driving forces and constraints.

2 Biomass Resources for Energy and Industry

The availability of biomass for energy production and industrial products depends on a wide range of rather complicated factors that often vary with local conditions, including:

- suitability of soils and climate for various crops;
- availability of water and other key resources for sustained growth;
- competition for other uses of biomass, especially food, feed, and fibre;
- impacts on local ecology, biodiversity, and other environmental factors;
- efficiency of agricultural systems in terms of land, water, and energy use; and
- socio-economic and cultural preferences.

A brief overview of the biomass resource base is provided below, with an emphasis on agricultural sources and residues, and especially those crops that are common or suitable for tropical and sub-tropical climates. The key reason for emphasising agricultural residues is that these resources are less likely to compete with other uses, and are sometimes available at the point of processing for existing agro-industries.

2.1 Biomass Potential

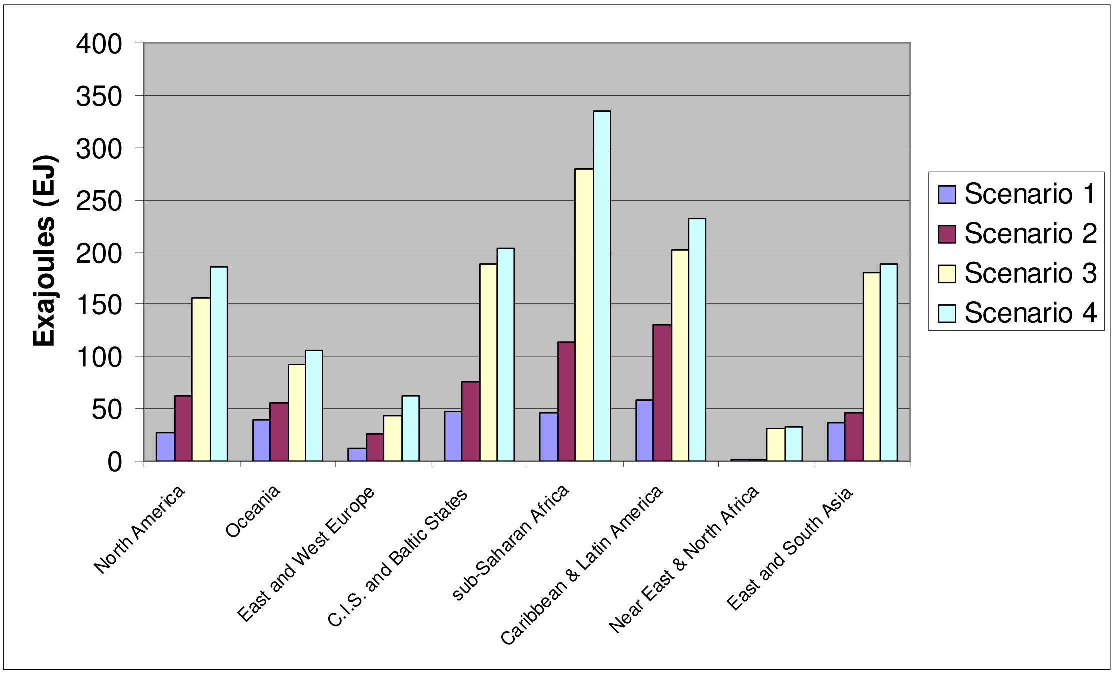
Biomass that is produced in tropical and sub-tropical climates has an average productivity that is over five times higher than that of biomass grown in the temperate regions of Europe and North America (Bassam 1998). Since developing countries are located predominantly in the warmer climates and lower latitudes, they have a considerable comparative advantage. In terms of today's utilisation of biomass resources, this comparative advantage is best illustrated by the development of sugarcane resources in Brazil, mainly for ethanol but also for some industrial products such as bio-plastics. The example of Brazil is referred to often in this report, since it provides the most commercially successful case of developing a biomass resource for energy and industrial applications.

Latin America, along with sub-Saharan Africa, has been estimated as having the highest biomass potential—after accounting for food production and resource constraints—among any of the major world regions (Smeets, 2004). Using four scenarios, the potentials were assessed for various categories of biomass and categories of land use (Figure 4). The high potential results from large areas of suitable cropland, the low productivity of existing agricultural production systems, and the low population density. Such estimates of the long-term bio-energy potential for the various regions can serve as guidelines for development strategies that can harness the biomass resource base in a sustainable manner.

Overall, the global potentials range from 30% to over 200% of current total energy consumption. Other sources of biomass that are not included in the potentials above include animal wastes, organic wastes such as MSW, bio-energy from natural growth forests, and water-based biomass such as micro-algae. 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 biomass production. Many other characteristics would have to be considered in assessing the potentials. However, the considerable potential does provide some indication as to the vast scale of land resources and the low levels of current utilisation (Johnson and Matsika, 2006).

As the role of biomass for energy and industry has become more economically competitive, there is increasing concern as to the impact on food security, especially for countries that are net food importers or those that experience droughts and other disruptions in the food supply. However, 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). There exist potential synergies between food and non-food uses, especially as new agro-industrial biotechnology methods are deployed. Where there are potential conflicts, it is crucial that bio-based industrial development is accompanied by investment in greater agricultural productivity and/or due consideration for distributional issues that arise when the agricultural sector and industrial sector compete for the same raw materials.

Figure 1: Global 2050 biomass 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)

2.2 Nature of biomass feedstock

Crops can be roughly categorised according to the composition of their (main) economic product as sugar, starch (grains, tubers), oilseed, protein, or fibre crop and crops for speciality products (pharma and cosmetics, dyes, fragrance and flowers). For this purpose the crops have been selected and bred. Beside the main harvested product, all crop processing systems yield more or less secondary products and residues which may find an application depending on demand and possibilities for economical conversion.

Biomass residues can be categorised into three main groups: primary biomass residues, available at the farm; secondary biomass residues, released in the agro-food industry; and tertiary biomass, which is remaining after use of products. The characteristics that impact availability and suitability as feedstock include whether the items are of a perishable nature, how much moisture content they have, the density, and the seasonality of supply.

Forestry residues are produced in logging industries in large quantities at the site of harvest (bark, branches, leaves) and in saw and ply mills (saw dust, cut off). Only 25% of the biomass is converted into sawn wood. Other under-utilised biomass resources from primary agricultural production, agro-industries, and municipal waste can be available in high quantities. More uniformly available biomass residues such as straws or seed hulls can be harvested and collected at the farm or at (central) processing sites. Others are only available in dispersed / diluted forms and need collection systems to be installed for concentration and preparation of the biomass.

Among the key issues is increasing the use of agricultural residues, which is in some respects an old topic that is now finding new applications in the developing world (ESMAP, 2005). Previously agricultural residues were promoted mainly for energy use, often at low efficiency; however, it is now more widely recognised that there are in fact many uses that may provide higher value-added or could serve as complementary products via co-production schemes alongside energy applications. Such “cascading” of value is a recurring theme in industrial biotechnology development (van Dam et al, 2005).

Table 1: Examples of biomass residues for different crops

Crops	Primary Residues	Secondary Residues	Residue ratio [a]
grains (wheat, corn, rice, barley, millet)	**straw (stover)**		1.0-2.0
	chaff (hulls, husks),	**bran, cobs**	0.2-0.4
sugar cane	**leaves and tops**		0.3-0.6
		bagasse	0.3-0.4
tubers, roots (potato, cassava, beet)	**foliage, tops**		0.2-0.5
		peels	0.1-0.2
oil seeds	**hulls**		0.2-1.2
		press cake	0.1-0.2
sunflower, olive,	***foliage, stems***		0.2-0.5
cocos, palm oil,	***husks, fronts***	***shells***	0.3-0.4
soy, rape, peanut	***foliage***	***seed coat, shells***	0.3-0.5
vegetables	**leaves, stems etc.**		0.2-0.5
		peelings, skin	0.1-0.2
fruits and nuts	**seeds**	**fruit pulp, peelings**	0.2-0.4

Sources: UNDP, 2000; van Dam, 2006, Rosillo-Calle 2007

a Residue ratio refers to ratio of dry matter weight to crop produced

The emphasis in this discussion is therefore on agricultural sources of biomass. Some examples of primary and secondary residues from agricultural crops are given in Table 1. There is considerable variation in the quantities available; in some cases, residues amount to only about 10-20% of the crop by weight, while in other cases the residues might actually be greater than the original crop. As shown in the table, grain crops tend to have the highest overall residue ratio, amounting to as much as double the crop weight; tubers have lower ratios. For this reason, utilisation of straw from grains should be a much higher priority in biomass utilisation, and one of the papers in this volume addresses this largely untapped reservoir of biomass resources (Gressel and Advani, this report).

2.3 Enhanced Utilisation of Agricultural Crops and Residues

A fundamental issue for exploiting agricultural biomass in the future industrial bio-economy is the minimisation of waste. It is common today that only a minor portion of a given crop's total biomass is actually used productively, while much is wasted. Agricultural and plantation residues form a major portion of this un-utilised or under-utilised waste stream. Ultimately, the goal should be whole crop utilization, since the bio-economy will place increasingly higher value over time on acquiring new alternative raw materials. Examples of how to increase utilisation for some tropical and sub-tropical crops are briefly discussed below.

2.3.1 Palm oil residues

Enhancing the sustainability of the palm oil production chain can be achieved by more fully exploiting the abundantly available biomass wastes (shells, fibre, press cake, empty fruit bunches, mill effluent, palm fronts, etc.) as renewable resources in added value products. Currently only part of the waste is used, i.e. as fuel feedstock in palm oil plant operations. The efficiency is, however, still low and more efficient boilers are required. Surplus fibre and shell creates an accumulating problem at the oil production plants and burning practices should be eliminated.

In addition to the palm oil extracted from fruits, the residual oil in pressing cakes and free fatty acids could provide a rich source for bio-diesel production. Improved production efficiency (8-9% of oil is left in the cake) and quality control (fresh fruits processing) requires optimised use of rejects (over-ripe fruits with high free fatty acid (FFA), that can be used for conversion into bio-diesel (Elberson, 2005). Malaysia has legislated that biodiesel be exported to the EU and not used locally; however, oil palm biodiesel is best for blending in fuel for the tropics rather than in the EU, based on the EN590 diesel standards.

Biomass wastes from palm oil can be converted by digestion (enzymatic, concentrated or diluted acid hydyrolysis) as fermentation feedstock to produce ethanol, bio-gas (methane) and even H2 or other components (ABE, acetone, butane, ethanol) that can be used as 'green chemicals' and bioplastics (e.g. polylactic acid, polyhydroxyalkanoids, etc). Demands on fermentation feedstock composition, conversion efficiency and microbial cocktails, product extraction and residue handling are relevant aspects to assess the feasibility for palm oil fermentation.

The Roundtable on Sustainable Palm Oil (RSPO) has adopted the principles and criteria for sustainable palm oil production (RSPO, 2007), including the environmental responsibility and conservation of natural resources and biodiversity. This includes the fact that waste should be reduced, recycled, re-used and disposed of in an environmentally and socially responsible manner.

2.3.2 Coconut husk utilization

Biomass in the form of coconut husks is often wasted, due to the lack of market development efforts. Effective and efficient conversion systems for marketable products require an integrated approach.

The coconut husk is composed of coir fibre and pith, which for traditional fibre applications in woven carpets, ropes, brushes and matting have to be separated by retting and decortication processes. Novel markets for the resistant coir fibre have been developed for erosion control mats and horticultural products. The residual pith, however, contains a large amount of lignin, which has been demonstrated as a thermosetting binder resin for the coir fibres by using a simple technology of hot-pressing the whole milled husk. A building board product with superior properties can be produced (Van Dam et al, 2002).

In addition to financing and investment, implementation of the technology requires, the organisation of the husk collection locally and marketing of the end-product. In many tropical countries, coconut husks are abundantly available but not used economically. In other countries like India and Sri Lanka, the coir industry is well established and provides labour and income in rural communities. In the Philippines, the concept of a fully integrated coconut bio-refinery plant has been worked out, combining the processing and marketing of food and non-food coconut products at local centralized conversion plants.

2.3.3 Banana fibres

The banana plant is highly valued for its fruit, but it also yields vast quantities of bio-mass residues from the trunk and fruit bunch (raquis), which are discarded on the field or – in the case of raquis – at the site of fruit processing (packing for exports). From these residues, good quality of fibres can be extracted along with numerous other plant components (juice) with bioconversion potential. Demonstration of its utility as a renewable resource for industrial applications would increase the profitability for farmers as well as for new industrial agro-industrial economic activities, generating innovative outlets for sustainable development. In the current production chain, the waste management is not addressed to a large extent. Examples of banana paper use in India are indicative of its potential for making pulp without use of wood.

2.3.4 Rice straw and rice husk in building applications

Applying straw in building elements could be attained by the use of silica ashes derived from rice husk or straw, which can be used as renewable pozzolanic additive in cement paste (Green Building Press, 2007). Building with straw is commonly combined with lattice truss or timber-frame building and loam or lime plaster covers. So far, only limited commercial building systems have been developed using these materials on large-scales. Development of standard sized building blocks and prefab elements could help to (re)introduce the straw based building products. Despite the abundant availability and large-scale burning of rice husks, there is no widespread use of this renewable building material. In other countries promoting organic agriculture, this is used in mineral mix for composting.

2.3.5 Jute based composites

Jute fibre production for sacking has seen a dramatic decline due to strong competition with synthetic yarns and bulk transportation of commodities. New venues have been developed for processing of jute fibre in reinforced thermoplastic composite materials for use in automotive parts and consumer goods. With significantly improved mechanical properties, the jute based composites may add up to 50% weight and fossil resources savings (Wageningen UR 2007).

2.3.6 Sugar cane bagasse

The production of sugar from sugarcane yields vast amounts of biomass, especially in the form of molasses, vinasse, and bagasse. Added value-products from bagasse are of interest. Conversion of lignocelluloses residues such as bagasse into furfural is an old established technology that has been employed at many plants. The demand for furfural as a renewable substitute for synthetic resins is increasing and novel methods are promising, such as the use of gravity pressure vessels and dilute acid hydrolysis (patented technology). However, its production could be much improved by using up-to-date know-how of bio-chemical process engineering and pretreatments using biotechnological methods. There are in fact many other uses of bagasse for energy, pulp, paper, and other fibre-based products (Rao, 1998).

2.3.7 Sweet sorghum

Sweet sorghum for ethanol production systems is promising in dryer tropical and subtropical regions, as it has considerably lower water requirements compared to sugarcane, while high yield can be obtained. This would be the most promising non-food crop for African agriculture and many of the technologies and management practices developed in sugar cane production could be adapted for sweet sorghum. Another advantage is its lower up-front capital cost, as it is an annual crop that does require extensive land preparations. Socio-economic advantages can thereby also be found in that it is more suitable than sugarcane for small-scale growers and possible smaller economies of scale in conversion platforms (Woods, 2001).

2.3.8 Other feedstocks

Other commodity crops with potential non-food use or as resource for bioenergy production and renewable bio-based products include:

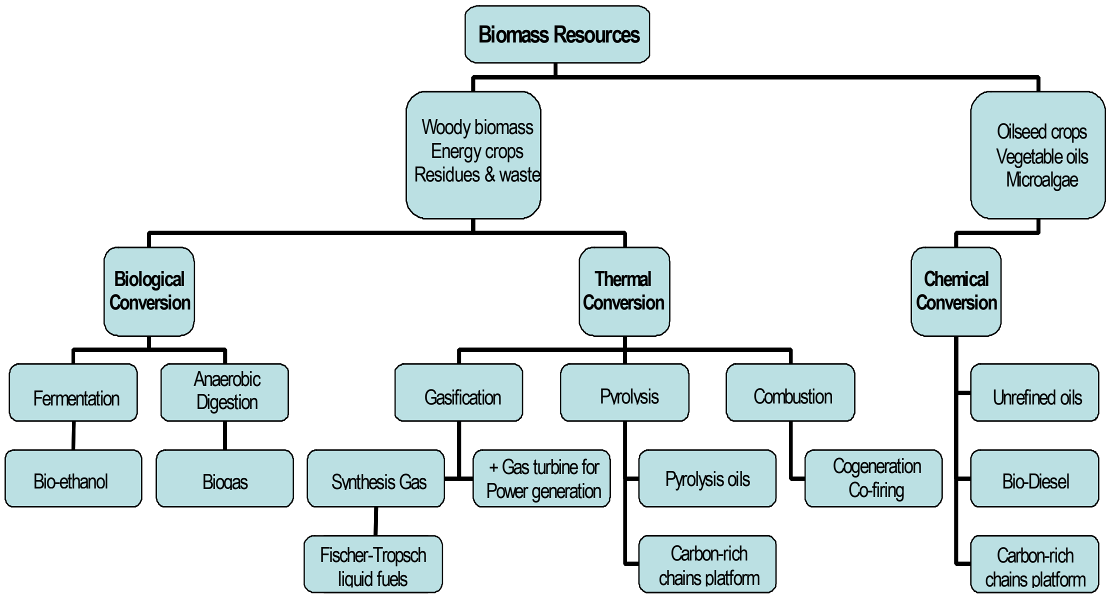
- Cassava for bio-plastics / ethanol production / extraction of protein;
- Jatropha for biodiesel;
- Sisal production residues valorisation, fermentation feedstock;
- Extraction of carotene from tomato peels;
- Thermoplastic starch based products produced from potato peels, cassava, etc;
- Cotton stalks for particle board production.

There are numerous other possibilities for residues from agricultural or plantation crops/trees being extended for other uses and products; for example, eucalyptus bark can be used as mulch, geo-textiles, or horticultural substrate. Eucalyptus wood chip production has been expanding considerably in the past few decades; consequently, huge amounts of bark, leaves and branches are accumulating at the site of production.

3 Biomass Conversion

There are many different routes for converting biomass to bio-energy and industrial products, involving various biological, chemical, and thermal processes; the major routes are depicted in Figure2. 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.

Figure 2: Conversion options for bioenergy and industrial biotechnology



There are some platforms that produce a wide range of both energy and industrial products, especially pyrolysis and the carbon-rich chains platforms. The carbon-rich chains platforms depicted in Figure 2 are being pursued in RD&D precisely because they offer the flexibility of making a wide range of industrial products at potentially large scales. Where more specific technical configurations are used, i.e. biorefineries or biomass platforms that are more customised and therefore more costly, the rationale will tend to be based on higher value-added products that justify the dedicated investments. It is important to note, however, that there are a wide variety of technical platforms at various scales, and these will need to be matched to the needs of particular regions and markets. The role of UNIDO and other actors in industrial development is to help in identifying and exploiting the most promising intersections between the technical options and market opportunities. Other than the sections below on pyrolysis and carbon-rich chains, the discussion below tends to emphasise energy conversion, since industrial product platforms are quite varied and it is difficult to generalise about them in this brief report.

3.1 Biological Conversion

Biological conversion is well-established, with the two main routes being fermentation and anaerobic digestion. Sugar and starch crops provide the main 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 components. The reaction is catalysed by enzymes or acids; acid hydrolysis offers the 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 providing surplus energy, resulting in significantly improved energy balances and resulting potential reductions in GHG emissions.

Fermentation is the oldest platform for biological conversion and continues to constitute the most fundamental and mature area of biotechnology. For thousand of years, fermentation was important for preserving and processing food and beverages. Only in the last several decades, however, has biotechnology been used to bring to market a wide variety of fermentation-based products, including antibiotics, amino acids, organic acids, and various agro-industrial feedstocks and chemical substitutes (Singh, 2003).

Anaerobic digestion uses micro-organisms to produce methane in a low oxygen environment. 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. Methane gas can be used directly for cooking or heating, as is common in China, or it can be used for electricity and/or heat production. For transport applications, the 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.

3.2 Combustion

Combustion is simply thermal processing, or burning of biomass, which in the simplest case is a furnace that burns biomass in a combustion chamber. Combustion technologies play a key role throughout the world, producing about 90% of the energy from biomass. Combustion technologies convert biomass fuels into several forms of useful energy e.g. hot water, steam and electricity. Commercial and industrial combustion plants can burn many types of biomass ranging from woody to MSW. The hot gases released as biomass fuel contains about 85% of the fuel’s potential energy.

A biomass-fired boiler is a more 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%. Combustion technology research and development is aimed at increased fuel flexibility, lower emissions, increased efficiency, flue gas cleaning, reduced particulate formation, introducing multi-component and multi-phase systems, reducing NOx/SOx formation, improving safety and simplifying operations.

Co-firing of biomass with fossil fuels, primarily coal or lignite, has considerable economic advantages, in that existing installations for coal can be used, reducing capital investment. Biomass can be blended with coal in differing proportions, ranging from 2% to 25% or more biomass. Extensive tests show that biomass energy could provide, on average, about 15% of the total energy input with only minor technical modifications.

3.3 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.

Gasification technology is not new; the process has been used for over 150 years, e.g. in the 1850s, much of London was illuminated by “town gas”, produced from the gasification of coal. Currently only gasification for heat production has reached commercial status. Gasification for electricity production is near commercialisation, with over 90 installations and over 60 manufactures around the world (Kaltschmitt et al, 1998; Walter et al, 2000).

3.4 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. The first commercial plants have recently come 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% weight 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. (Pyne, 2005).

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 than can potentially be obtained, particularly liquid fuels and solvents, and also the large number of chemicals (e.g. adhesives, organic chemicals, and flavouring) that offer companies good possibilities for increasing revenues.

3.5 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 also measures are needed to avoid solidification of the fuel in cold climates, since the various oils differ in their freezing points. Because the effect on engines varies with both engine type and the raw material used, there is still much debate on how much straight vegetable oil (SVO) can be blended with petroleum diesel without damaging the engine and/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. Equivalently, 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 trans-esterification, 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 liquid—is a valuable by-product of the process, and is an important raw material for various pharmaceutical, industrial, and household products (Johnson and Rosillo-Calle, 2007).

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.

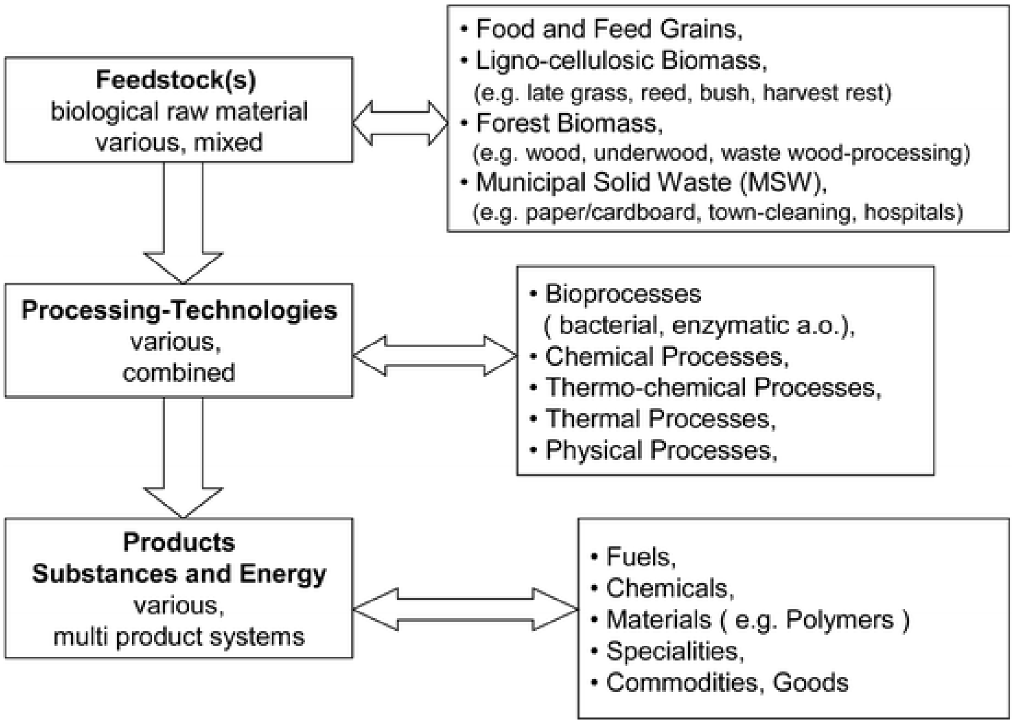
3.6 Carbon-rich chains

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 wide variety of industrial products that could potentially be produced, which are to some extent bio-degradable and/or the result of biological processes. Such platforms might be based on the carbon chains C2 and C3, which would in some respects lead to bio-refining processes that are analogous to the petroleum refining process (van Dam et al, 2005).

3.7 Bio-refineries

Raw materials used in the production of bio-based products are produced in agriculture, forestry and microbial systems. The content of the material undergoes treatment and processing in a refinery to convert it, similar to the petroleum. While petroleum is obtained by extraction, biomass already exists as a product (Kamm & Kamm, 2004) that can then be modified within the actual process, to optimally adapt the results so as to obtain particular target product(s). This is contained within the technology of the bio-refinery whose objective is to convert the raw material into intermediate and final useful products. The basic principles of the biorefinery are shown in Figure3. A biorefinery can utilise different feedstocks, can incorporate many different processes, and can result in many different end products. The exact configuration of a particular biorefinery will depend on market prices of inputs, demand for final products, access to the appropriate technologies, availability of financing, operational knowledge, and supporting policies and institutions.

Figure 3: Basic principles of a biorefinery (phase III biorefinery) (Kamm & Kamm, 2004)



The range of bio-based products is not only as replacement products for those produced in petroleum refineries, but also products not accessible to these refineries. The potential range of products is extremely broad once the essential biomass building blocks are available. Innovative technologies are required to convert the feedstock to useful substances, products and energy. Further research and development are necessary to increase understanding, improve agricultural, processing and efficiency of these systems and to create the policy and markets to support this technology.

4 Environmental Sustainability

The environmental impacts of biomass utilisation for energy and industrial products are quite significant, and are arguably greater in scale and scope than any other class of energy resources—renewable or non-renewable—due to the intensive use of land, water and other resources. Unlike fossil resources, however, the impacts can be positive or negative, depending on the effect on soils, local ecology, and nutrients. The long-term sustainability of biomass utilisation, industrial biotechnology, and bioenergy production can be assessed along several dimensions, including soils, nutrients, fossil fuels, and water use (Reijnders, 2006). Other categories of environmental impacts include biodiversity as discussed below.

4.1 Impact on Soils

Some physical qualities include soil density, permeability, porosity, temperature, thermal conductivity and heat capacity. These properties dictate how the biological micro organisms which feed on the plant organic matter survive. For example the penetration of heat, water and other essential organic residue depends on the density of the soil. Bio-energy crops with their extensive and heavy root system have an essential role to play here. In addition to increasing the soil carbon content they can improve soil density and porosity.

The constituents of soil—namely mineral, organic matter, water, air, etc.—play an important role in providing the right environment for plant growth. The organic matter of the soil has the most important role to play, as it is primarily responsible for making the soil loose and porous, thereby preventing packing of minerals and aids in aeration and penetration by water. Also the organic matter of the soil improves the water retention capability of the soil to a great extent. The presence of organic matter in the soil not only helps the growth of crops but also in the sustaining the lives of many biological micro organisms in the soil.

Sources of organic matter include leaves, twigs and other plant residues. A constant replenishment of organic matter is essential to maintain a healthy soil. Bio-energy crops can be an important source of organic matter. Husks and press cakes of many non-toxic energy crops can be used as a source of origin matter to maintain a constant cycle of replenishment.

Soil acidity/alkalinity, moisture content and other factors influence the chemical quality of the soil. The chemical qualities such as the acidity/alkalinity influence the activity of micro organisms and the availability of various essential soil nutrients. Energy crops play an important role in maintaining a good chemical quality by raising the carbon content (by raising the organic content), thereby buffering soil acidity/alkalinity.

Biological micro organisms are important to maintain a productive soil. Energy crops usually support a more diverse microbial population than typical agricultural row crops. Some studies suggest that energy crops change the agricultural land biota to the ones quite similar to forest environment. Increased soil carbon, more consistent soil moisture, lower soil temperature (due to proper cover) help in the restoration of the agricultural land biota.

Soil erosion may result in degradation of soil structure, loss of essential organic matter, nutrients, reduced water retention and nutrient retention capacity. Energy plantations can in some cases reduce the harmful effects of soil erosion, by serving as a protective cover for the soil top layer from phenomena such as blow-off. Energy crops with heavy root systems can absorb large quantities of water, thereby preventing soil erosion by water tillage and aid in keeping the top layer of the soil intact.

4.2 Nutrient Cycling

Decomposed plant matter is the main source of essentials nutrients. The harvesting time of energy crops, quantity (of energy crop rich in nutrients) removed during harvest influences the nutrient cycle of the soil, as nutrients are removed along with the crops during the harvest. This removal of nutrients with harvesting, leads to the taxing of essential nutrients in the soil.

With a constant demand of biomass for industrial uses, a regular or rapid rotation harvest involving extensive removal of energy crops will result in reduced soil quality and result in increased use of fertilizers (e.g. nitrogen fixing chemicals) that can be harmful to the soil and to micro-organisms. Extensive use of fertilizers may also have a negative impact on local water resources, i.e. run-off of chemicals into streams, resulting in eutrophification.

4.3 Fossil Fuels and GHG emissions

The sustainability of biomass and bioenergy use depends on the extent to which fossil fuels can be displaced. Both direct and indirect energy inputs, outputs should be considered. In terms of energy production, this would include:

- Production of seeds, fertilizers, pesticides
- Production and usage of machinery
- End-to-end transport of biomass
- Drying and storage of biomass for processing
- Conversion of biomass to a usable product
- Transportation and storage for final use

The avoided greenhouse gas emissions include the CO2 sequestered and the N2O emissions avoided during the cultivation of energy crops and production of biomass.

4.4 Toxicity

Some energy crop species are rich in toxic chemicals (such as allelochemicals in Jatropha). These toxic oilseed crops can enter the food chain in many ways. Research studies on the toxicity have highlighted the potential negative impacts on the ecosystem, including other plants that might grow in the vicinity.

Pesticides impact the environment at several levels (from production of fertilizers to cultivation of energy crops). Studies show that the environmental footprint is comparatively larger during the cultivation process. Thus, a detailed analysis is required to quantify this criterion. The environmental impact can be calculated by using determining the toxicity of the pesticides used and the amount used to protect crops from natural field diseases and weeds. The amount of pesticides used or present in the environment can differ with the type of crop, the application procedure and the type of pesticides used.

4.5 Water Quality

Energy crops depending on the type of crop (being cultivated), the land replaced, managed practise followed may have either a positive or negative impact on the water quality. Although energy crops do not require large quantities of fertilizers, herbicides, pesticides, etc, they demand a good management during their cultivation and irrigation.

Improper management could lead to increased sedimentation of streams, lakes and other water bodies. In some case, high demanding energy crops may require 300 to 1000 tonnes of water per ton of biomass grown. This may have a negative impact on the ground water table, by depleting it. With heavy and extensive root systems, they can draw large quantities of water from deep water tables. On the other hand, energy crops can also be an effective tool in water table management in poorly drained and flood-prone areas.

Depletion of ground water resources can lead to complete desiccation of the surrounding areas. Reduced ground water 'inputs' and reduced ground water 'outputs' are the main causes of ground water depletion which affects all living organisms directly or indirectly.

The extent of ground water depletion depends on many factors, more importantly on the type of crop in consideration. Majority of the energy crops require some form of irrigation therefore their influence on the depletion of ground water resources have to be evaluated. Their potential influence on the depleting/draining of agricultural land is currently not well understood.

One way to get around this situation is to understand the water use of crop during growth, as this period demands maximum input. With this information, the contribution/influence of energy crops on water resources can be understood. Water requirements of a plant species can be calculated by estimating the minimum amount of water per hectare yield (or water limited-yield), which is based on the potential yield of the crop species and the availability of water.

Water use of plants (evapotranspiration) is dependent on the plant species. Evergreen plants, such as coconut have high evaporation rates and thus high evapotranspiration, thereby increasing the potential of ground water depletion.

The local conditions like the climate, amount of rainfall, solar radiation, relative humidity, etc, also influence the ground water depletion potential to a great degree.

4.6 Impact on natural habitat

The impact on the natural habitat is of great concern at present. Increasing demand could force the destruction of natural habitats, breeding grounds, removal of winter cover, shelter beds for some species. Mechanization of agriculture saw the destruction of nests, burrows, etc. Similar impact but with greater intensity can be expected to result from energy crop plantations.

Extending energy crop farming into unusable, non-agricultural land can have a negative impact on that particular eco system. However, generally, energy crops are believed to have the potential to support a diverse eco-system and support genetic biodiversity. Although, energy crops cannot act as a substitute for natural habitat, they can act as a support for early-to-mid succession species.

Replacing agricultural land for energy crop plantations, as the former lack proper structure (because of following mono agricultural pattern) cannot be justified by any possible terms. The biodiversity that energy crops support can have a positive impact on one type of species where a completely harmful impact on another.

Planting non-indigenous crops for the sake for increasing production and profit may harm the local bio diversity even further. Often non-indigenous crops destroy the natural landscape and may lead to fragmentation of the ecological diversity. It is a common belief that energy crops plantations can serve as buffer zones/corridors that are capable of providing additional ecological services. Proper evaluation is required to further justify this claim.

5 Market Development: Key Issues and Case Studies

In this section, some basic issues for advancing the industrial bio-economy are discussed, by reference to the resource base, conversion options and alternative products and services. The emphasis is on tropical and sub-tropical biomass resources, although some of the processes and products are also relevant for temperate climates. The discussion below is not intended to be an exhaustive list of potential resources and products, but rather to provide a flavour for some of the options available. Nor is it possible to discuss the many possible conversion paths and the impacts of these conversion paths; again, the intent is to briefly summarise a few examples and case studies that are somewhat representative of the conversion paths and products that can be pursued.

5.1 Biomass processing and scale

The scale and operation of the supply chain of biomass production is influenced by geographic conditions, availability and economics of feedstock supply and volumes of value-added product. Energy balance and the environmental impact of the processes and products are essential considerations in selecting a sustainable option. The growth of bio-based industry in developing countries will require greater investments for both large volume products (e.g. biofuels) and high value-added products, such as bio-based specialty chemicals or consumer goods.

The growth in large volume product markets can potentially facilitate—at lower cost—the adaptation and/or creation of the appropriate physical infrastructure elements as well as stimulating enhancements in human capital—both specialised and general—to support the bio-economy. Markets for the higher-value added products in industry and consumer sectors can benefit from the improved infrastructure, and will providing more varied and sophisticated development alternatives in different parts of the world, depending on the natural and human capital available and the comparative advantages in different regions.

5.2 Development factors

Crop production in the past has focused mainly on reduced inputs provided per kg of economic product, however, in a bio-based economy, new paradigms are emerging. Net energy balance is one feature that has to taken into account for sustainable production systems. Furthermore, comparing the environmental impact of processes and products is necessary, as they are criteria for selecting the most sustainable option. In assessing the life cycle of bio-based products, the different effects on the environment and socio-economic prospects will have to be accounted for as well.

Successful development of regular feedstock supply to processing plants depends on many factors. Some key factors and examples for introduction of industrial biotechnology in the agricultural production system of developing countries are listed below.

5.2.1 Production Systems

- Improvement of existing primary production systems of biomass feedstock for energy and products
- Mechanisms of transfer of established know-how for expansion of bio-refinery production (North-South and South-South technology transfer)

5.2.2 Feedstock options

- Enhanced utilisation of forestry residues as feedstock for energy and products
- Identification of suitable energy crops high biomass yielding crops for hydrothermal conversion (elevated temperature and pressure used to chemically convert biomass into water-soluble fuels ex. miscanthus, bamboo, coppice)
- Selection of suitable crops for biodiesel production with options for blending of feedstock for better quality oil (more homogeneous composition of fatty acids)
- Study of germplasm of under-utilised oil seed crops, and adjustment of fatty acid profile to requirement of composition for biodiesel; development of selected crops for regional production

5.2.3 Agricultural practices

- Identification of existing agro-production chains and the unused residues liberated in the extraction process of the marketable product, e.g. straw, stem, bark, fibres, shells, peels, chaff, leaves, press-mud, vinasse, de-oiled cake, pulp, etc.
- Identification of differences in productivity and climatic conditions affecting choice of favoured crops in different geographical regions
- Effects of agricultural management systems, traditional crops (small farmers: coconut, cassava) vs. plantation crops (large estates: oil palm, rubber, sugarcane).

5.2.4 Sustainability

- Sustainability of energy / non-food crop production and competition for land with food and feed production systems
- Competition for feedstock with local use as cooking fuel, animal fodder, soil carbon and nutrients
- Effects of increased demand for biomass resources on deforestation rate, loss of biodiversity, desertification
- Need for improved and sustainable crop management systems, increase of land productivity in developing countries
- Evolution of traditional breeding vs. GMO: crops used today as feedstocks were originally never bred for the purposes for which they are being used. Plant breeding for biofuel and industry applications is still a new concept.

5.2.5 Resources

- Availability of water for crop irrigation and improvement of efficiency of water use
- High investment in equipment for mechanisation vs. involvement of cheap labour is determined by economic considerations

5.2.6 Organization

- Organisation of production and supply by a systems approach at local level. Involvement and education of farmers, and small holders
- Organisation of logistics, transports, storage and supplies, quality control and certification
- Mechanisms of value addition / market pull

5.3 Developing the Resource Base

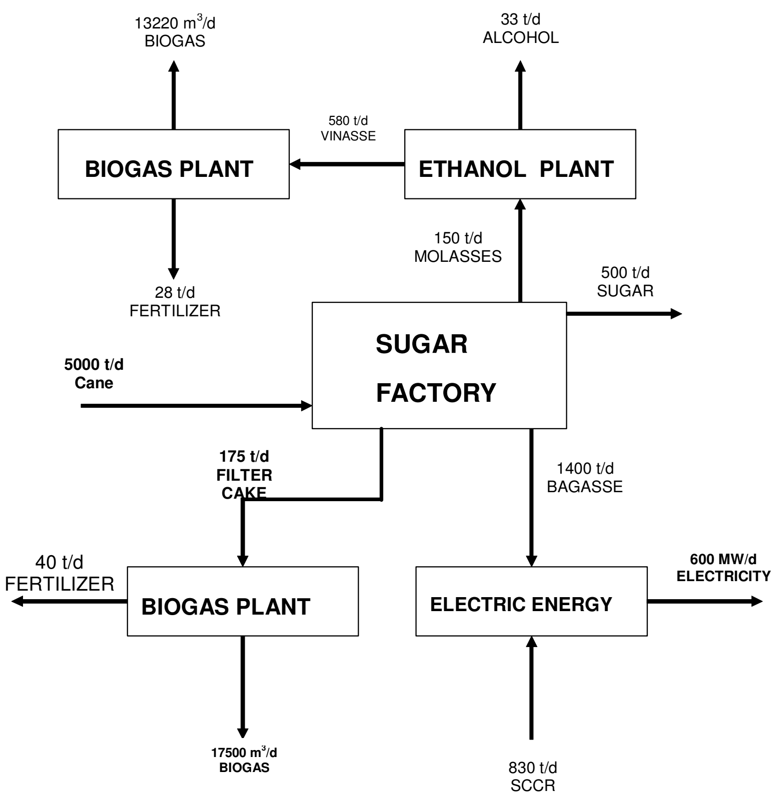
Developing the biomass resource base for industrial sector applications requires a reliable supply of feedstock and processing technologies that are adapted to these feedstocks. Both quantity and quality of feedstock have relevance, while the geographical and physical structure of the resource generally determines the spatial extent of market development. A few examples here serve to illustrate the alternative resource development paths. The first is the case of sugarcane, which has one of the widest potential product portfolios of any industrial crop, and has long been prominent from an energy-industry perspective due to the ready availability of fibrous bagasse at the factory site. The second is coconut, which offers a tremendous resource base that remains largely unexploited due partly to difficulties in gathering its residues. The third example

5.3.1 Products from sugarcane agro-industry

Sugarcane has been primarily used to produce sugar and molasses. It is crop that is grown in tropical and subtropical climates due to its higher agricultural yields. However, there are several co-products that can be obtained in various stages of the handling of the crop that contribute to the aggregate value to the production, which is of importance in developing countries facing increasing prices of non-renewable fuels and cyclical variation of sugar prices.

For cane sugar industries in operation around the world, there is a substantial processing of sugarcane. Appropriate handling of residual of the sugar and co-products production can limit the impact on the environment while obtaining a positive economic result. Figure 4 indicates the potential of co-products available from processing of 5000 tons of sugarcane per day.

Figure 4: Material balance of main streams of a sugar factory [5000 tons of cane per day]



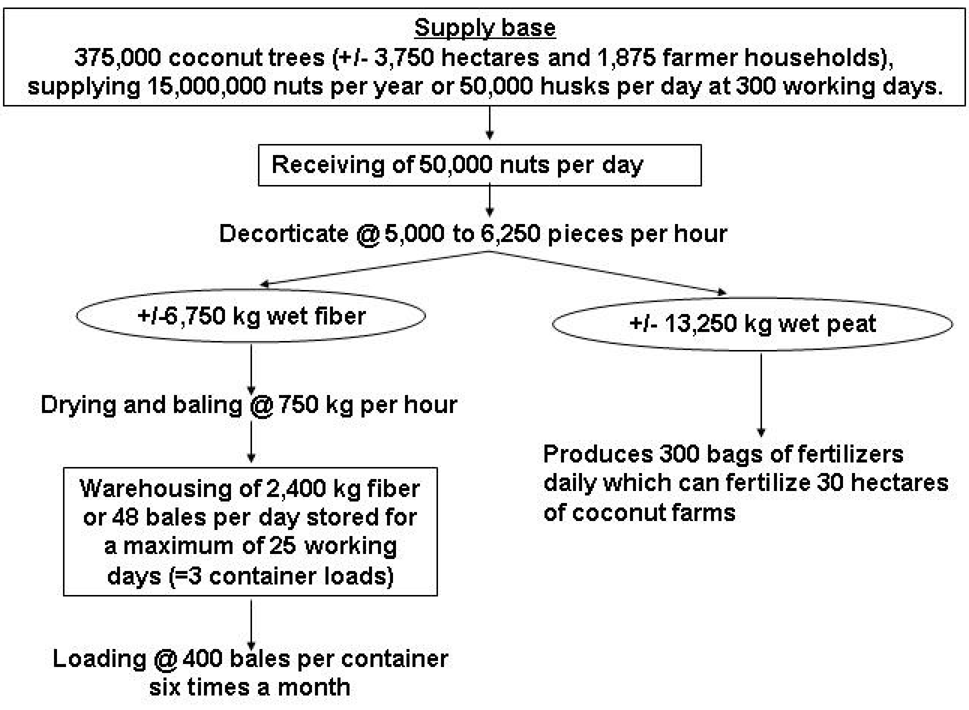
The co-products can be classified with regard to its use and source as those for: Direct or Industrial food production (human and animal), Fuels and biofuels from final streams, industrial productions and agricultural uses. The Ibero-American Program CYTED Science and Technology for Development has edited a catalogue with commercial co-products of networks participants, mentioning over 89 products from the agro-industry for the aforementioned uses. Clearly, there is a staggering potential to positively affect the sugarcane processing industry, from a development of the market and the economics of production.

5.3.2 The potential of coconut

Coconuts are produced in 92 countries worldwide, and in the Philippines, over 20 million people depend directly on coconuts, especially in rural areas. However, the coconut industry in this country has not changed in over 50 years. This and other country coconut industries have been plagued by low productivity, low quality products, inefficiency, underutilisation and uncertainty. Restructuring of the industry is necessary to transform it into an industrialised system with benefits of productivity, reduced costs increasing farmers' income, localised industrialisation and community development, amongst others.

The Coconut Industrialization Centre (CIC), set up in every 4,000-hectare coconut producing community can utilise the plants' multitude of products to generate power, supply construction and packaging material and other products. Six operating teams are proposed under one general manager: The Nut buying team (procurement, logistics of supply, price setting), The Copra Processing/Shell Production Team (handling of copra drying, charcoal production, supply of coconut husks and water), The Husk Decorticating team (husk processing), The Fiber Production Team, The Organic fertilizer Production Team, and finally The Special Services Team (operation of the commercial facility).

Figure 5: Material balance and process flow



It is estimated that over 1.5 million coconut farms will benefit directly from increased prices of their coconuts. Productivity will increase as will income from the coconuts and by-products. Additionally, there will be employment for the families of farmers and workers, directly by the centre and additionally in weaving and twinning coconut fibre projects. Reduction of waste by processing the entire coconut has positive environmental effects. Use of organic fertilizers in this project will reduce the harmful residues from chemical fertilizer runoffs and the products can also have a higher value.

There remain challenges to establishing a commercial demonstration of this plant; a number of these include funding, monitoring and documentation with the support of developed countries, promotion and generation of demand of fibre products and creation of related markets, government incentives to encourage private investors and stakeholders to participate in the program, generation of interest and actual contribution of international investors and technology providers, standardization of products and removal of tariffs and other barriers for coconut products.

5.3.3 The forgotten waste biomass

With a scenario for population growth exceeding the grain available, the question remains as to where the food needed to feed expanding humanity will come from. About half of the aboveground biomass of grain crops, such as grain straw, currently has a negative economic value, if not burned than usually decomposed with fungicide, with a limited amount fed to animals due to its low calorific value.

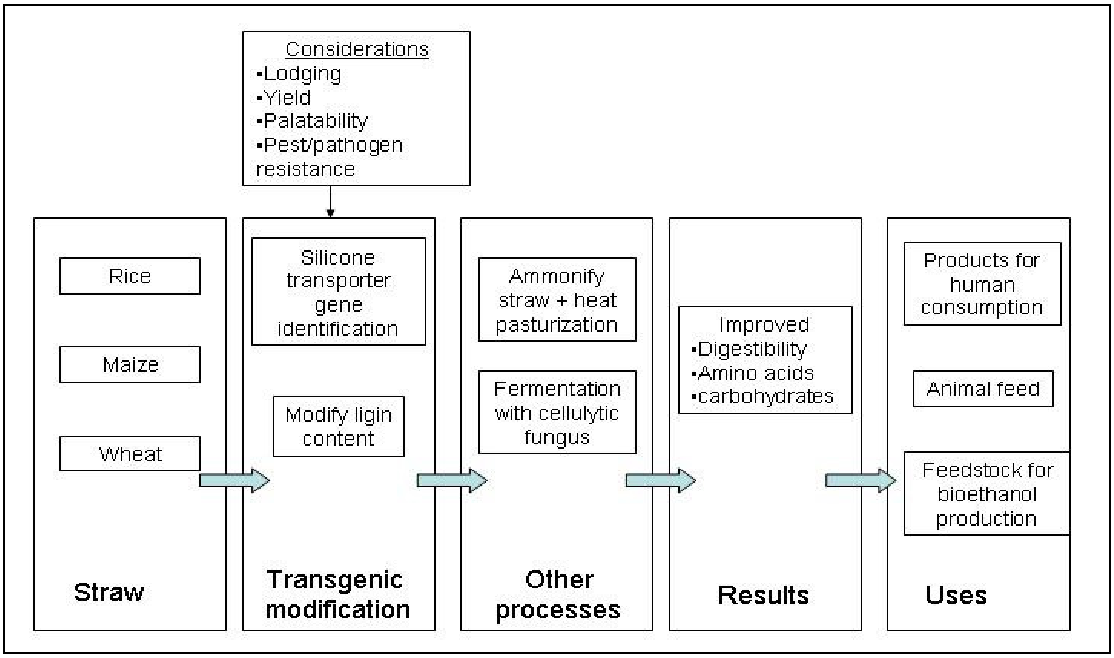
One solution to the environmental problem of this waste is to transgenically modify the straw so that it can be better digested by ruminant animals, decreasing the amounts of grain feeds that would otherwise be used, or alternatively modified to modulate the lignin content to be used for more efficient ethanol production.

Attempts at breeding to modify lignin have to consider the other grain quality characteristics, such as lodging (propensity of stems to buckle over in high winds), resistance to rootworm damage and corn-borers (digestable walls could make crops more appealing) and more importantly, crop yield (it is unlikely that farmers will cultivate a lower yield crop to gain more a digestable straw). Modification of the lignin content of straw would render more carbohydrate available to animals, but would still not have the equivalent protein content of hay. The question remains as to whether it is necessary for animals to digest proteins directly or if mineral nitrogen sources could be converted by bacteria into the amino acids required by the animals instead. For the latter, biotechnology can contribute so that ammonia mixed with lignin-modified straw (with heat pasteurization), can add to nutritional quality of the product.

Alternatively, transgenic modification of the amount of cellulose or modifying its structure to make it more available to ruminants could increase the food value of straw. Attempts at modifying two poplar plant genes, CEL1 and CBD, have resulted in species with increased growth rate, enhanced biomass accumulation, which would be advantageous for results for grain crops. There have been attempts to breed maize with a higher digestibility, but there are few publications dealing with wheat and rice straw, despite the latter being more widely grown.

Silicone inclusions in rice straw are an additional deterrent to digestibility. The benefits of Si are keeping the leaf blade erect and increasing pest resistance, among others; however it is not clear whether all the silicone is needed. The gene related to synthesis of these inclusions, once found, will enable researchers to ascertain the role of Si in rice (Figure 6.).

Figure 6: Processes in conversion of straw to useful products



A mixture of transgenic and other technologies could yield over two billion tons of inexpensive, high quality hay or sillage, replacing about a billion tons of feed. The on-the-farm use of waste will reduce water pollution caused by feedlot operations, and remove plant-disease carrying straw from the field. The present oversupply of grain and meat in the developed world has limited development of biotechnologies. However, issues of the future supply of grain, public fears relating to scientific and technical issues, and the benefits of grass-fed ruminant produced meat need to be addressed in parallel with investment in technology today so that the necessary research can commence, and with luck, be ready for anticipated food shortages.

5.4 Alternative product options for energy and industry

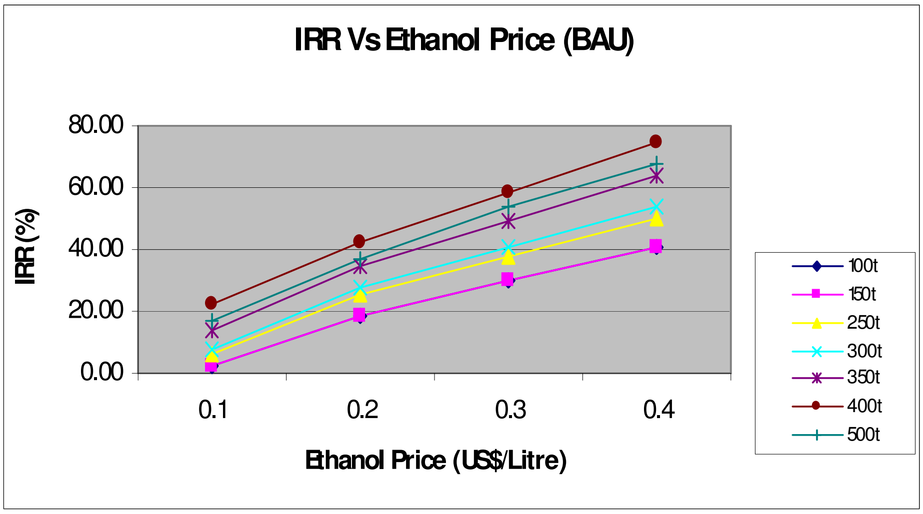
It is necessary to ensure that the scale of conversion is suitable for the economic competitiveness of a bio-refinery. The resulting products and by-products of the refinery contribute to intensive use of facilities and feedstock. Case studies based on Brazil offer insights and experiences in that country's ethanol success story.

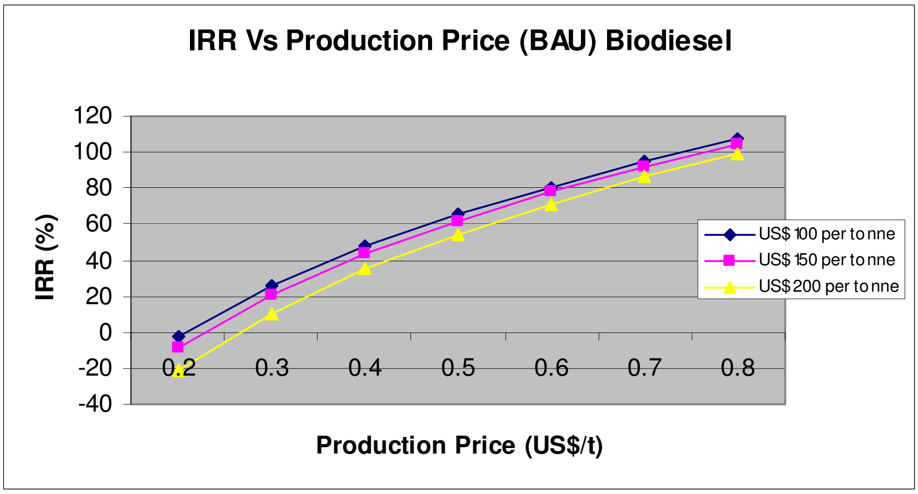
5.4.1 Prospects and challenges for the developing world

Global concerns over security of fuel supply have intensified interest in the biofuel sector, especially when coupled with the need to reduce poverty in Africa, and the motivation to cultivate energy crops to supply the growing market. Africa has a significant role to play in the market created in the EU for biofuels. Within the continent itself, the EU Preferential Trade Agreement Sugar Reform and the Africa Dakar Declaration (replacement of lead as an octane enhancer for gasoline fuels) will impact biofuels development. Awareness, favourable regulatory policy, and the requirements for social, environmental and development impacts are necessary to encourage sustainable biofuels development.

An economic analysis of the effects of these policies on three scenarios (sugar only, sugar + ethanol and sugar + ethanol + electricity sales) shows advantages of product diversification. Sugar-based feedstock provides the most economic conversion, given well known production methods for bioethanol, the main steps being fermentation and distillation. Hydrolysis is required for conversion of starch/cellulose based feedstock to simple sugars, involving additional complexity and cost. The commonly used biodiesel conversion is based on catalysed esterification of fat/oil. Large-scale plantations and processing in Southern Africa could make biodiesel economically competitive. Factory capacity, feedstock prices and yields are important factors affecting profitability [see Figure7], through economies-of-scale and operation costs (Yamba, this volume).

Figure 7: Financial Scenario for varying factory size (ethanol) and feedstock cost (biodiesel)





There has been recent interest in two promising crops; Sweet sorghum and Jatropha have characteristics that make them effective feedstock for ethanol and biodiesel production, respectively. The strategy to address biofuel development in Africa links aspects such as:

- Markets
- feedstock availability at reasonable costs
- production technology
- economics
- stakeholder involvement
- Regulatory fiscal and policy framework.

The markets for ethanol and biodiesel have common drivers. For the transport sector, biodiesel is more diverse than ethanol (commonly used for blending up to 10% in gasoline) and can have an economic impact due to high oil prices as well as the inevitable increase in the EU demand for biodiesel.

5.4.2 Sugarcane industrial products in Brazil

Ethanol and sugarcane have been the main products of the Brazilian sugarcane industry which has been developed to become a sustainable industry, limiting the use of consumables, and recycling of effluents. The contribution of by-products and generation of electricity for sale serves to further enhance the economics of the sugarcane industry.

Increases in industrial efficiencies and improvement in agriculture have facilitated the removal of subsidies to sugarcane ethanol production in Brazil. As a result, there has been an increase in interest in the non-energy component, including various biological products as substitutes for petrochemical-based products. Amongst the sources are; waxes, fusel oils, yeast, vinasse and filter cake.

The production of yeast and derivative processes have been explored and tested. These include: extraction of excess yeast, followed by autolysis and separation processes and another based on mechanical cell disruption and consequent isolation of the protein fraction. These were developed with the intention of creating human food ingredients and animal feed blends. At present, there is limited use of yeast products for food ingredients, which can be improved with successful market development and changes in consumer habits. As an important protein enhancer as well other probiotic and prebiotic properties of its products, yeast provides a good substitute to synthetic antibiotics that may be used in animal feed (Leimer, this volume).

Competitive Production of biodegradable plastic (PHB) can feed the growing demand for biodegradable, environmentally sound products. A pilot plant, a joint venture between industry and research institutes in one of the Copersucar mills, has provided some characteristic production data for PHB, showing it can be produced at low cost when necessary energy and raw-materials are available year round. Only a small amount of sugar has to be deviated form the sugar production.

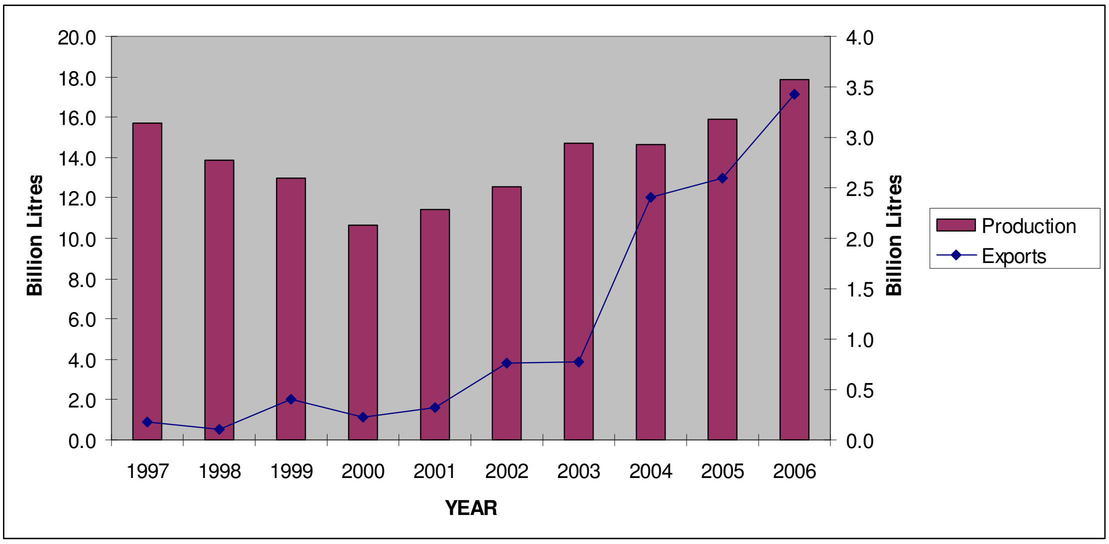
Intensive use of facilities, materials, excess energy potential and recycling of wastes present opportunities for increasing revenues of the sugar industry. Given the enormous available arable land, now occupied by low-grade pastures, the overall sugar production in Brazil should be unaffected by this prospect.

5.4.3 Global markets for bioethanol

Until the mid-1990s, fuel ethanol—as well as essentially all biofuels—had product markets that were local or national; the existence of the fuel ethanol market was generally the result of national mandates or policies for blending of ethanol, especially in Brazil and in the U.S.A. Since that time, a number of factors have come together that have led to a global market for bio-ethanol: the threat of climate change, high oil prices, concerns about energy security, and greater interest in supporting rural economies in developed and developing countries alike.

Brazil has led the creation of the global market, starting in 1975 with the Brazilian Alcohol Program (PROALCOOL). Through continuous productivity increases and costs reductions, Brazil has become the world's most efficient producer of both sugar and ethanol. In the last ten years, the rapid increase in global demand has resulted in tremendous growth in exports, amounting now to nearly 20% of production, as shown in Figure 8. A further expansion is also now occurring in domestic demand, due to the introduction of the flex-fuel vehicle (FFV) in 2003; using a sensor, its engine adjusts the operating conditions for any combination of gasoline and ethanol. The flex-fuel vehicle has also seen widespread use in the U.S.A., where it allows blends up to 85% ethanol.

Figure 8: Production and exports of bio-ethanol in Brazil



Source: F.O.Licht, 2007

In the past, biofuels policies have been largely driven by agricultural rather than by energy and environmental concerns. However, imports from countries that can produce at lower costs will foster the market and even induce technology improvements. Mandates and targets for biofuels, based on climate change concerns, are stimulating import demand, which has been concentrated in a few OECD regions, especially the EU and Japan.

In order for the global market to develop, other cost-effective producers will be needed. Corn-based ethanol in the U.S. is neither cost-effective nor environmentally beneficial compared to cane ethanol, due to the relatively poor energy balance of corn-based ethanol. As cellulosic ethanol conversion technologies mature, there will be much better opportunities for cost-effective production outside of Brazil. Thus, in the short-term, low cost ethanol can be produced only from sugarcane; in a mid to long-term scenario, ethanol from cellulose and possibly other sources could become cost-effective. Product certification of sustainable production will need to be defined in such a way as to ensure that it does not results in the imposition of additional trade barriers.

5.5 Governance and Policy

Policies and governance related to biotechnology establish a framework for developing countries to participate and succeed in a bio-based economy. Partnerships with the industrialized countries can stimulate progression in technology, while certification of resource management, such as forestry, and standardisation of products assure quality and encourage trade in the international market.

5.5.1 Governance

The application of biotechnology in agriculture, industrial process and production management has grown significantly in the past decades. Biotechnology cuts across all sectors of the economy; together with nanotechnology, information and material technology, biotechnology creates optimism that this century will advance new and alternative products and services. Governance has a key role to play in enabling developing countries to participate in the new bio-based economy.

Industrial biotechnology can involve replacement of conventional processes with biological systems or use biological systems to create new products and services from renewable resources. Trends in the industry encompass a wide range of applications and there are overlaps in the technologies, products and services. One such niche is fuel cell research that could drive the applications of fuels to generate electricity; on the other hand, enhancement of fermentation in biofuel generation is sought by using genetically engineered organisms.

Favourable government policies, environmental concerns, economic benefits and new industrial opportunities have created successful programs in various regions, such as the ethanol production in Zimbabwe, Brazil, Columbia, India, Thailand and so on. Similar support from the US government has seeks to stimulate biofuel investment. Motivation for firms to adopt biotechnology applications are driven by different forces (Table2). Science plays a major role in technology adoption, but it alone cannot stimulate the adoption of biotechnology by firms.

Table 2: Summary of main forces for adoption of a biotechnology process by three firms.

Company	Hoffmann La-Roche, Germany	DSM, Netherlands	Mitsubishi, Japan
Product	**Riboflavin (vitamin B2)**	**Cephalexin (antibiotic)**	**Acrylamide**
Economic	**Increased productivity; 50% reduction in cost**	**Efficiency and improved quality**	**Low investment in equipment**
Environmental	**Reduced emissions**	**Reduced waste and toxicity**	**Low energy consumption**
Process	**1-step instead of 6**	**4-steps instead of 10**	**Simple**
Length R&D	**7 years**	**5 years**	**9 years**
Determinant	**Science push**	**Competition**	**Economic factors**

Source: (Konde and Juma, this volume)

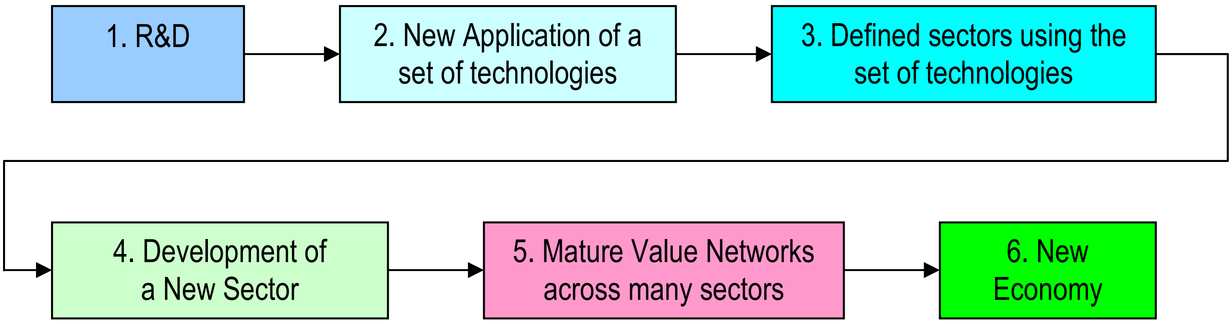
Policies on intellectual property rights and bio-safety regulations affect the development, dissemination and trade in biotechnology products and services. While developed countries face challenges in establishing adequate intellectual rights protection while still encouraging investment in R&D and technology transfer, developing countries, still in early stages of technology learning, face greater hurdles. Access to markets for agricultural products from developing countries face several barriers such as tariffs, high levels of subsidies in developed countries, quota allocations, among others. Efforts to reduce these barriers, forming of international alliance and partnerships¸ international agreements for technology acquisition may all encourage wide adoption of industrial biotechnology and could help developing countries diversity their product range, increase production and promote exports. There are several successful examples of such arrangements between Europe/North America and Africa/Asia/South America. Realization of this opportunity offers social, developmental and environmental benefits to developing countries. It requires the vision to provide consistent policies and incentives to enable research, development, uptake and adoption of these technologies.

5.5.2 Biotechnology in South Africa

"A bio-based economy is defined as an economy that uses renewable bio-resources, efficient bioprocesses and eco-industrial clusters to produce sustainable bio-products, jobs and income" [OECD, 2004].

South Africa's economic growth has been fuelled by mining and non-renewable resources. Recognition of the role of biotechnology and its wide use in numerous industrial sectors can progress the sector to an economic machine for the country [Figure9].

Figure 9: Progression of a technology to a sector and then an economy [1, 2]



[1] *This progression is not always linear*

[2] *[Verna Allee, 2000]*

Although a net exporter of food, South Africa still faces food security challenges with a reduced agricultural human productivity related to the death toll and HIV-related pandemic. The poor continue to face limited affordability of commercial energy and rely on wood fuel. There is a heavy reliance on coal, a fuel emitting high greenhouse gases, due to the country's abundance of coal reserves. Nonetheless, South Africa is committed to sustainable development, of which bioenergy and bioproducts presents an opportunity.

Historically, there has been research into the utilisation of lignocellulose as well as production of ethanol. However, there have been constraints to development of the sector, amongst which are a lack of cohesive research programs, investment in technology, entrepreneurial and technology transfer skills, clear policies to advance commercialization of related projects (Webster and Adani, this volume). At present, there are great opportunities for development of the biotechnology industry in South Africa enhanced by activities such as; recent interest of investment in ethanol production, maturation of R&D activities related to biotechnology and bio-applications. A new bio-based South African industry can have social-economic advantages, simultaneously mitigating energy related environmental impacts and diversification of non-renewable energy supplies.

5.5.3 Standards and certification

Certification of forest management practices while ensuring that forests are harvested sustainably, also provide decision support for choice of technology and improvement to the imperfections of the chosen emerging alternatives. Standards for biofuels are necessary to assure overall quality and simplify transactions as the international biofuel trade increases.

The practice of sustainable forestry can be examined from the criteria of economy, ecology and social values. The economy is positively affected; additional income is received from forest fuel utilisation, and there are reduced costs of planting and soil scarification from cleared areas. Ecological benefits are the global reduction of greenhouse gases by use of biofuels in lieu of fossil fuels. Residue removal enhances forest recreation, such as berry and mushroom picking. Care needs to be take to ensure there are no risks of over-utilisation of forest residues (limiting soil nutrient replenishment) and coarse deadwood (limiting species of insects, lichens and fungi).

Certification pertaining to harvesting of forest biomass for fuels, such as the ISO9000 and ISO14000, are suitable for technical and administrative specifications, and important to ensure that proper forest management occurs. However, these are unsuitable for the standardization of products from biomass. The European Committee for Standardisation (ECN) is in the process of developing technical standards for biofuels. Technical committee 335 (Solid Biofuels), lead by the Swedish Standardisation Organisation, are preparing technical specification for solid biofuels, including classification, specification and quality assurance, based on origin and source. Such specifications will benefit the producer and consumer, ensuring that specifications are agreed upon, controlled, thus simplifying transactions.

Forest energy use can positively affect the economy, society and the environment. Standardisation and certification of forest biomass contributes to public acceptance, simplification and rationalisation of international trade and enhancing GHG control. It assures the credibility of a bio-economy and supports sustainable development. In light of the increasing global trade, the standards created must reflect the global markets.

6 Trade, Financing, and Investment

6.1 International Trade

Among major regions in the developing world, it is clear that, in the long term, only a few are potential exporters of large volumes of bio-based products (e.g. biofuels and their co-products). Countries with high population densities and large internal markets (e.g. India, China) will have difficulty to develop export markets without impacting food production and/or requiring greater food imports. Brazil, southern Africa, and some other parts of sub-Saharan Africa and Asia could have significant opportunities for export. The export of bio-ethanol from Brazil is already fairly significant and similar markets are emerging for co-products of the sugar industry.

A major condition for the growth of bio-based industries is the reduction and eventual elimination of import tariffs and harmonisation of standards and certification processes that affect the terms-of-trade. Subsidies to agriculture in OECD countries often outweigh the natural competitive advantage of many developing countries. Harmonisation within developing country markets is also important, as many countries continue to protect certain industries and a number of regulations are based on the local value-added content of products so as to prevent re-export of goods purchased at lower international prices. Furthermore, some OECD countries still place tariffs on a number of renewable energy products and services, including biofuels and various renewable energy conversion devices (OECD 2005). The classification of certain industries as environmental goods and services under the WTO could facilitate some markets, although the implications will depend on other regional economic developments.

6.2 Industrial biotechnology and climate change

Climate change effects on the developing country populations and its relation to industrial biotechnology present an opportunity of setting a foundation for a transition to and industrial economy via mitigation options set about in the Kyoto protocol.

The relationship between industrial biotechnology and climate change cuts across three major spheres of climate change science and policy: impacts, mitigation, and adaptation. The impacts of a changing climate on agriculture and land use will affect the availability of biomass as well as food production. Developing country populations will suffer disproportionately, especially since some of the regions that may be most negatively affected are located in small island states and in already impoverished areas of sub-Saharan Africa.

With respect to mitigation, the expansion of industrial biotechnology can offer new opportunities for fossil fuel substitution and carbon sequestration. If genetic modification is employed, the linkages to both mitigation and adaptation would be even more direct. A given crop might be adjusted so as to yield better characteristics for energy production (e.g. more fibre, faster growth, less lignin). With respect to adaptation, varieties might be developed that require less water or are otherwise more suited to the new climate.

Biomass and industrial biotechnology can address GHG emissions while at the same time providing a more sustainable foundation for the developing world's transition from an agrarian to an industrial economy (Bird, 2006). Novel implementation platforms and identification of existing technologies that are under-utilised or inefficiently utilised will generally be preferred to developing new technologies, particularly in smaller and/or poorer developing countries. The following options could be considered:

- Improving the efficiency of biomass to energy conversion (e.g. advanced cogeneration, biomass gasification)
- Creating biomass resource options from agricultural or process wastes
- Use of agricultural or process wastes as inputs to industrial processes
- Substitution for products made from fossil sources (e.g. fertilisers, bio-plastics)

The above options tend to have medium-to-large economies-of-scale. Alternatively, in the context of poverty reduction in rural areas, there may be a preference for options aimed at expanding energy services (e.g. biogas for cooking) and/or creating income-generating opportunities (e.g. small-scale agro-industrial plants). At the same time, smaller-scale options with many end-users require more effort for replication and dissemination, and thus entail higher transaction costs.

Detailed analysis of impacts, adaptation, and enhanced sequestration are quite complicated and beyond the scope of this report. Mitigation options through the Kyoto mechanisms (Emissions Trading, Joint Implementation, and CDM) are of greatest near-term interest, not only because of the opportunities to obtain financial support, but also because expanded platforms for industrial biotechnology can address long-term sustainable development goals at the same time that they offer greenhouse gas (GHG) emission reductions. Since only Annex 1 parties have Kyoto obligations, Emissions Trading and JI are only indirectly related to developing country crediting via the linkages from GHG credits that are generated.

6.3 Carbon Finance and Biomass Resources

The Clean Development Mechanism (CDM) is currently the only formal avenue for developing countries to obtain support for climate mitigation efforts from Annex 1 parties. In principle, almost any GHG-reducing measure or project in a non-Annex 1 signatory country is eligible to qualify for credits under the CDM. In practice, of course, the application process itself requires time and resources, which can, in turn, impact the type and location of projects submitted and approved.

A great deal of detailed analysis is required in order to document the baseline GHG emissions and project boundary to determine the emissions reductions that will be "additional" to those that would have occurred in the absence of the CDM project. The major sources of GHGs in the developing world are:

- Stationary combustion of fossil fuels, mostly for electricity generation;
- Non-stationary combustion of fossil fuels (e.g. for transport);
- Deforestation;
- Agriculture and land use (e.g. methane emissions from animals, landfills, or decaying agricultural or forest residues);
- Industrial processes

Availability of technological solutions is one issue, particularly for developing countries, and investments in infrastructure, physical and human capital is another. Yet, the concept deserves further analysis and could address many factors that are relevant and have a positive impact on the economy and society in developing countries.

When Annex 1 countries are looking for host countries or when project developers in developing countries are seeking support, the host country's infrastructure, administrative apparatus and institutional capacity were all important factors. The larger developing countries thus have clear advantages, especially since the state-to-state nature of the UNFCCC process means that larger countries simply have more to offer. In terms of expected annual emission reductions at the end of the commitment period (2012), three countries account for over two-thirds of the total credits: Brazil, China, and India (Fennhann, 2006).

Transaction costs also make certain types of projects (and certain countries) less attractive for CDM, and consequently a separate category with streamlined procedures were established for small-scale projects, which are currently defined as (UNFCCC 2006):

- renewable energy projects up to 15 megawatts maximum capacity (or an appropriate equivalent);
- energy efficiency improvements that reduce energy consumption, up to the 15 gigawatt/hours per year; or
- other projects that reduce anthropogenic emissions and directly emit less than 15 kt CO2 equivalent annually.

The streamlined procedures appear to have been useful for some types of energy efficiency and renewable energy projects. In the case of biomass and bio-based products, they appear to be less useful because the definition is based on the fact that many projects deal with one major output, whereas biotech deals with many simultaneously.

Best-practice guidelines would facilitate technical convergence and reduce the transaction costs associated with matching technical options to different physical and socio-economic conditions. In some cases, it will be appropriate to identify key products that can offer a "market opener," for certain regions, based on their comparative advantage. In other cases, the design and scale of facilities might be sketched in general terms, but with the possibility to add some regional content. Bio-refinery platforms might be established from which local variations can optimise for varying conditions.

7 Conclusions

Developing countries have a vast agricultural resource base for alternatives for bioenergy and industrial biotechnology. Production of value-added by-products serves to expand a bio-based economy, offering substitutes for fossil-fuel based products, and facilitating a lower overall cost of production. A greater reliance on bio-based resources and biological processes is an inevitable part of an overall sustainability transition, and thus the main questions for technical innovation and policy development relate to how to positively impact the nature and pace of such changes.

In many developing countries, biomass is currently a significant source of energy and materials only for local and traditional uses; biomass is generally used inefficiently, with very few higher value-added product markets. Bio-based renewable resources can provide raw materials for many new and growing industries, while also stimulating rural development, job creation and GHG reduction. In assessing the options and strategies of a bio-based economy, economic, environmental and social issues need to be addressed to ensure that sustainable development objectives can be met.

Finally, it is worth noting that biotech is another case where more attention to the “development dividend” would provide much-needed support in the climate policy arena. As defined in the Kyoto Protocol, the CDM was supposed to deliver both economic efficiency for Annex 1 countries and sustainable development and technology transfer for non-Annex 1 countries. In practice, the CDM focused on GHG reductions, with few processes in place to promote sustainable development. The special status of biotech in supporting long-term sustainability (under appropriate biomass use conditions) should be recognised in future climate agreements.

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PART TWO

Scientific Papers

1

PAPER

Coproducts from the Sugarcane Agroindustry

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Ministry Science Technology and Environment

Summary

The Co-products obtainable from field, intermediate and final streams from the agro-industrial cane sugar production can have a positive effect on the aggregated value of this production specially for developing countries in order to face not only the increasing prices of the non renewable fuels but also to contribute to support the cyclical variation on the sugar prices. There are four main streams from this production: (i) the sugar itself; (ii) the sugar cane crop residues; (iii) the sugar cane industrial residues (including bagasse and the filter cake; and (iv) the final molasses.

It is possible to produce many different co-Products from this agro-industry for animal and human food, bio-fuels, industrial production and Agricultural uses, by use of physical, chemical and/or biological processes. It is shown that around 89 products can be used for the mentioned requirements; some of them can substitute actual products that are being made from petrochemical industries.

Several of the products obtained correspond to research projects of National Research Programs that are being managed by the Center for Management for Priority Programs and Projects (GEPROP) of the Ministry of Science Technology and Environment of Cuba.

The Thematic Net: Sugar Biomass for Food, Energy, Co-products with Environment Protection (IVH NET), that corresponds to the Area 3 - Industrial Development Promotion- of the Iberoamerican Science and Technology for Development Program (CYTED) has edited a CATALOGE with some of these products and technologies that could be used as a way for the promotion of its use.

I) Introduction

The sugar cane is a plant that is being harvested in tropical and subtropical climates, and has the advantage of higher agricultural yields in comparison with other crops. Its main components are the fibre, the sugar and the water have direct usage from its industrial processing. There is no other plant producing more soluble carbohydrates per unit of planted area than sugar cane, up to 15 tons per hectare-year. (1)

The sugar produced from the sugar cane represents about 65-70 % of the world production of this sweetener and food, and in 67 countries sugar production from the sugar cane takes place, in 39 it is obtained starting from the sugar beet and in 9 both plants are used for its production. In a general sense the beet sugar production takes place in temperate climates while the cane sugar is produced in tropical and subtropical climates. In the entire world, 2520 factories produce sugar, of which 1700 use the cane as raw material and 820 the sugar beet. (2)

The co-products obtainable from field, intermediate and final streams of the agro-industrial cane sugar production can have a positive effect on the aggregated value of this production specially for developing countries, in order to face not only the increasing prices of the non renewable fuels but can contribute to a lower greenhouse gas emissions, can contribute to support the cyclical variation of the sugar prices and can also contribute in substituting actual products that are being made from petrochemical industries. There are four main final streams from the agro-industrial production of sugar from the sugar cane: sugar itself, sugar cane crop residues, the sugar cane industrial residue (bagasse and filter cake) and the final molasses.

Physical, chemical and biological processes are being applied to produce different co-products that can be obtained from this biomass.

The main objective of the sugar Industry has been to produce sugar and molasses but it can also deliver fuel and thermal or electric energy after satisfying its own necessities. The sugar biomass—bagasse and crop residuals—represents two solid renewable fuels that are produced cyclically in short periods of time. In production of one million tons of sugar, about 2.5 million tons of bagasse and 2.3 million tonnes of cane residuals are obtained as by-products; considering its caloric value this represents a global quantity of 800,000 tons of a renewable fuel. (3) These residues with certain quantity of fibres can be used directly as fuel or for the production of different co-products. This biomass permits the generation of thermal and electric energy that can be used not only for fulfilling the requirements of this production but it is also possible to increase the efficiency in this area and obtain surplus of fuel and energy for other co-products production.

In the case of the cane sugar industry actually in operation in the world, around 951.5 million tons of sugar cane are processed every year with a production of more than 266 million tons of sugar cane bagasse and 313 million tons of sugar cane crop residues, also 33.3 million tons of final molasses are obtained that could allow the production of 7.6 million tons of ethanol. Also a similar quantity of filter cake or cachaza is produced. The ethanol production has a residual of around 114.6 million tons called vinasse. From the filter cake and vinasse, about 3.3 and 2.9 million cubic meters of biogas, respectively, could be produced.

As can be observed, with regards to the environmental protection, the residues and residuals of the raw sugar and the co-products production can be treated and used in such a way that there will not be a negative impact on the environment and can also offer economical results.

The Center for Management for Priority Programs and Projects (GEPROP) of the Ministry of Science Technology and Environment of Cuba has a number of research projects on the various co-products. The Thematic Network: Sugar Biomass for Food, Energy, Co-products with Environment Protection (IVH NET), within the Iberoamerican Science and Technology for Development Program (CYTED) has catalogued some of these products and technologies in order to promote the development and marketing of the sugar cane co-products.

II) Co-products from the sugar cane agro-industry

As mentioned, the main streams of sugar processing can be a starting point for co-products processing. They have different technological and economical attributes that make them more or less suitable as raw material for a wide variety of co-products using appropriate technologies.

The Sugar Cane Crop Residues can be used for Animal food, as Fuel for domestic and social uses, as fuel for industrial necessities and for the production of Compost, Furfural, Table boards, etc.

The main Sugars that are being produced in a crystalline form are the: Organic Sugar, the Raw Sugar, the Plantation White Sugar, the Glucose Sugar, the White Refined and Instant or Amorphous Sugar and in a liquid form: the Liquid Sucrose, the Inverted Liquid Sugar, the Glucose Syrup and the Fructose Syrup.

The Sugar Cane Bagasse is a biomass that can be used to produce: Pulp and Paper such as: News paper,, Pulp to dissolve, Filters paper -base cellulose- for soft drinks and other liquids, Paper supports for microorganism cultivations, Filters for drinkable water for domestic use, Dehumidifier panels, Absorbent pulp for sanitary products, Surface Impermeability, Spherical cellulose for chromatography and Chemical Pulp. Agglomerated Products such as: Particle and Fiber Boards of Low, Medium and High Density. Also chemical products as Furfural can be produced.

The principal co-products that can be obtained from the sugar cane Molasses are related to the production of ethanol, animal feed (saccharomyces or torula yeast), molasses with pith or bagasse and/or urea, protein rich molasses, predigested-pith from sugar cane crop residues or bagasse, among others.

There are several co-products that can be produced from the Filter cake, **including** compost, waxes, pharmaceutics, fertilizers, fuels, biogas.

It is possible to classify these co-products with regard to its uses and source:

A.- Co-products for Direct or Industrial Food production.

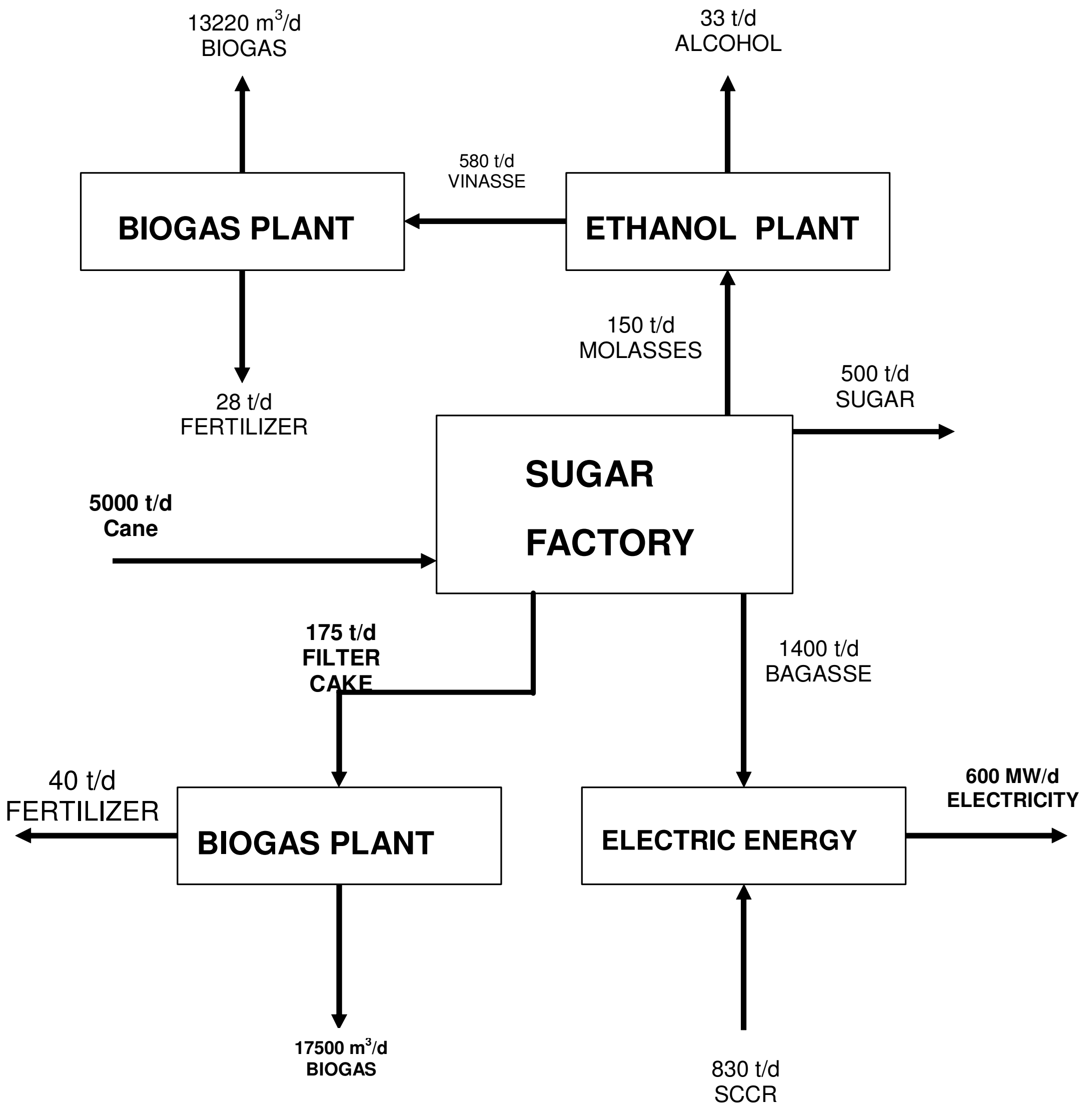
B.- Co-products production as Fuels and Bio-Fuels from final streams.

C.- Co-products from Industrial productions.

D.- Co-products for Agricultural uses.

Figure 1 shows a material balance for a sugar factory of 5000 tons of cane processing per day.

Figure 1: Material balance of main streams of a sugar factory processing 5000 tons of cane per day.



A.- Co-products for Direct or Industrial Food production

Co-products for Animal Food

The sugar cane biomass and the juices, syrup, and different type of molasses, due to the dissolved carbohydrates, organic matter, potassium and some phosphates present in them, become very suitable as carbon and energy sources for fermentation processes, and for animal feeding. In the production of cane sugar, there are many streams rich in sucrose and other sugars, which not only become direct food to energy suppliers with commercial animals - cattle, swine and poultry-, but also, in addition, supply other chemicals present in those streams, which may be no longer rich in separable sucrose and through adequate biological treatments, eventually, may go in metabolic nitrogen source products, such as the Saccharomyces and Torula yeast.

Bagasse, pith and harvest residues. The sugar cane crop residues, the bagasse or its pith are used for cattle feeding as is or as in a hydrolyzed form in which the digestibility is increased either by chemical or thermal processes, allowing the rupture of the lacing between the hemicellulose, cellulose and lignin. The digestibility increase of the food is quite suitable for ruminants feeding

Molasses. An excellent raw material for the fermentative industry is the sugar cane molasses because of its sugars content. The presence in it of many substances among them the so called probiotics, which promote or help in the growth and reproduction of microorganisms and potassium, whose presence in the substrate for the development of microorganisms is essential.

Yeast Also obtained within this biomass is the Saccharomyces and the Torula, yeast containing high digestible nitrogen and vitamins creating an important source of animal food. They are single celled microorganisms with high protein content and vitamins specially B complex.

Co-Products for Human Consumption

Sugars. in all its forms: in crystallized or liquid form, such as sucrose, glucose or fructose is a source of carbohydrates that can satisfy the human daily food requirements. These different types of sugars that are being industrially produced in crystalline or liquid form, can also be used for other industrial productions related to food, soft drinks, beverages and pharmaceutical products.(4)

Edible fungi. The edible fungi (oyster mushroom-pleurotus ostreatus) is a protein food obtained from lingo cellulose residues such as the SCCR and the bagasse that can be used as a substrate is a product that can be used for human consumption. Oyster fungi is inoculated in the biomass and 22 days after, the fungi is obtained with a component of 10 % of dry matter, nitrogen 24%, fiber 14%, phosphorus 9%. A yield of 12% was obtained, meaning that from 1 kg of substrate 120 grams of fungi was obtained. (5) The residue of the fungi production can be used for animal food or as a fertilizer. This Pleurotus fungi has a high nutritive value with more than 25% protein content, with all of the essential amino acids, vitamin b, etc.

Xanthan gum. Gums are considered as a polymer that can be dissolved in water to form viscous solutions, suspensions or gels. Xanthan gum is considered an important microbial polysaccharide. It can be used to control the fluid characteristics such as viscosity, and it can be considered to have a pseudo-plastic performance. It is highly stable with pH and maintains practically a constant relation of viscosity with temperature in a certain range of these parameters. The production of Xanthan gum by biological process has advantages over natural sources of gums, as its production does not depend on the conditions for their cultivation and harvest. It has a very wide range of industrial usage: in food, pharmaceutical, textile, drilling, paint production, cosmetics. Mainly it is used in drilling oil wells and as a stabilizing product in juices and beverages. It has been used as a commercial product since 1964. (6)

Ethyl ester of fatty acids. The ethyl ester of fatty acids is one of the more important co-product obtainable from sucrose that can be used in food, cosmetics, ceramics, textile with a wide range of applications because of its properties as humectants, surfactants and detergents, it is non toxic and biodegradable. (7)

Yeast for human consumption. The production of yeast for human consumption is obtained at a stage of the torula yeast production. It is related to the separation of the nucleic acids from the yeast cream. It has a high protein content: 40 to 45 %, a humidity of 8%, from 3 to 5 % of ashes, total carbohydrates of 30 to 35% and 3% of nucleic acids. From 1.15 tons of torula yeast cream one ton of yeast at 92 % dry matter can be produced. (8)

Polihidrilical alcohols. Sorbitol, manitol, xilitol are polihidrilical alcohols that have a wide range of applications such as: food, tooth paste, paper, textiles, chemical, tobacco and pharmaceutical industries. (9)

In Cuba there have been productions of different co-products from the sugar cane. In Table 1 is shown a number of these products and the quantity that has been produced.

Table 1: Co-products in Cuba from streams of cane sugar production

Products	**Units**	**PRODUCTION**	
		CROP 1988/1989	CROP 1989/1990
Brown raw sugar	($t*10^3$)	8121.0	8040.4
White refined sugar	($t*10^3$)	665.0	656.8
Molasses/urea/pith	($t*10^3$)	214.3	219.9
Predigested pith	($t*10^3$)	309.3	339.8
Molasses and urea	($t*10^3$)	512.1	463.6
Enriched protein molasses	($t*10^3$)	204.3	329.4
Bio ethanol	($Hl*10^3$)	1296.1	1373.8
Torula yeast	($t*10^3$)	64.4	79.0
Saccharomyces yeast dried	tons	2092.4	2061.7
Compost	($t*10^3$)	40.0	47.8
Table boards	(m^3*10^3)	85.0	80.1

B.- Co-products production as Fuels and Bio-Fuels from final streams

The sugar production also facilitates the possibility of obtaining fuels and renewable energy as co-products that can increase the value of this production. The Electric Power Generation using the sugar cane crop residues and the bagasse, the production of Alcohol starting from the final molasses or mixed juice, the Hydrogen production by chemical or biological procedures and the use of the filter cake and vinasse as a source for the production of Biogas and fertilizers are examples of the energetic potentialities that can be reached during the production of this sweetener and food, as well as the increment of its production value.

Electric Power Generation

The production of more than 950 billions of kilowatt-hr per year could be possible using the sugar cane biomass with actual technologies that permit an energy generation of more than 100 kw-hr per ton of cane ground.

Alcohol Production

Ethanol is a product quite employed in different industries such as cosmetics, pharmaceutical and food. Since years ago its use as a carburant, basically, due to high environmental pollution levels that are provoked by combustion gases from vehicles.

In relation to the alcohol production, 4.4 tons of final molasses are needed to produce one ton of ethanol. (10) Meanwhile if sugar juice is employed 18 tons are needed. For example in a sugar factory that processes 5 000 tons of sugar cane per day there is a final molasses production of 175 tons per day and 40 tons of ethanol is produced, and if sugar juice is employed 278 tons of ethanol can be obtained. In Table 2 is shown the quantity of alcohol production and its diesel equivalency.

Table 2: Data on Alcohol production

SOURCE	ALCOHOL PRODUCTION (tl/d)	DIESEL FUEL Equivalent (t/day)
Final Molasses	40	25
Cane Juice	278	180

The alcohol production indicates a 25 to 180 ton per day of diesel substitution on account of the source for its production. It is necessary to mention also that intermediate streams of the cane sugar production can be used -as filter juice and secondary juice from the extraction stage- for ethanol production. Also at present there have been studies carried out regarding the use of high fiber sugar cane in order to operate the sugar factory, producing electric energy the year round and producing ethanol from the extracted juices that has low sucrose content.

The production of ethanol from final molasses -as the source of carbohydrates - is a known and used technology, nevertheless the use of molasses prevents its use for other products such as animal food. The production of ethanol from cellulose is a prominent way to use the fiber residues from the cane sugar production: SCCR and bagasse. It is required to mention that there are many other sources of cellulose that could be used for this purpose such as different crop residues: wood, banana etc.

The cellulose, hemicellulose and the lignin are the main elements that are present in the sugar cane bagasse. The cellulose and hemicellulose are needed to be converted to sugars in order to be able to proceed in its fermentation and ethanol production. Obtaining ethanol from bagasse implies the need of an hydrolysis stage. Two ways are possible: an acid or an enzymatic process.

Ethanol can be used as a direct or mixed fuel in motors that use gasoline or diesel fuel, and different technologies have been developed. Hydrated ethanol is been used as only fuel and absolute ethanol in mixtures. Actually MTBE (methyl terbutil ether) or ETBE (ethyl terbutil ether) has been added to gasoline for octane increase and decrease of the emission of carbon monoxide. The addition of one of these product substitutes the lead that has been in use. The ETBE has been preferred as it has a lesser effect on the environment. Also from ethanol it is possible to produce acetal to be used as an additive to gas-oil.

Hydrogen Production

Hydrogen is considered a fuel for future especially because its combustion has water as its residue. There are different ways for its production; the reformulation of hydrocarbons and its separation from water molecule by electrolyzers is the industrial method more widely used. Actually the reformulation of methanol and ethanol, and the use of microbes are being studied.

The possibility to reformulate ethanol for hydrogen production is an alternative in countries with corn and sugar cane plantations, making possible its direct use or by means of fuel cells. A study made on generating electric energy in fuel cells using hydrogen that has been produced by the reformulation of ethanol, and also uses the solid residues for biogas production and this biogas supplies the fuel necessary for the processes of distillation and ethanol reformulation. (11)

Microbiological hydrogen production directly from solar energy by means of anaerobic, phototropic and cyanobacteria or blue green algae bacteria or mixed cultivation, also including the use of the hydrogenase and the nitrogenase enzymes, are prominent sources for its production. Research work is being done in this sense, with important aspects to be studied related to yield and economy. (12) (13)

It is necessary to mention also that producer gas—a mixture of H_2 and CO—provides valuable raw material for synthesising a wide variety of organic and inorganic elements.

Biogas Production

The anaerobic treatment is necessary in order to neutralize the negative effects of organic residuals on the environment if they are emitted directly to aquatic mediums. In addition to environmental remediation, it produces a gas that can be used for cooking or for electricity production. Its production can be made in small, medium or large digesters, depending on the type and amount of residual to be treated.

Table 3: Characteristics of the main residuals from sugar, ethanol and yeast production. (14)

Parameters	**Liquid Residuals**			**Solid residual**
	Sugar	Alcohol	Torula yeast	Cachaza
Temperature (ºC)	32 a 44	77	35	35 a 40
pH	5,5 a 6,5	3 a 4	5	5,0 a 7,6
DQO (mg/L)	5 000 a 7 000	60 000 a 75 000	10 000	65 000
Flow	0,5 m^3/t cane	1,6 m^3/hL alcohol	80 a 100 m^3/t	35 kg/t cane

Environmental results

The use of diesel for transportation with 0.856 % carbon content indicates an emission of 3.14 kg CO_2/ kg of diesel consumed. It is possible to calculate the contribution of each fuel in the avoided emission of this greenhouse gas. (15)

Table 4: Avoided Carbon Dioxide emission using these fuel alternatives.

FUEL SOURCE		DIESEL EQ (t/d)	Avoided CO_2 (t/d)	% B	% B+R
H_2 (m^3)	BAGASSE	20.8	65.3	33.4	--
	SCCR + BAGASSE	44.1	138.5	--	51.4
ALCOHOL (hl)	MOLASSES	25.0	78.5	40.1	29.3
BIOGAS (m^3)	FILTER CAKE	8.5	26.7	13.5	9.8
	VINASSE	8.1	25.4	13.0	9.5
TOTAL: BAGASSE		62.3	195.6	100.0	--
TOTAL: SCCR+BAGASSE		85.6	268.8	--	100.0

The data obtained indicates an avoided greenhouse emission of 195.6 to 268.8 ton of CO_2 per day or from 29340 to 40320 ton of CO_2 per crop.

C.- Co-products from industrial production

Enzymes, cold welding resin, construction and furniture materials, papers, plastics, detergents, pharmaceutical production can be some of the industrial production that can be made from the different primary products obtained from the sugar cane.

Enzymes are important co-products that promote chemical processes without being altered or destroyed during its application. They are obtained using sugars basically from molasses, and some of the enzymes to be produced are: Alfa-amilase, Dextranase, Cellulase, Xilanase and, Invertase. They are used as catalyst in many biological processes applied directly to the medium or by used in immobilized bed reactors.

Cold welding resin, made from the hydrolysis of bagasse into furfural, is used for repairing parts of equipment and machines – aluminium, brass, and/or iron, as well as plastic, wood, and glass junctures. Furfural's chemical properties indicate that it can be used for synthesis of organic compounds on account of its high reactivity, its thermal stability in absence of oxygen and low toxicity. Its main use is related to the production of furfurilic alcohol. From 12.4 tons of bagasse at 20% humidity, it is possible to obtain 1 ton of furfural (16) Some of these products are used for metal cold welding and junctions in order to restore and/or repair parts made from aluminium, brass, iron, wood, ceramics, glass, rubber, plastics as well as anticorrosive electric insulator.

Paper and/or Pulp from bagasse for: newsprint, copy paper, printing and writing, tissue and domestic, bags, multiple layers, stucco, carboximetil cellulose, pulp to dissolve and absorptive pulp, among others. Their production from bagasse requires some pre-treatment, including the moist depithing, and eventually the drying process, before the baling or packing, as a way of storing the bagasse for running the process the whole year.

Bales of dried and depithed bagasse have been widely used with different dimensions, weighing up to 750 kg, and due to the low water content, there is no fermentation and losses are a minimum.

Bulk storage is mainly used for paper, in store piles, which may hold 25 000 ton of bagasse and are elevated to 20 to 25 meters over the ground. In general, bagasse, when piled in bulk, arrives in wet piles in order to not be dragged in air, and avoiding fermentation through the use of biological liquors.(17)

In relation to paper production, paper has been produced commercially using bagasse as a main raw material for more than half a century, reaching total world production of about of 1.4, which is about 0.5 % of total paper production. (18)

Paper is the final, finished product for direct use in industrial, commercial, personal purposes, while pulp is a half way bench mark in paper making, between main raw material, that is, wood, bamboo, bagasse, etc. and paper. That intermediate material is the basic fibrous material for producing paper, and it is the product of a treatment done to the raw material, either mechanical, thermal or chemical, or a combination thereof, to condition the fiber, while eventually reducing the lignin and the hemicellulose. Pulps are converted to paper directly in the same factory where it is produced, and commercialized as such.

Materials for construction and furniture are being produced as table and fibre boards of different densities, using bagasse as the raw material. These agglomerated products, in order to be produced, need to use an agglutinating agent, which may be artificial resins added or derived during the proper process, and are mixed with particles or fibers to produce boards used as a substitute for wood as panel elements, known as particle boards and fiber boards.

Plastics for multiple uses employ ethanol by the Alco-Chemistry Route: using ethylene or acetaldehyde as the basic raw materials for the plastics productions. They can replace substances traditionally obtained by petrochemical routes, being feasible from technological standpoint and can stimulate the economic development of rural areas.

The Alco-chemistry route, if integrated energetically to the sugar industry, could produce oxygenated chemical additives, synthesis gas and ethylene or acetaldehyde as basic raw materials for plastics production. Some of them do not require the addition of complementary products and others demand substances of easy access, like water and oxygen. This is the case of the polyethylene production, ethylene oxide, ethylene glycol, acetic acid, acetic anhydride, polyvinyl acetate and polyvinyl alcohol. It is necessary to mention also that determined products can be obtained directly, starting from ethanol, for example, the butadiene. (19)

Pharmaceutical products include fitosterols from filter cake, mono-crystalline cellulose, isasorbide dinitrate. (20) (21)

Other industrial products include detergents, surfactants, humectants, anticorrosive, activated carbon. **Detergents, surfactants, humectants** are totally biodegradable products obtained from sucrose that can be used in different industrial and domestic applications using one of the product as a source of triglycerides in the cattle suet or coconut oil. They have advantages over the ones produced from non renewable sources such as: Simpler process, low energy consumption, raw materials used from renewable sources such as sucrose, vegetable oils and natural fats, no contaminants are sent to the environment, the obtained products are not toxic, nor irritants and are completely biodegradable in anaerobic or aerobic conditions. (22) (23)

Anticorrosive products can be made to protect different equipment parts in operation as well as spare parts during operation and/or storage. (24) (25)

Activated carbon can be produced from bagasse to be used as absorbent in decolorizing processes, chemical protection and sewage water treatment, among others. From 36.76 tons of bagasse at 50% humidity is possible to produce 1 ton of activated carbon. (26)

Filter medium from sugar cane bagasse for different industrial and laboratory filtration requirements. (27)

D.- Co-products for agricultural uses

There are different products that can be produced from this agroindustry for agricultural uses such as -plague attack, drought, nutritional deficit, fitotoxicity from agrochemicals, growth regulation, fungus inhibitors, substitute of chemical pesticides, biofertilizers, etc.-

At present there are some Biological pesticides, fertilizers and biological plague control that have been developed and can substitute partially for the inorganic products; among them are (28) Azotobacter, Azospirillum, Rhizobium and Microrizass.

Also the borer insect is a wide dispersed plague of the sugar cane that can be effectively controlled in a biological way using the *lixophaga diatraea fly*. (29)

It is necessary to mention also that recent development with regards to the sugar cane plantation is the in vitro production of seeds of the plants. (30)

Co-Products from sugar cane final streams processing

Some of the different products that could be obtained from this ago-industry using physical, chemical and/or biological processes have been described. In Table 5 is shown that around eighty nine products can be produced, and shows their use and the main process to be employed in its production.

Table 5: Co-products obtainable for different uses from the sugar biomass

No	**Use**	**Number of products**	**MAIN PROCESS**		
			Physical	Chemical	Biological
1	**Direct or Industrial Food production.**				
	Animal food	15	**X**		**X**
	Human food	17	**X**		**X**
2	**Energy.**				
	Fuel	5	**X**	**X**	**X**
3	**Industrial products.**				
	Enzymes	5			**X**
	Cold welding	7	**X**		
	Paper / pulp	15	**X**	**X**	
	Construction/Furniture	6	**X**		
	Pharmaceutical	3	**X**	**X**	
	Others	6	**X**	**X**	
4	**Agriculture uses.**				
	Agronomical Practices	10			**X**

Iberoamerican Program CYTED (Science and Technology for Development)

Since 1984 there has been an Iberoamerican Program named CYTED Science and Technology for Development in which all the Latin American countries and Spain and Portugal participate. This program is divided into six technical lines in which each line refers to the Promotion of Industrial Development and includes a Thematic Net named Sugar Biomass for Food, Energy, Co-products with Environment Protection (IVH NET). This net began in 2003 and has related more than 60 groups from research, producers and high degree institutions. At present there is an edited CATALOG that presents different products that are in a commercial state from groups that participate in the Thematic Net. It is necessary to mention that in near future more products will be incorporated to the CATALOG from the participants in the Thematic Net. In Table 6 are shown these products.

Table 6: Products in commercial state obtained by different groups of the CYTED Thematic Net: Sugar Biomass for Food, Energy, and Co-products with Environment Protection (IVH NET)

NO	PRODUCT	USES
DRINKS AND LIQUORS		
1	OLD GREAT RUM VIGÍA, VODKA KUBINSKAYA, RUM RESERVES REAL, LIQUOR DE VIGÍA	Drinks
COLD METALLIC WELDINGS		
2	FURAL A, AA, B	Rehabilitate industrial pieces, aviation and ships. Weld pipes of copper/brass
SPECIAL RECOVERIES		
3	FURAL BONO, FURSOL, PREMAD	Anticorrosive protection of metals, buried concretes, wood preserving, etc.
PRODUCTS		
4	MULTINUTRICIONAL BLOCKS	Animal food
5	EATABLE MUSHROOMS	Human food
6	BIOENRAIZ	Vegetable growth regulator
7	FITOMAS	Growth plants
8	INOCULANTE AZOSPIRILLUM	Plants nitrogen fixer
9	PROBICID	Prevention of gastrointestinal dysfunctions and other infectious illnesses
10	LIGMED	Use for digestive dysfunctions in animals.
11	PREDICAL	Food for bovine livestock
12	MICROCRISTALINE CELULOSE	Production of medicinal pills and medication
13	IFOPOL	Preserver of the quality of the cane during the crop and during the extraction of their juices.
14	CORROSION INHIBITORS: ANTICOR, PROTEKTOR.	Temporary recoveries, cutting liquids, new anticorrosive materials: plastics - rubbers - vitreous - stainless steels- steels of high chromium content
15	SORBITOL	Pharmaceutical formulations
16	TECHNOLOGY FOR OBTAINING OF SURFACTANTS DERIVED From SUCROSE: Mat of Sucrose,	Pharmaceutical industry, soap and detergents -liquid and powdered-, paintings elaboration, pesticides, surfaces recovery, elaboration of

	Potassium Soaps, sugar, textile.	bread and, ice creams, base for pharmaceutical creams.
17	Healthy fats from sucrose	Substitutes hipocaloric of eatable fats diminish levels of cholesterol. Formulation of butter, mayonnaises, cheeses, ice creams, to fry, elaboration of baked products
18	GLUCONATO DE CALCIO	Source of calcium to combat lack of calcium in the organism.
19	NATURAL SYRUPS: Melao syrups from raw and white sugar, liquors refine, golden syrup, crystalline glucose and syrup with 55-60% fructose.	Food industry.
20	PROCESS TO OBTAIN OXÁLIC ÁCID	Refinement of marbles and other materials, treatment and weather beating of skins, finish and whitening textile, treatment and cleaning of metals, recoveries, protectors and paints
FILTRATION MEDIUMS		
21	FILTEC 00, FF, SF, FG, AL, PB	Filtration of beers, rums, syrups, vinegar, lubricant oils, paintings and varnishes.

Conclusions

The Co-products obtainable from field, intermediate and final streams from the agro-industrial cane sugar production can have a positive effect on the aggregated value of this production specially for developing countries in order to face not only the increasing prices of the non renewable fuels but also to contribute to support the cyclical variation of the sugar prices. There are four main streams from this production: the sugar as itself, the sugar cane crop residues, the sugar cane industrial residue –the sugar cane bagasse- the filter cake and the final molasses.

It has been pointed out how it is possible to produce different Co-Products from this agro-industry for: Animal and Human Food, Bio-Fuels, Industrial productions and Agricultural uses, by use of physical, chemical and/or biological processes.

It is mentioned that around 89 products that can be used for the mentioned requirements, some of them can substitute actual products that are being made by petrochemical industries.

There have been research works that has, as a final result, a commercial product. Different research and high degree institutions, as well as, producers have developed several of these products, corresponding to research projects of National Research Programs that are being managed by the Center for Management for Priority Programs and Projects (GEPROP) of the Ministry of Science Technology and Environment of Cuba.

It is necessary to point out also that the Thematic Net: Sugar Biomass for Food, Energy, Co-products with Environment Protection (IVH NET), that corresponds to the Area 3 - Industrial Development Promotion- of the Iberoamerican Science and Technology for Development Program (CYTED) has edited a CATALOGE with some of these products and technologies that could be used as a way for the promotion of its use.

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Opportunities for Bio-based Products in the Brazilian Sugarcane Industry

by

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Abstract

For many years, attention has been paid only to production of sugar and ethanol, the two main products in the Brazilian sugarcane industry. Only recently, the important contribution for generating electricity for sale to power distribution utilities makes it clear that there are other products that can increase the income of the industry. Two other products that have attracted commercial interest in the Brazilian sugar industry are yeast and its derivatives (a co-product from alcoholic fermentation) and waxes (a co-product extracted from filter-cake). Many other co-products still could be recovered and eventually transformed into some added-value products depending on technical and economical feasibility and the market.

The low production costs for sugar in Brazil and the supply of bagasse energy make sucrose very attractive to several other products. In Brazil, there is commercial production of amino acids, organic acids, sorbitol and yeast products as well as developments for bioplastic.

The production of compounds obtained from ethanol returns to become again a reasonable alternative for substituting products from the oil-derived industries.

After a brief overview about the most common co-products, two products are highlighted in order to underline how attractive these applications are already.

1 Introduction

Sugar cane growing in Brazil covers an area of more than five million hectares, which corresponds to 0,6% of the whole extent of the country. By exploiting a crop area of 60 Mha, sugar cane comes only third after soybean and corn in area planted.

The sugar cane industry in Brazil can be considered as highly sustainable mainly because of its limited use of consumables (pesticides, fertilizers and fuels) in the agricultural sector and of the use of bagasse as a renewable energy source as well as the total recycle of effluents such as vinasse and filter cake in the industrial sector.

Over the past fifteen years, environmental concerns have led to the use of biological products as substitutes for petrochemicals that cannot be considered as environmentally sound and desirable as the former. Several mechanisms have been used to foster new technologies in the energy sector. Practically all of them originally sought feasibility through direct subsidies. That happened for instance with the National Alcohol Program (Proálcool) in Brazil, the corn ethanol program in the United States and the biodiesel programs in various countries in the world.

For more than 20 years, many improvements in agricultural techniques and the breeding of better cane varieties, besides the increase in efficiencies in the industrial sector, made it possible to remove the initial subsidies to sugarcane ethanol. That program brought along a very interesting non-energy component in the field of products of biological origin, replacing petrochemicals as it happened in the 80´s in Brazil in the alcohol industry.

With the steady raising oil prices and the stabilization of sugar and alcohol prices on the world market, many new products can be produced from sugar cane. Another cost advantage is due to the fact that the mills are self-sufficient in thermal, mechanical and electrical energy by burning bagasse. Depending on the pressure of the steam generated in the boiler, more or less energy is available for other processes linked to the mill.

That is why sugarcane sucrose is a good choice in becoming an economic raw material in many processes. However, many other products can be obtained from sugar cane processing.

A brief review will be made to enumerate the most striking and successful products with emphasis on two products which can be produced very competitively and have ensured a safe place on the market.

The first product is yeast and its derivates as a co-product from the ethanol fermentation. The other product is a PHB (polyhydroxybutyric acid) and related copolymers, which can be advantageously produced when integrated into a sugarcane mill.

2 Products in Sugarcane Processing

2.1 Bagasse

By carrying out process improvements over the past years, increasing amounts of bagasse can be now used for alternative uses. Commercially available technologies may lead to consumption decreases in the mill processes, resulting in excess bagasse of up to 45% (Macedo de Carvalho, I. 2005). Nowadays, there is a clear preference for production of excess electrical power by using high pressure boilers integrated with the mill operation. For instance, in operating these boilers with a 40-percent trash recovery in the fields and with an 80% implementation of the systems, around 30TWh of excess electricity could be produced at the present sugar cane production level, which stands for 9% of the current electrical power consumption in Brazil.

For the future, biomass gasification integrated with gas turbine combined cycles (BIG/GT) will increase even further the potential of generating electrical power.

Hydrolysis of bagasse is another promising alternative for transforming bagasse into more convenient fuels. The acid route for production of ethanol is being developed in Brazil by the DEDINI Company with governmental support. The integration of this new process with the sugar mill would allow an increase of up to 30 litres of alcohol for each ton of sugarcane, depending on the excess of bagasse and the success in fermenting pentoses.

Other uses of bagasse of some importance in Brazil

- alternative fuel for near-by industries (citrus-processing industries)
- pre-hydrolysed bagasse for animal feed (enhanced with nitrogenous material)
- furfural (factory was closed in the 80´s)
- charcoal (steel-works)
- boards

2.2 Waxes

Waxes from the stalks are concentrated in the filter cake where recovery by solvent extraction is economically feasible and amounts to 0,1% of the harvested sugarcane or up to 10% of the dry filter cake. Purification procedures can render some high valued products such as phytosteroids and policosanol.

2.3 Carbon dioxide

Carbon dioxide is the main co-product in alcoholic fermentation. Economical use was hindered by seasonality of ethanol-production. Storage of big quantities of this product turned out to be uneconomic. The extension of production period until 12 months may turn CO2-recovery into something economically feasible.

2.4 Fusel Oils

Alcoholic fermentation generates the so-called higher alcohols, which have to be separated during distillation in order to avoid ethanol losses in the distillation process. Approximately 0.2 litres per 100 litres of ethanol with a 70% fraction of fusel oils can be obtained, which are transformed into valuable products for chemical industry after further purification.

2.5 Yeast

In the Brazilian sugarcane industry, all distilleries operate on fermentation processes with cell-recycle. About 4% of yeast (on a dry basis in relation to ethanol production) is co-produced on average. By controlling losses at the centrifuges, up to 70% of the generated yeast can be withdrawn from the process for further processing. More details about this by-product will be given in chapter 3.

2.6 Vinasse and filter cake

Vinasse is the residue from the distillation whereas filter cake is the residue from the cane-juice treatment. Both are recycled to the fields for its nutritional value, mainly for potassium in the case of vinasse and for phosphorus in the second case. A large number of studies with respect to leaching and possibilities of underground water contamination with vinasse indicate that there are generally no damaging impacts for applications of less than 300m^3/ha. Both materials can be considered raw-material for further processing like the production of biogas in the case of vinasse and the extraction of wax for filter cake.

2.7 Sucrose as a raw material for other products

In the early 90´s, around 60 products worldwide, obtained from direct sugar fermentation, could already be listed (Macedo, 2005). Only a small number of these products are commercially important. However, intensive research expects to enlarge the list of new products. Such growing diversification of sucrose applications to produce intermediate and end products (besides sugar and ethanol) is mainly motivated by the low sugar production costs that Brazil has attained (US$130,00 per ton of crystal sugar). The production of sugar cane sucrose derivatives can also supplied with energy independency through the bagasse.

Sucrose can substitute for glucose in almost all fermentations. The main categories are: sweeteners (Clarke, 1989), polyols, solvents, biodegradable plastics (Chapter 4: case study 2), amino acids, vitamins, polysaccharides, organic acids, enzymes, yeasts (Chapter 3: case study 1) and esters (Danner and Braun, 1999). Some products use large amounts of sugar (commodity products such as plastics and solvents) while others products lead to fine chemicals (cosmetics, functional foods) and specialty chemicals (medical uses, diagnostics, bulk additives) (Godshall, M.A. 2001).

In Brazil, there is commercial production of citric acid, lactic acid, amino acids like lysine and MSG (mono-sodium-glutamate), yeast derivatives, manitol, sorbitol and poly-hydrobutyrate; the latter one in a pre-commercial stage.

2.8 Ethanol derived products

During the early stage of the Proalcool (National Alcohol Program), Brazil had already developed an industry, which rendered products from fermentation ethanol (Alves Macedo, 2005). Routes based on ethylene, acetaldehyde and, in several cases, direct transformations, have been developed and implemented. They are all widely known processes without any major complexities. The relative prices of naphtha and ethanol and the national oil-based chemical industry development policy made alcohol chemistry unfeasible.

In the ethylene route, important products include polyethylene, polyvinyl and ethyl chlorides, ethylene glycol and acetaldehyde.

In the acetaldehyde route, important products include acetic acid and chloroacetic acid, ethyl, vinyl, polyvinyl and cellulose acetates, acetic anhydride and butadiene.

Direct transformations lead to butadiene, acetone, n-butanol, ethyl ether, vinyl ethyl acetate, acrylate chloride and ether.

In the middle of the 80's, the national alcohol chemistry reached its peak by processing 500.000m^3 per year. In 1993, there were around 30 ethanol derivatives in production in Brazil. Of these, 14 had installed capacities in excess of 100.000 tons per year.

The ability to work on much smaller scales than those of oil based factories, the decentralized production and the ability to get synergies with the mill's traditional production will enable a revival of an alcohol based industry.

3. Case Study 1 – Production of Yeast and its Derivatives

3.1 Process

Alcohol is being produced by feed-batch or continuous fermentation, both operating with cell-recycle. Depending on process conditions (final alcohol content, fermentation temperature) and raw-material, 15 to 60 g of yeast (dry matter) per liter of alcohol are produced. Normally, 10 to 25 g/L can be separated from the process as a co-product ready for sale.

The typical process stages consist of bleeding, starvation, thermolysis, centrifuging and drying. In order to obtain purer, less contaminated and less deteriorated products, thermolysis is being replaced by counter flow washing with clean and cold water.

3.2 Composition and specification of distiller´s yeast

A typical composition and specification of Dried Distiller´s Yeast are shown in Tables 1 and 2, respectively (Ghiraldini, 2003).

Table 1: Distiller´s yeast composition

Moisture (%w/w)	5 - 10
Crude Protein (%w/w)	35 - 43
Lipids (%w/w)	0.9 – 1.0
Fibre (%w/w)	0.3 – 0.8
Ash (%w/w)	4 – 5
Non-Nitrogen Extract (Carbohydrates) (%w/w)	44 - 55

Table 2: Distiller´s yeast specification

Appearance	powder
Moisture max. (%w/w)	8
Crude Protein min. (%w/w)	35, 40, 43
pH	> 5
Taste	Characteristic (non acid)
Odour	Characteristic

3.3 Production

As stated previously, there has been a solid increase in the production of dry distiller´s yeast during the past 10 years (Leimer,K.H.;Finguerut,J. 2003). While in the 95/96 crop, only 15.000 tons have been produced, this year will end up with an overall production of nearly 60.000 tons. Considering a production of more than 16 million m^3 of alcohol per year, the potential of more than 300.000 tons of yeast is far from exploited.

Export was pushing the production rate at the beginning of the expansion. Although this trend is to be continued, the internal market is growing at a faster pace lately.

3.4 Quality factors

The following factors exert an important influence on yeast quality:

- Protein content: values in the range of 38 to 40% or higher facilitate its commercialisation, especially for the blend to animal feed.
- Moisture: a range of 6 to 8% is highly recommended in order to guarantee product stability.
- Colour and flavour: Constant colour over the whole season is important, preferably light beige. Moreover, sour flavour due to bacterial contamination in the fermentation stage is to be avoided. Preference is given to the typical yeast flavour. In general, several process sections, starting from sugarcane harvesting, through to milling, juice-treatment and fermentation and ending with the process for yeast removal itself, determine the quality of the yeast product.

3.5 Uses of Dried Yeast

- Growth promoter; source of metabolites and unknown growth factors (UGF).
- Immune stimulant action.
- Improves feed palatability.
- Source of B vitamins.
- Improves the feed conversion in stress situation (ICC site, 2004; Halasz and Lasztity, 1991).

3.6 Suggested Inclusion Rates (Machado, 1983)

Table 3: Suggested inclusion rates

Type of animal	
Poultry	1 - 2.5%
Swine	2.5 - 5%
Ruminants	100 -250 g/animal/day
Equines	20 g/animal/day
Aquaculture	2.5 - 5%
Pets	2.5 - 5%

3.7 Economical profile

The total investment costs of a drying facility for a production of 15tons a day, including packing and storage, can be estimated at U$1.2 million. As a co-product, no costs for generation of yeast should be taken into account. Calculations are based on sales prices of U$260 to 300 per ton of dried product and a production period of 170days a year. The pay-back period can be considered to be something between 2 and 3 years.

3.8 Fractionation technology (Autolysis – Cell-disruption)

In order to make use of the special properties of yeast and succeed in increasing its market value, efforts have been made to explore, test and adapt some well-known techniques for the cane industry.

Two distinct routes for processing surplus yeast have been investigated more carefully. After laboratory trials, final tests were carried out in a small pilot plant (Sgarbieri et al., 2001).

In the first process, excess-yeast from the distillery was resuspended in water and mixed with auto-lyzing and plasmolyzing agents, which consist of fresh yeast autolysate as an accelerator, sodium chloride and ethanol, in a volume-ratio of 6 to 1 in the following proportions: fresh yeast autolysate as an accelerator, sodium chloride and ethanol. No exogenous hydrolytic enzymes were used.

After having adjusted the pH to 5.5, autolysis was carried out at a constant temperature under vigorous stirring over a period of about 24 hours. These specific conditions permit the release of high amounts of cytoplasmic material.

Afterwards, the autolysate was separated by centrifugation into supernatant and sediment fractions. The diluted supernatant fraction was concentrated by vacuum evaporation before being dried in a spray-dryer. Autolysate and the cell wall fraction did not have to be concentrated prior to drying (Kollar and Sturdik, 1992).

The second alternative is based on a mechanical cell disruption and a consequent isolation of the protein fraction.

Cell proteins were liberated by disrupting yeast in a high efficiency bead mill (Dyno Mill) and, on a few occasions, in a high-pressure homogeniser (Niro Soavi – GEA). Temperature was controlled at a low level to avoid denaturation of the proteins.

After centrifuging the treated material, pH of the supernatant was increased to 11 by using caustic soda, and sodium trimetaphosphate was added. Precipitation of the proteins was accomplished by lowering the pH. The phosphorylated protein was submitted for subsequent washing before carrying out drying.

Both processes have been developed with the intention of creating human food ingredients as well as material for animal feed blends.

Table 4: Chemical characterization of yeast derivatives

	Whole Yeast	Yeast Autolysate	Yeast Cellwalls	Yeast Extract
Crude Protein (N x 5.8)	39.6	40.4	18.8	50.7
Carbohydrates				
- Total	31.4	31.2	67.8	3.3
- Insoluble	1.09	0.98	3.8	Undeter.
- Soluble	30.3	30.4	74.4	3.3
Ash	7.3	6.8	1.4	15.1
Lipids	0.5	1.2	2.3	0.4
Nucleic Acids	9.0	5.6	3.4	8.3
Other	12.2	14.8	6.3	22.2

3.9 Characterization for food manufacturing

Table 4 shows the chemical components of yeast derivatives. Digestibility is of a big importance for the use of these derivatives in the animal feed industry, because it measures the amount of nutrients that can be assimilated. As a matter of fact, a substantial increase of digestibility could be observed in the yeast products as indicated in Table 5.

Table 5: True digestibility of yeast products

Dried Yeast Derivates		Real digestibility
Washed yeast cells	(WY)	68.0
Autolysate	(YA)	76.6
Yeast Extract	(YE)	91.0
Yeast Protein concentrate	(YPC)	89.9
Casein (reference)	(CR)	93.5

3.10 Yeast for food manufacturing

Many other properties, such as solubility, emulsifying capacity, oil-binding capacity, water holding capacity, hygroscopicity and viscosity of each fraction, were determined once they play an important role in food manufacturing.

After the full characterization of each of the four yeast products, comparative tests were carried out with food formulations containing predetermined amounts of yeast products. Different types of food enriched with yeast products were characterized by their composition, nutritious value and their sensorial properties (Sgarbieri et al., 2001).

The addition of yeast extract in biscuits not only improved the profile of essential amino acids drastically but also had a positive effect on its organoleptic properties, especially taste and smell. Noodles also could be enriched with either yeast autolysate or yeast extract, improving their nutritious value. On the other hand, larger amounts of yeast extract could be incorporated in powder spices and rather small amounts of this product can be handled in mayonnaise.

Furthermore, addition of small amounts of yeast autolysate and yeast extract resulted in good acceptance when used in dark bread, whereas white bread was negatively influenced by darkening of its colour. The extensive use of yeast extracts in soup essence is widely known already. Finally, comparative tests were made with different yeast products in sausages.

At the present time, there is a limited use of yeast products for food ingredients. As already stated, yeast extract is widely used as a major ingredient for instant soups. Other uses, as suggested above, will need changes in consumer habits. That means that a new market for yeast-enriched food products still has to be developed.

3.11 Yeast products in animal feed

Dried yeast has been used in the past as an important protein enhancer because of its special composition of essential amino acid (rich in lysine), which allows a good balance with other protein sources. But more and more, yeast is being used in blends because of its outstanding properties.

Its importance as a growth promoter surpasses its former use as a protein source. Cell fragmenting techniques, such as autolysis and cell disruption, increase cell digestibility in a significant way, which ensures a better utilization of the nutrients.

Cell wall fractions, which are rich in glucan, provide other interesting properties such as immune stimulation and disease control. These probiotic and prebiotic characteristics become especially interesting when an increasing number of countries are banning chemobiotics and synthetic antibiotics from use in feed. Yeast products have the possibility to at least partially substitute for these forbidden products (Houdijk et al., 1999).

3.12 Outlook for the future

Relatively simple process transformations with excess yeast, such as autolysis, enable distilleries to produce some distinct products with interesting properties. Depending on the conditions of the fermentation process and the quality of the downstream plant, the new cell products i.e. yeast autolysates, yeast cell wall fractions and yeast extracts, can be used as food ingredients for human consumption. Smaller investments are necessary to carry out autolysis for obtaining products, which could be sold for blends in animal feed.

Recent tests especially with poultry showed clearly the high efficiency of yeast autolysates with respect to food conversion. 0,2% of the autolyzed product will do the same job as 2% of normal dried yeast.

This looks like a very promising opportunity, since the animal feed market will be able to accept larger quantities of these products in the future, and also because there are no significant problems to solve in the process.

4. Case Study 2– Production of biodegradable plastic – PHB

4.1 Integration of processes with the sugar mill

Almost all sugar mills in Brazil are producing sugar and ethanol with the interesting characteristic of generating all the energy needed by burning sugarcane bagasse. Steam is expanded in turbines to provide the necessary mechanical and electrical power as well, after expansion, the thermal requirements of the sugar mill and alcohol distillery. The net energy balance of the whole unit is positive even when using medium pressure boilers. By using high pressure steam (60bar), an even bigger surplus of energy can be obtained that can be directed for generation of electrical power sold to the power distribution utilities or be used for other processes attached to the sugar mill.

Practically all effluents and wastes of the sugar and alcohol process are used as bio-fertilizers in the cane fields, opening a good chance to blend with effluents from other processes.

Finally, sugar as produced under Brazilian conditions furnishes an excellent but still low-cost carbon source for fermentation processes.

This greatly contributes to the integration of large-scale biotechnological enterprises into sugar mills.

4.2 Assumptions for production of PHB

Even though there is a growing demand for biodegradable products, especially in countries where society is willing to pay for environmentally sound products, it is necessary to keep production costs of the resin at a level competitive with conventional plastics. Additionally, environmental legislation, making it compulsory to use a certain amount of biodegradable polymers, would certainly contribute to the success of the product.

The model for the integration of a poly-3-hydrobutyric acid (PHB) production plant into the mill takes into account the following important characteristics of the sugar agro-industry in Brazil:

- availability of thermal and electrical energy from renewable sources;
- effective residues- and waste-disposal management;
- availability of sugar at low prices and large quantities and stable conditions;
- availability of large-scale fermentation technology;
- availability of natural solvents for the extraction process.

In 1995, a pilot-scale PHB production plant was assembled in one of the Copersucar mills (Usina da Pedra) aiming to produce enough PHB to supply the market for testing the material (Nonato,R.V.;Mantelatto,P.E.;Rossell,C.E.V. 2001). Also, data for scale-up and economic evaluation of the process are derived from the activities in the pilot plant.

Some characteristic data about the polymer produced at this pilot plant are presented in Table 6.

Table 6: Characteristic data for production of PHB

Fermentation	
Biomass concentration	120-150 kg/m^3 (dry basis)
PHB content in biomass	65-70%
Productivity	1,44kgPHB/m^3/h
PHB yield	3,1 kg sucrose/kg PHB

Extraction	
Yield	95%
PHB purity	>98%
PHB molecular weight	400.000 – 600.000 Dalton

Energy	
Steam consumption	39,5kg steam/kg PHB
Electrical power	3,24 kWh/kg PHB

Cost composition for PHB production	
(10.000tons/year plant estimate)	
Raw material (sugar)	29%
Other chemicals	20%
Equipment depreciation	27%
Energy	11%
Others	13%

4.3 Properties of PHB

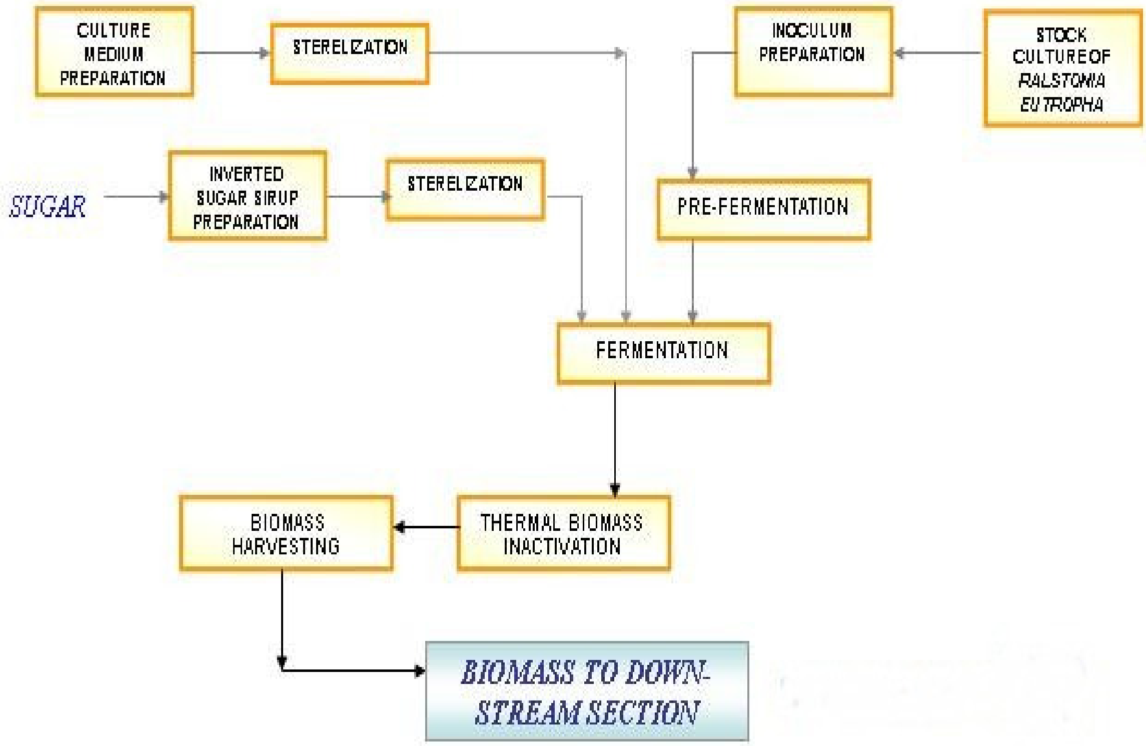
Poly-3-hydroxybutyric acid and related polymers are natural polyesters, synthesised by various bacteria strains. They are biocompatible and totally and rapidly biodegraded by a large number of microorganisms. They can be compounded to thermoplastic resins that have physicochemical and mechanical properties similar to petrochemical-based polymers, e.g., polyethylene and polypropylene. Standard plastic-engineering moulding procedures can be applied to them.

PHB itself is quite brittle, a fact that demands the addition of nucleating agents, plasticizers and other additives, enabling PHB to be used in several conventional processes of plastic manufacture.

4.4 PHB production process

The PHB production process was developed by a joint venture between Copersucar, IPT (Technological Research Institute of São Paulo) and ICB (Biomedical Institute of University of São Paulo). It comprises of a fermentation step in which strains such as Ralstonia eutropha are aerobically grown to a high cell density in a well balanced medium consisting of cane sugar and inorganic nutrients, as shown in Figure 1. Cell growth is then shifted to PHB synthesis by limiting some nutrients. After 45-50h, the fed-batch fermentation process is stopped, with a final dry cell mass of 120-150 kg/m^3, containing close to 70% PHB. The fermented medium is thermally inactivated, diluted with water and flocculated. Separation and concentration procedures yield a cell sludge containing 25-30% solids, which is then submitted to a multi-stage extraction process. The extract is purified for cell debris removal and then cooled down to recover a PHB gel. Solvent from the gel is removed by a mechanical and thermal concentration. The resulting PHB paste is mixed with water and distilled to remove the remaining solvent. PHB granules are then collected by a sieve, vacuum dried, compounded and extruded as pellets.

Figure 1: Process Diagram PHB Fermentation Step

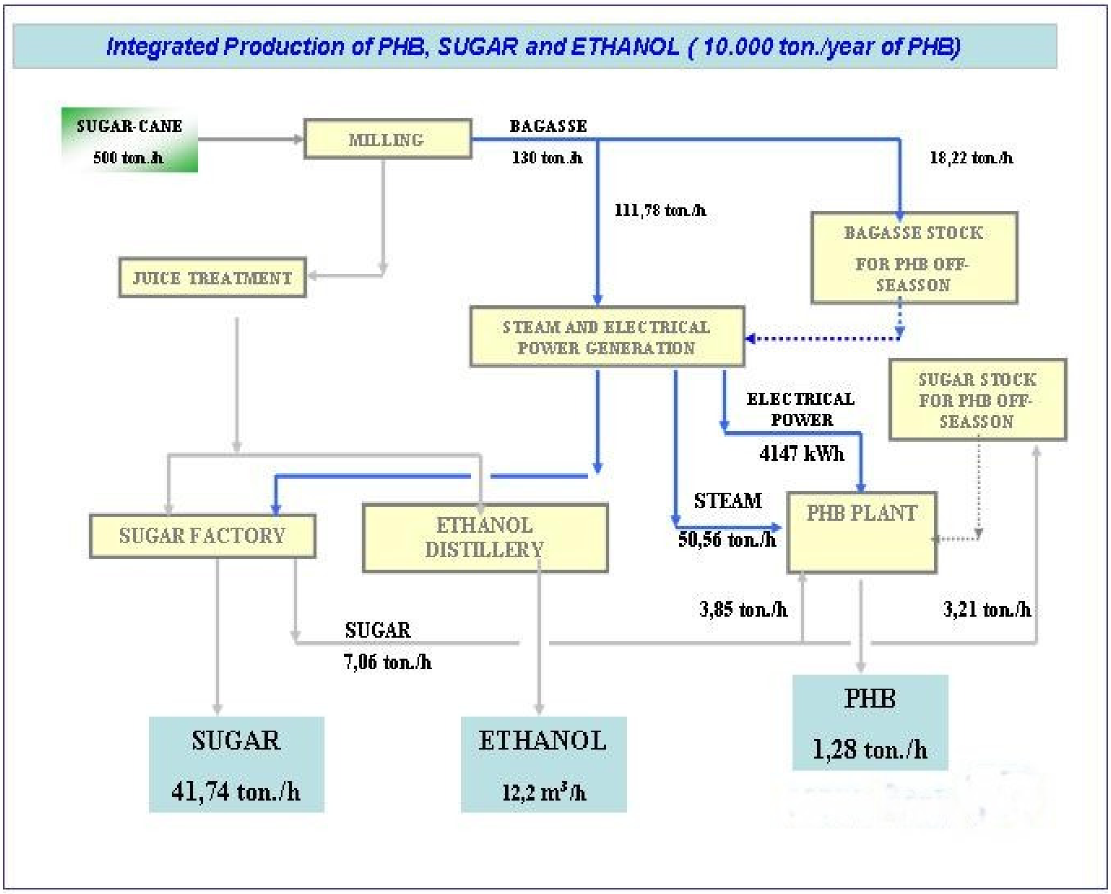


4.5 Mass and energy balance

PHB integrated into a sugar mill and ethanol distillery, can be produced at low cost when the necessary energy and the raw-materials are available throughout the whole year. Figure 2 shows a mass and energy diagram for sugar, ethanol and PHB production.

A typical mill crushes 12,000 tons of sugarcane per day during a milling season of approximately 180 days. When sugar and ethanol are produced at the same period, the PHB plant has to be operated for 12 months. In order to guarantee the necessary amount of energy for producing 10,000 tons, several process improvements have to be accomplished. The medium pressure boilers should be replaced by high pressure boilers and high efficiency, multistage turbo-generators need to be installed to increase electric power production. Low-pressure demand has to be decreased to 350kg of steam per ton of cane, mainly in the juice treatment, evaporation and distillation sector. These measures enable provision of a sufficient stock of bagasse for the off-season.

Figure 2: Integrated Production of PHB, Sugar and Ethanol (10.000 ton/year of PHB)



4.6 Economical profile

The production of PHB requires 3,1 kg of sucrose per kg of final product. Therefore, sugar prices are playing a major role in the cost formulation for 29% of the final cost, not considering taxes. At present, this process demands a large quantity of steam (39,5 kg/kg PHB) and electrical energy (3,24 kWh/kg PHB), although these figures can be reduced in a short time. For a plant with an annual production of 10.000-ton PHB, the costs of equipment for the fermentation, extraction and purification plant including utilities is estimated at approximately US$40.000.000,00.

Several cost estimations for PHB-plants have been carried out in recent years. The lowest cost at US$2,65/kg PHB (Lee,S.Y.; Choi,J. 1998) has been achieved for a 100.000-tons-per year plant with the use of fossil fuels estimating (Lee and Choi 1998). The favourable situation in Brazil regarding raw-material and energy-costs enables admission that the production costs could very much approach those around US$3,00 per kg PHB.

4.7 Conclusions

The integrated model proposed in this case study makes intensive use of facilities, materials and excess energy from the sugarcane industry that would be otherwise wasted or sold at subsistence prices. Also, it permits wastes from the PHB plant to be returned to the cane fields, reducing the need for fertilizers. Since all the carbon involved as feedstock and fuel comes from sugar cane, CO2 emissions from the production plant also return to the fields by means of photosynthesis, which means that the net carbon balance is close to zero.

Large-scale production of PHB in sugarcane mills presents a successful opportunity for greatly increasing the revenues in the sugar industry. As demonstrated in the mass and energy balance in Figure 2, only a small amount of sugar has to be deviated from the sugar production. The overall sugar production will not be affected and no significant impacts on sugar prices can be expected, especially keeping in mind the enormous amount of still unexplored arable land, now occupied by low-grade pastures, which can be utilized for future increase of sugar and ethanol production. Nevertheless, the revenue obtained from the production of biodegradable plastic is quite significant, surpassing ethanol and even sugar.

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Opportunities and Challenges for Industrial Biotechnology in South Africa

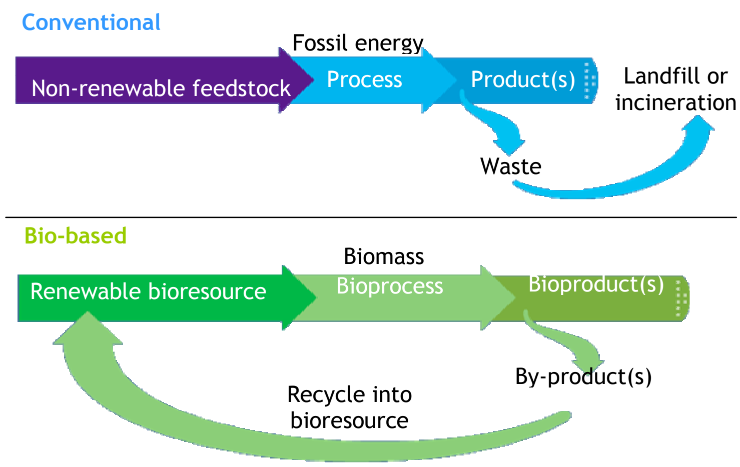
Webster JW, Akanbi RT.

1. Introduction

Biotechnology has evolved over the last 25-30 years into a powerful set of tools used in many sectors. It is referred to as a cross-cutting technology. The role of biotechnology in the future will be vast and many predict that the next big advance will be the global development of a Bioeconomy[1,2].

"A bio-based economy is defined as an economy that uses renewable bioresources, efficient bioprocesses and eco-industrial clusters to produce sustainable bioproducts, jobs and income"[3] See figure 1 below.

Figure 1: Comparing the structures of conventional vs. bio-based economies



George Anderl, 2003[4]

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[4] George Anderl, 2003: *Sustainability And The Biobased Economy*

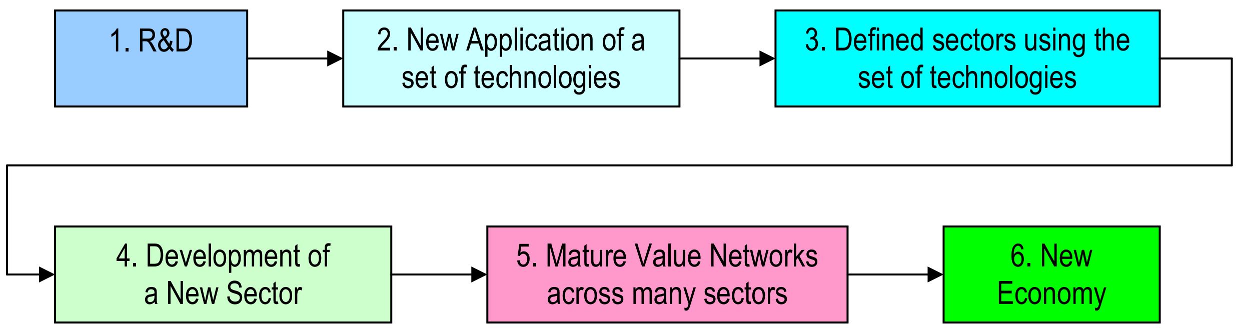
Countries moving towards a bioeconomy will provide new opportunities for industry and farmers and will reduce greenhouse gas emissions. Bio-based products include fuels, energy, chemicals, lubricants, plastics, paper construction materials and advanced composites. Numerous major companies have increased their involvement in the development of bio-based products. For example, DuPont aims to produce 25% of their products from renewable resources by 2010 and Cargill Dow LLC has invested approximately US$1 billion in the development of biodegradable plastics and fibres made from maize. The United States (US) National Research Council predicts 50% of US fuels and 90% of organic chemicals will come from renewable resources by the turn of the century.

2. Is South Africa Moving Towards a Bioeconomy?

South Africa (SA) has grown its economy primarily by mining and utilising non-renewable resources. As these resources are limited, new technologies are being utilised to enable economic growth. One of these technologies is biotechnology.

South Africa now recognises the role of biotechnology in economic development; the government's adoption of the National Biotechnology Strategy in 2001[5] commits R450 million to the further development of biotechnology in the next 4 years. To date, South Africa has had only a very small bioeconomy, although biotechnologies are widely used in a number of industrial sectors, including forestry, mining, food and beverage sector, as well as the waste water treatment sector. The emphasis in South Africa is still at the R&D level (see Figure 2) with certain sectors using the technology and moving towards the full development of a bioeconomy.

Figure 2: Progression[6] of a technology to a sector and then an economy[7]



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2.1 Status of biotechnology industry in South Africa

South Africa has been involved in biotechnology research and development for over 30 years. In 2003, 622 research groups engaged in 911 research projects relevant to biotechnology in South Africa[8]. Of the research projects 30% were core biotechnology and focused on the developments of commercial products, 25% were biotechnology activities with the potential to spin off commercial products, 39% focused on fundamental research and 6% offered biotechnology services[9]. The majority of research groups are small, engaging between 1 and 10 researchers. Biotechnology research projects are spread across eight sectors (human health, animal health, plant, food and beverage, industrial, environmental, support services and other).

From the 45 companies that were using biotechnology in food, feed and fibre in 1998, 30 plant biotechnology and 22 food and beverage companies were reported in the National Biotechnology Audit[10] in 2003. It must be noted, however, that in the 2003 audit certain traditional 1st generation biotechnology companies and SA-based multinational companies, where 3rd generation biotechnology was not part of their core activities in SA, were excluded.

Out of 106 companies, 47 were core biotechnology and 59 non-core biotechnology. Of the core biotechnology companies, 39% were in human health, followed by the support services sector (13%). There is an even distribution across the plant, animal health, food and beverage, industrial and environmental sectors and a small proportion of companies (3%) contributing to the "other" category. The majority (26%) of the non core biotechnology companies are in the plant sector with 15% engaged in the human health sector and another 15% in the industrial sector.

The number of companies engaged in core biotechnology has increased since 1984 (from 4 to 47) whereas growth in non core biotechnology companies has been slow to stagnant. Thirty-three percent of the core biotechnology companies are new start-ups, 37% spun off from research groups and 30% from other enterprises. Only around 10% of the biotechnology companies are involved in highly innovative research and development.

Few local products are developed, in spite of 20 years of research and development. The sector is heavily dependent on imported technology, which is driving commercialisation and industrial growth. This is reflected in relatively low levels of local technology innovation and only 2 start-ups for every 100 patents[11].

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8 National Biotechnology Audit, Final Report. September 2003
9 National Biotechnology Audit, Final Report. September 2003
10 National Biotechnology Audit, Final Report. September 2003
11 NACI DACST 2002 Research and development: Key facts and figures.

3. South African Realities

3.1 Food security in South Africa[12]

South Africa is unlikely to appear in the 'high risk' category in any international rating of food security. Despite its comparatively unfavourable (only 16% of its land is arable) agricultural condition, in most years, it is a net exporter of agricultural commodities. Its per capita income is high for a developing country. The southern tip of the African continent does not have a tight foreign exchange constraint. It is not landlocked. Its transport infrastructure is generally good. Its constitution entrenches the right to adequate nutrition for all and it has devised a national Integrated Food Security Strategy (IFSS). Clearly, food ought always to be available in South Africa. So why should food security be a priority policy issue for South Africa?

The answer lies in the fact that, more than 14 million people, or about 35% of the population in South Africa, are vulnerable to food insecurity. As many as 1.5 million, or about one quarter of the children under the age of 6 are stunted as a result of malnutrition. The Constitution - if not society's values and the sheer economic cost of forgone production potential - dictates the need to reduce and, if possible, eliminate vulnerability to and the negative consequences of food insecurity within South Africa.

More often than not, the reference to 'food' in 'food security' is taken to identify the problem as essentially agricultural. While it would be incorrect to characterise it as being focused exclusively on agriculture, South Africa's IFSS declares its 'primary objective (to be) to overcome rural food insecurity by increasing the participation of food insecure households in productive agriculture sector activities'. Since roughly 70% of the country's poorest households live in rural areas, there is a need to develop agriculturally based job opportunities for them.

The HIV/AIDS pandemic has caused severe damage to so many rural households' and indeed to national physical, financial and human asset bases. The enormous death toll and HIV-linked productivity costs make it increasingly difficult for agricultural communities to restore their production to previous levels, even with adequate rainfall and political stability. Food insecurity that is already widespread and acute may likely become chronic.

Energy use can be considered an indicator of quality of life in rural Africa. Although South Africa is committed to providing universal access to electricity by 2012; many poor rural households may still not be able to afford the highly subsidised energy sources. Most rural dwellers today with access to grid electricity are usually not able to afford higher consumption of electricity and limit its use to lighting. The percentage of rural household income used for energy consumption remains high.

The above issues need to be considered when developing biomass and biofuel strategies and projects.

[12] http://www.sarpn.org.za/documents/d0000685/page1.php

3.2 Energy in South Africa

The energy sector in South Africa has both first world and third world elements. On the one hand South Africa produces and consumes over 60% of the electricity on the African continent and it is the twelfth highest carbon emitter in the world. On the other hand, well over half of South Africa's rural households use wood fuel energy to a greater or lesser degree (ranging from a few times per month to daily), as do numerous urban households. Even with the substantial household electrification programmes of the last ten years and one of the lowest electricity prices in the world for consumers, most newly electrified households continue to use wood fuel because they cannot afford the capital outlay and running cost of electrical appliances[13].

Due to an abundance of coal reserves, South Africa has traditionally relied on coal for the majority of its energy needs. This reliance on coal made South Africa one of the top greenhouse emitters globally on a per capita basis[14].

South Africa is a signatory to the UN framework on climate change as well as the Kyoto protocol. South Africa's greenhouse gas emissions are not capped within the first commitment period of the Kyoto Protocol. Notwithstanding, South Africa has committed to sustainable development along a path that does not lead to additional adverse climate change where possible.

The South African government has set a target of producing 10,000 GWh or approximately 4% of its energy consumption by 2013 from renewable sources. South Africa however is lagging behind other developing countries in terms of the implementation of biomass and bio-fuel projects.

[13] Local Environmental Action Plan, Comprehensive Audit Report Executive Summary Submitted 17 November 2004

[14] SA's White Paper on Renewable Energy, November 2003

4. Manufacture from Renewable Resources in South Africa[15]

4.1 Biomass

In line with global trends, there is a growing need to explore alternative and/or renewable raw materials for the production of commercially important products. Plant biomass is widely considered a potentially useful substrate for use as raw material; however, notable process optimization is required to make this a feasible option. Traditionally, South African agriculture does not process plant by-products, resulting in > 20 million tons of under-utilized resources per annum. The uncon-trolled growth of invasive plants if harvested, could add a further 17 million tons of plant biomass. There is therefore a need for enabling technologies that provide a feasible conversion of biomass to a variety of value added products at an industrial scale and that at the same time create jobs.

Plant biomass consists of about 40-50% cellulose (β-1,4-glucose chains), 20-30% hemicellulose (heterogeneous β-1,4-xylose chains for xylan and β-1,4-mannose chains for mannan, which also contain arabinose and galactose as minor constituents) and 20-30% lignin (polyphenolic complex). The hexose sugars (glucose, mannose, and galactose) can efficiently be fermented to bio-ethanol and sold as a fuel-extender commodity product. Fermentation of pentose sugars (xylose and arabinose) into ethanol however is still inefficient and requires construction of the necessary recombinant strains. Alternatively, the sugars can be fermented to lactate, which could be polymerised into polylactate for the production of biodegradable plastics. Other fine chemicals that can be derived from the hemicellulose fraction include ferulic acid as food antioxidants, as well as furfural. The lignin fraction can be hydrolyzed to phenol acids, which can be converted to vanillin and related products (this is being researched by the CSIR). After removal of the fermentable sugars, the lignin fractions could be subjected to gasification, based on a modification of current technology developed by SASOL for coal conversion, and could then be used as an alternative energy source.

4.2 Biofuels

4.2.1 History and current status

Before 1994, three large distilleries in South Africa (National Chemical Products in Transvaal (now Gauteng), National Chemical Products in Natal (now KwaZulu-Natal) and Natal Cane Byproducts Ltd. used molasses as the raw material for the production of ethanol for more than a decade. In addition, the CSIR began funding research on the utilisation of lignocellulose through the Cooperative Scientific Programmes (CSP) between research institutes and universities. In 1979, this research was consolidated into a goal-oriented cooperative programme focused on a single feedstock (bagasse), a single product (ethanol), and a single approach to overcoming the recalcitrance of cellulose (enzymatic hydrolysis). The initial goal of the programme was the development of a technically and commercially viable process to convert bagasse into bio-ethanol.

Since the 1990s amidst increased activities abroad, much of the activities in South Africa ceased. The major reasons being that the fossil fuel boycott was lifted and that South Africa has large coal reserves. Except for research activities at a few tertiary institutions and interest by a few private sector players there have been no major developments in biofuel production and, at present no commercial biofuel production takes place in South Africa

[15] W H van Zyl, Stellenbosch University. SA Biotechnology Roadmap 2004. Energy Manufacture from Renewable Resources

However, in September 2005, South Africa's Energy Development Corporation (EDC), a division of the Central Energy Fund, announced its plan to buy a 25% stake in Ethanol Africa, a company set up by commercial farmers to turn surplus corn into ethanol. Other investors are Alco, a Belgian Biofuels company, and Grain Alcohol Investments, a farmer consortium. The EDC has a mandate to invest in commercially viable renewable energy in sectors with insufficient private sector activity. South Africa's farmers having faced years of high input costs, drought and low grain prices, are unable to risk such a substantial investment. The farmer organisation, Grain SA projects a 4.5 M ton surplus of corn in South Africa by April 2006 (southafrica.info). A typical ethanol plant could convert 370 000 tons of maize per annum to produce 155 400 000 litres of ethanol. With an annual demand for petroleum in South Africa of 10.5 B litres; 4.5 M tons of corn could thus produce sufficient ethanol to replace around 18% of South Africa's petroleum consumption. In contrast, current biofuel production from 60 M tons of corn in the US provides less than 3% of domestic gasoline consumption. Most of the alcohol produced in South Africa today however is exported to Africa, Asia and America.

4.2.2 Global Leading Ethanol Producers (2004)

Country	Gallons (M)
Brazil	3,989
US	3,535
China	964
India	462
France	219
Russia	198
South Africa	110
UK	106
Saudi Arabia	79

4.2.3 Potential market – local or international

The Kyoto agreement necessitates the search for alternative fuels, such as bio-ethanol. During the past five years, both the USA and Europe started focusing on the development of technologies for the large-scale production of bio-ethanol at costs comparable to that of fossil fuel production.

4.2.4 Players

Currently, some of the major activity in this field is at the University of Stellenbosch. Research pockets with expertise and technology in plant material degradation also exist at the University of the Free State, University of KwaZulu-Natal, CSIR, University of Cape Town and Limpopo University. Much of this work has been done with limited support of the paper and pulp industry operating mainly in KwaZulu-Natal with the purpose of reducing the use of bleaching chemicals and alleviating pollution.

4.2.5 Infrastructure available/required

With the dismantling of facilities producing bio-ethanol from molasses, no industrial facilities exist at present in South Africa. However, considerable expertise is still present and with a focused programme, South Africa can regain a key position within the international context, particularly in Africa. Although the government has not yet endorsed bio-ethanol production, eight new bio-ethanol plants are planned for construction by the private sector for the end of 2006.

5. South Africa's Potentials & Challenges

Advances in the life sciences are making a reality of the prediction that this will be the century of biotechnology. Driven by an increase in the intensity of biological knowledge, a wide range of R&D activities are maturing at a remarkably rapid pace: improved healthcare technologies drawing on genetics, genomics and proteomics; more sustainable and higher value-added food as well as fibre production systems; cleaner, more eco-efficient biofuels; enzymatic processing that cuts energy and water consumption and the generation of toxic wastes during manufacturing; stronger versatile and functional bio (nano) materials. Twenty or thirty years from now, these and other bio-applications may well become part of everyday life. The impact could be dramatic; improved health, a cleaner environment, and more sustainable energy production could have effects equalling those of the information and communication technologies developed in the last two decades[16].

Convergence with other technologies, such as information technology and nanotechnology, will allow biotechnology to transform the way products are designed, manufactured and used. That transformation of production and consumption cycles will generate sustainable growth in developed and developing countries such as South Africa. But it will also generate complex policy challenges, as these changes pervade economic and societal activities. There is no guarantee that the transformations will spontaneously occur in ways that optimize benefits to society.

South Africa has great potential for the further development of the biotechnology industry with the following contributing factors in its favour:

- A sophisticated and lengthy tradition of first generation biotechnology
- World class researchers and research institutions
- A pipeline of projects that could lead to new products or processes
- An unrivalled biodiversity and biological resource base
- Indigenous medical knowledge going back centuries
- Access to a large human genetic diversity pool
- Access to a high number of clinical samples for major infectious diseases
- A relatively low cost base for research, product development and manufacturing
- A sound legal and regulatory framework, and a world class banking system and ICT infrastructure

Despite these factors, IP generation and technology transfer in the biotechnology field to date has been slow.

[16] The Bioeconomy In 2030:A Policy Agenda

The major factors inhibiting the biotechnology industry to date include:

- A general lack of cohesion in research programmes
- Lack of investment in, and development of, technology platforms
- A shortage of market-focused research and a relatively low tendency among academics to commercialise research
- A scarcity of suitably qualified R&D personnel, particularly at the MSc and PhD levels
- A lack of clear IP policies that incentivise commercialisation
- An overall lack of confidence in African governments which affects foreign investment
- A severe shortage of entrepreneurial and technology transfer skills and mechanisms
- Insufficient public and private funding for research and product commercialisation

Even with these constraints South African industries are using and developing the technology. These include large companies in various industrial sectors such as forestry (Mondi and Sappi) using tissue cultured trees and developing new disease free varieties, sugar (SASEX) developing new varieties of sugarcane, starch (African Products) using enzymes for glucose production, crop seeds (Pannar) developing virus resistant maize, energy (Eskom) investigating renewable energy through biomass and fuel cells, mining (Mintek) commercialising bioleaching.

In general, industry supports the development of all aspects of biotechnology. However, some companies are facing constraints due to consumer perceptions.

To address the issues described above the South African government supports the biotechnology industry through:

- Department of Science and Technology which develops and implements the National Biotechnology Strategy and Biotechnology Roadmapping Project
- Department of Trade and Industry which focuses on innovation and commercialisation as well as modifying the Patents Act and supporting venture capital through the IDC
- Department of Agriculture which implements the GMO Act
- Department of Environments Affairs and Tourism which focuses on the environmental issues through the GMO Act, the Biosafety Protocol and Biodiversity Bill
- Department of Health which implements the Labelling Bill as well as playing a strong role on safety issues in the implementation of the GMO Act

The approaches taken to ensure biotechnology R&D projects are commercialised are as follows:

- The setting up of three Biotechnology Regional Innovation Centres (BRICs) and one national biotechnology innovation centre that develop and implement consortium based projects
- The implementation of a National Bioinformatics Network
- The attachment of bio incubators to the BRICs
- Establishment of technology transfer offices within universities and research organisations
- Investment in, and development of, technology platforms e.g. genomics

Besides generating funding for biotechnology, developing stronger international partnerships and eliminating trade barriers the biggest challenge facing the South African biotechnology sector at the moment is the fact that the public is not well-informed. As a result, the Department of Science and Technology (DST) has requested its agency, the South African Agency for Science and Technology Advancement (SAASTA) to implement an awareness campaign. The success of this campaign and the awareness, education and training programmes of AfricaBio are important in raising the level of public understanding and facilitating public acceptance of the technology.

5.1 Analysis of barriers and problems associated with South Africa attaining a bio-based economy

The following general barriers to the further implementation of renewable energy have been identified (Department of Mineral & Energy 2004):

Many renewable energy technologies remain expensive, on account of higher capital costs, compared to conventional energy supplies for bulk energy supply to urban areas or major industries.

Implementation of renewable energy technologies needs significant initial investment and may need support for relatively long periods before reaching profitability.

There is a lack of consumer awareness on benefits and opportunities of renewable energy.

The economic and social system of energy services is based on centralised development around conventional sources of energy, specifically electricity generation, gas supplies, and to some extent, liquid fuel provision.

Financial, legal, regulatory and organisational barriers need to be overcome in order to implement renewable energy technologies and develop markets.

There is a lack of non-discriminatory open access to key energy infrastructure such as the national electricity grid, certain liquid fuels and gas infrastructure.

5.2 The potential impact of renewable energy system on rural community will be as follows:

Small-scale farmers will have a ready market for their crops, transforming them from subsistence to small-scale commercial farmers.

With a biofuel factory and animal feedlot at the centre of such a production area, technical information transfer, training and input supply by the factory could be arranged to benefit the farmers.

The cash injection for the community will be around R500/t for maize and R750/t for sunflower

The number of people who will become economically active instead of being subsistence farmers indicates the potential for job creation[17].

[17] Gisela Prasad, Eugene Visagie. June 2005: Renewable energy technologies for poverty Alleviation Initial assessment report: South Africa

6. Conclusions

Renewable energy is one of the areas that the South Africa government is considering pursuing in order to manage energy-related environmental impacts and diversifying energy supplies from a non renewable energy dominated system. Considerable interest in bio-ethanol from sugar cane and maize has been expressed by industry in South Africa, although the process economics are still unfavourable without subsidies and price stability. The possibility of extensive job creation in depressed rural areas through new bioenergy and associated bio-based industries is helping to stimulate further interest; eight biofuel plants have been planned by the private sector. No coordinated national bioenergy research program currently exists at present although various groups are working on the bioconversion of lignocellulosic biomass as feedstock for biofuels. South Africa recently joined the International Energy Agency (IEA) Bioenergy Technology Implementing Agreement, in order to interact with international efforts for analysing and stimulating biomass and bioenergy development. Serious attention needs to be given to the socio-economic advantages in production of biomass and biofuels, in terms of their labour-intensive nature, and as a black empowerment opportunity for South Africa.

4

PAPER

Challenges and Opportunities for Biofuels Production, Marketing, Economics and Policy Implications in Southern Africa

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1. Background

Recent events related to global uncertainties in fossil fuels supplies and high world oil prices, on one hand, and the need to reduce poverty, particularly in Africa, on the other hand, have intensified the motivations to shift to biofuels use.

There is now a growing "frenzy" of interest, especially among farmers in Africa, to grow energy crops from different sources. This interest is being induced by the realisation that biofuels markets are expanding, with growing applications for heating, power generation and transport purposes. Because of this motivation and interest, an excellent opportunity does now exist to propel biofuels production for sustainable development.

Despite this potential, there exist local, regional and global challenges that need to be considered. In some cases, the challenges can be addressed as a way to enable agriculture biomass, a huge resource in Africa, to be converted into a variety of biofuels such as ethanol and biodiesel. Ethanol can be made directly from sugar bearing crops, and indirectly by converting the cellusosic portion of biomass into sugar [1]. Biodiesel can also be produced from vegetable oil seeds through use of extraction technologies, and a chemical process known as "esterification" [2].

2. Challenges and Opportunities for Biufuels Development

2.1 Global Challenges

From global perspectives, growing concern about sustainability of energy supplies (especially in the transport sector), supply security and the need to take action on climate have all served to increase interest in biofuels [3]. With regards to security of supply, both biodiesel and ethanol can play an important role to increase use of domestic resources in the transport sector, and at the same time address local, regional and global environmental concerns.

The key driving forces for biofuels in the EU are the Directive for Promotion of Biofuels and Directive of Fuel Quality [3, 4]. The former, which requires member states to set indicative targets of biofuels sales in 2005 (2%) and 2010 (5.75%) is motivated by the need to cut Green house Gases (GHGs) and increase energy security by reducing dependence on imported fuels [3]. As a result of this Directive, it is estimated that a market demand of 10.5 billion litres of biofuels will be created [4].

With regards to meeting the Directive on Fuels Quality, biodiesel has useful properties as it is known to release fewer solid particles than conventional diesel, and contain no sulphur and release no SO_2, which contribute to acid rain. Besides, biodiesel has rapid biodegradability, low toxicity to people and the environment and a high flashpoint. Ethanol, on the other hand, is "CO_2 neutral" because the carbon diode released during combustion is absorbed from the atmosphere by the next generation of crops. Furthermore, ethanol can compete with MTBE as an octane enhancer in addition to having fewer and less severe impacts on the environment (both air and ground), and less damage to health.

Due to limited land availability, and relatively high cost of the feedstock, rape seed, it is unlikely, the anticipated demand of 10.5 billion of biofuels in the EU will be met by domestic supply. This market is of significance to creating a biofuels industry in Africa.

2.2 National Regional Perspectives

Apart from high world petroleum products, two other factors beginning to have an impact on biofuels development in Southern Africa are the EU Preferential Trade Agreement Sugar Reform, and the Africa Dakar Declaration on replacement of lead as an octane enhancer for gasoline fuels. The Dakar Declaration, which comes into effect at the end of 2005, requires substitution of lead as an octane enhancer.

Some refineries in the region as a short term measure have resorted to use of MMT – a manganese based additive. But MMT also faces different concerns over potential health risks, and is thus viewed as controversial [5]. Another approach is for refineries to manufacture high octane gasoline through use of catalytic reforming units. For many refineries in Africa, this will require upgrades, and large capital outlays, which will not be affordable [5]. In the medium term, most countries in the region are seriously considering use of ethanol as a substitute for both lead and MMT.

The recent announcement under the EU Sugar Reform to reduce EU's intervention price by 36.0% will have an impact on the competitiveness of sugar industries within the African, Caribbean and Pacific regions (ACP). For them to survive, it will require innovative diversification plans into other core products such as ethanol and co-generation.

To assess the impacts of their returns on sugar industries in Southern Africa, an analysis has been undertaken for three scenarios. The first scenario involves assessment of IRR on sugar sales only with 50% domestic sales and 50% exports, based on a typical 250 tonne/hr sugar plant and current EU intervention price (US$630/tonne), followed by a combination of domestic price and reduced EU intervention price (US$460 /tonne), and that of international market price (US$200 /tonne).

The second and third scenarios involve additional investments in ethanol, and cogeneration plants, respectively. Ethanol prices are pegged at a competitive price of US$0.30 per litre of gasoline equivalent, and US$ 0.05 per kWh for sale of surplus electricity to the national grids. Given in Figures 1a and 1b are the results of effects of IRR and Net Present Value (NPV) based on the three scenarios.

Results from Figure 1 demonstrate that many sugar industries are likely to seize the opportunity to diversify to other core products (ethanol and surplus electricity generation) because of both the EU sugar Reform and low world market value of crystalline sugar.

Figure 1 (a): Variation of IRR with Different Pricing Structures

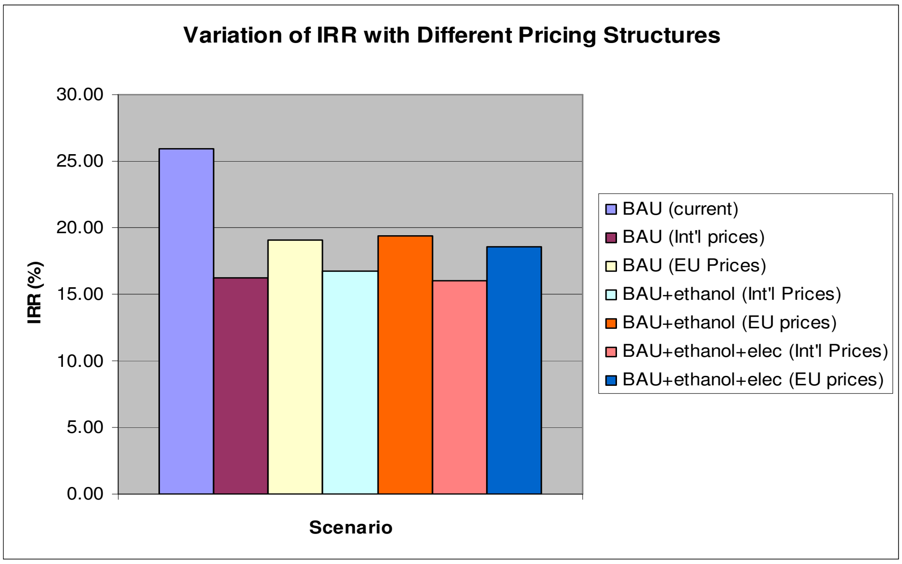
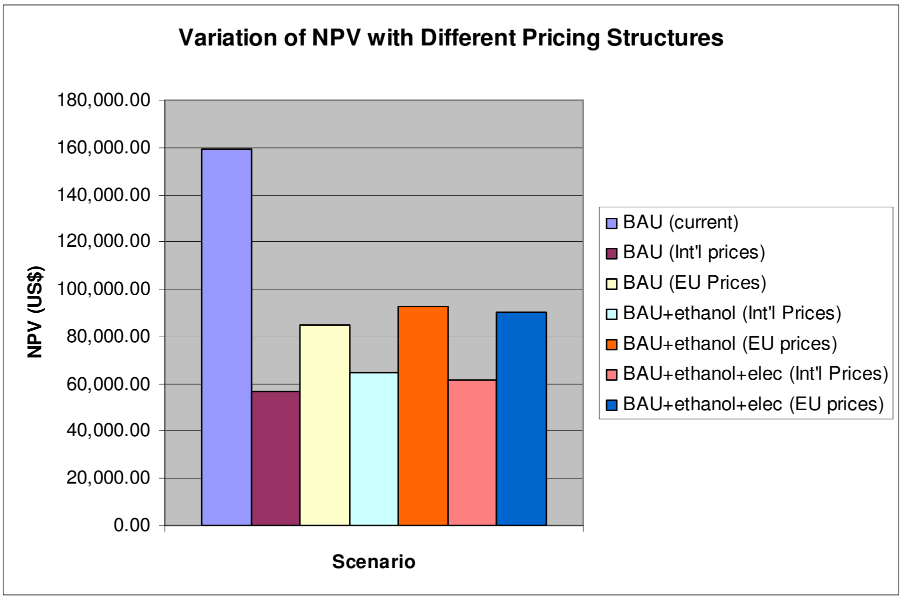


Figure 1 (b): Variation of NPV with Different Pricing Structures



3. Pre-requisites for Biofuels development in Southern Africa

To meet the challenges requires adopting a holistic approach involving formulation of a biofuels strategy with interlinkages for the following:

- Markets
- Feedstocks availability at reasonable cost
- Production/technologies
- Economics
- Involvement of stakeholders
- Regulatory, fiscal and policy framework

3.1 Markets

The strategy will initially be required to satisfy national/regional biofuels market/demand in SADC countries. Concurrently, planning can start to develop the expected biofuel industry to meet high demand for biofuels especially the EU.

3.1.1 Ethanol Markets

Ethanol market development in SADC region will greatly be influenced by the following driving forces:

- High oil world prices
- Sustainability and competitiveness of the sugar industry
- Need to substitute lead and eventually MMT as an octane enhancer for gasoline fuels
- Policy decision on the level of blending
- Local employment and poverty

Possible start up will most likely be based on E5 and E10 blends due to limited current feedstock and acceptable ethanol/gasoline ratio to meet manufacturer's warranty requirements. Based on E5 and E10 blend, possible market for SADC countries is given in Table 1. The table also shows expected demand for the year 2015 at a growth rate of 2.0% of gasoline consumption.

Table 1: Ethanol Markets Based on E5 and E10 (million tonnes) blending scenarios

Country	2000		2015	
	E5	E10	E5	E10
Malawi	4.81	9.62	6.54	13.07
Mozambique	3.33	6.66	4.71	9.41
South Africa	511.9	1,023.8	691.45	1,382.9
Swaziland	4.64	9.28	6.21	12.42
Zambia	8.89	17.7	19.0	25.31
Zimbabwe	23.46	46.91	28.89	57.78
TOTAL	557.03	1,113.97	756.8	1,500.89

Depending on the blending ratios, the current demand for ethanol at 10% is estimated at 1.1 billion litres against a potential of 0.37 billion litres from C molasses. This leaves a deficit of 0.74 billion litres. The deficit increases to 1.0 billion litres by the year 2015. To meet such a deficit requires investments in new technologies of both sugarcane and sweet sorghum, purely for ethanol production. This will require an area of 250,000 – 350,000 Ha of a combination of sugarcane and sweet sorghum.

3.1.2 Bio-diesel Markets

Diesel is widely used in the transport sector, electricity generation and boilers and furnaces. Since diesel fuels play a significant role in economic activities of all SADC countries, the need to reduce on its dependency cannot be overemphasized. Being an environmentally friendly fuel with clean and substantial advantages over hydrocarbon diesel, bio-diesel can be used to substitute diesel in most mobile and stationary combustion systems in Southern Africa. In view of this diversity of use of biodiesel, it has a wider market than ethanol, and most systems can use 100% blend. The only limiting factor is the use of biodiesel in mobile systems. Due to warranty concerns, its blending ratio is currently recommended at 5.0% [3].

The key driving forces for bio-diesel market development in Southern Africa are the need to reduce the huge impact of high oil world prices on their economies, and large scale employment to be generated from creation of nurseries, planting and maintenance of trees, and the harvesting and processing of seeds. The demand for diesel in SADC is estimated to be over 3.0 billion litres per annum.

A hidden driving force for biodiesel market development in Southern Africa is the need to meet the inevitable increase in biodiesel demand from the EU, and the limits on the capacity of the EU members' agriculture sector to meet that demand estimated at 9.5 million tonnes of biodiesel by 2010 [4].

3.2 Production Processes/Technology

3.2.1 Ethanol Production

Production of ethanol requires two steps: fermentation and distillation. Given in Table 2 are the raw materials, processing temperatures and enzymes for pre-hydrolysis, content of fermentable sugars and potential ethanol yields per 100g dry weight.

Table 2: Raw materials, processing temperatures and enzymes for pre-hydrolysis, content of fermentable sugars and potential ethanol yields per 100g dry weight

Raw Material	Temp. (°C) used for pretreatment / enzymatic hydrolysis	Enzymes (type)	Hexoses (g/100g)	Pentoses (g/100g)	Ethanol potential
Sucrose and Starch					
Molasses	None	None	50	0	32
Sugarcane	None	None	65	0	28
Corn	130 - 160/52	Amylases	76	0	32
Wheat	130 - 160/52	Amylases	72	0	31
Rice	130 - 160/52	Amylases	80	0	34
Rye	130 - 160/52	Amylases	70	0	30
Barley	130 - 160/52	Amylases	72	0	31
Potato	130 - 160/52	Amylases	56	0	24
Lignocellulose					
Bagasse	190 - 210/50	Cellulases	45	45	26
Corn stover	190 - 210/50	Cellulases	41	25	25
Wheat straw	190 - 210/50	Cellulases	37	25	23
Aspen	190 - 210/50	Cellulases	51	17	26
Willow	190 - 210/50	Cellulases	40	12	19
Spruce	190 - 210/50	Cellulases	61	5	25
Waste					
Municipal solid waste	190 - 210/50	Cellulases	42	18	23
Cellulose sludge	190 - 210/50	Cellulases	39	7	17

However, not all feedstocks such as starch based (corn, cassava, wheat, etc) and cellulose based (wood materials, agriculture waste, black liquor from pulp and paper, bagasse, forestry waste) contain simple sugars. In both cases hydrolysis (addition of water, e.g. enzymes) is needed to convert starch/cellulose into simple sugars (glucose) followed by fermentation of glucose to ethanol. In terms of cost, fermentation of starch and lignocellusose to ethanol is more due to additional complex and costly investments for converting them into ethanol.

3.2.2 Biodiesel Production

The production of biodiesel is well known. Three basic routes to diesel production from oils and fats exist, and are listed below:

- Base catalysed transesterification of the oil with alcohol
- Direct acid catalysed esterification of the oil with methanol
- Conversion of the oil to fatty acids, and then to alkyl esters with acid catalysts

The most commonly used and most economical process is called the base catalysed esterification of fat/oil with methanol, typically referred to as “the methyl ester process”, due to the following [2,6]:

- Low temperature (65.6^{o}C) and pressure (20psi) processing
- High conversion (98%) with minimal side reactions and reaction time
- Direct conversion to methyl ester with no intermediate steps
- Exotic materials for construction are not necessary

Prior to this process, some of the suitable feedstocks may require some pre-processing to remove materials that may affect the process. Pre-processing can take the form of refining, degumming and/or filtering to remove the impurities. Degumming involves mixing a small amount of water (about 3-5%) with the feedstock which precipitates the gums which then can be separated by centrifuging the mixture. The crude or unrefined vegetable oils contain free fatty acids and gums that must be removed before entering the “methyl ester process”. The esterification process involves reaction of the crude oil with an alcohol (usually methanol) and a catalyst (sodium or potassium hydroxide) to produce biodiesel and a co-product glycerine [2,6].

The key to producing low-cost biodiesel is to select cheaper feedstocks while maintaining acceptable product quality. After feedstock prices, yields are the second largest factor affecting profitability. For example, a 10% drop in yield reduces profitability by approximately 25.0% [5]. Early biodiesel plants had a transesterification yield of 85 – 95%, with the remaining 5 – 15% of the feedstock converted to less profitable glycerine. Modern plants convert all the free fatty acids as well as the glycerine to achieve yields of 100%.

3.3 Feedstocks

3.1.1 Ethanol

From an economic point of view, very few materials can seriously be considered as feedstock. And from Southern Africa’s perspective, sugarcane and sweet sorghum offer promising feedstocks (examples: Brazil, Malawi, India, Kenya and Zimbabwe) [7]. Quantities of ethanol and feedstock required depend on the demand, which in turn is influenced by the level of blending (5%, 10%, 15%). At present, most of the ethanol is produced from cane molasses, which, however, have limited availability, being a by-product of sugar factories and has limitations on wastewater control.

In view of such limitations, there is need to exploit new agro-based feedstocks. For such feedstocks to be attractive, they need to have the following characteristics: sugar bearing, remunerative for the farmers, low cultivation costs, viable for alcohol production and giving zero discharge of waste water. Taking into account the climate and soils in Southern Africa, one such feedstock that can be effectively exploited is sweet sorghum. It has following characteristics:

- Sugar bearing feedstock
- Short cycle crop –3.5 months
- Can be grown across warm climate regions
- Easier to grow and handle (Vis-à-Vis sugarcane)
- Low cultivation costs
- Known to farmers – Robust crop- Practices similar to sugarcane
- Gives fodder for cattle
- Gives bagasse similar to sugarcane – Energy for distilleries

A recent study on sweet sorghum as a supplementary feedstock to ethanol production [8] yielded encouraging results on yield and sucrose content, and comparable to sugarcane as shown in Figures 2 and 3.

Figure 2: Accumulation of sugar in different varieties of sweet sorghum at UNZA Farm.

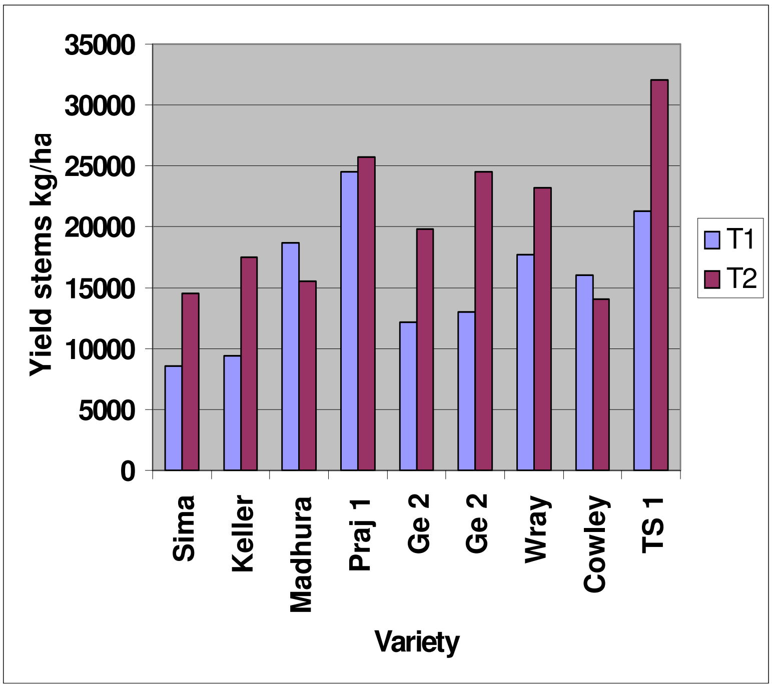
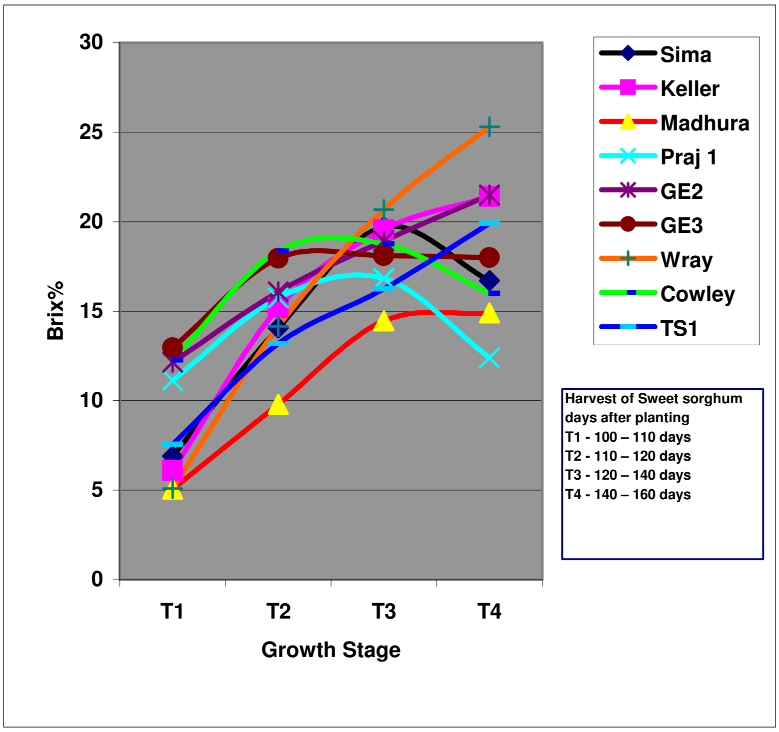


Figure 3: Accumulation of sugar in different varieties of sweet sorghum at UNZA Farm.



As indicated under markets for ethanol, an area of 250,000 – 350,000 ha for both sugarcane and sweet sorghum is required to meet a SADC market potential of 1.1 billion litres by 2015.

3.3.2 Biodiesel Markets

The amount of feedstock requirements in the region to produce biodiesel depends on the amount of diesel consumed and the level of percentage blending. Traditionally, conventional major feedstocks for the "methyl ester process" are cotton seed oil, soy bean and peanut oil. Another suitable feedstock for the "methyl ester process", which can be used and grown in Southern Africa, is Jatropha, in view of uncertainty of conventional feedstocks and also to avoid conflict between energy and food, since it is a non-edible oil. The characteristics of Jatropha that makes it superior to conventional feekstocks are listed below [9]:

- Jatropha curcas L. belongs to the family euphorbiaceae
- Growing period = approx. 100 days
- Drought resistant
- Grows on well – drained soils with good aeration, and is well adapted to marginal soils with low nutrient content
- Yield ranging between 5 to 10 tonnes per hectare
- Oil content = 40%
- Grows as a shrub, and needs no fertiliser

To meet an expected demand of 0.15 billion litres of biodiesel in the SADC market based on 5% blending ratio will require an area of between 800,000 – 900,000 ha of jatropha. This is based on extraction rate of 40% and average yield of 7 tonnes of jatropha seed per hectare.

Jatropha diesel fully complies with the current European EN14214 standards for automotive diesel [4]. Its cetane number is higher than hydrocarbon diesel enabling smoother and clean burn at high temperatures. When mixed with regular diesel, both fuels combust more clearly. Jatropha diesel's greater lubricity reduces engine wear and has a higher flush point. B5 jatropha blend can be used without engine modifications for mobile use [4].

Jatropha grows wild across sub-saharan Africa, India, South East Asia and China. If it is grown on a large scale involving small sale farmers on an out grower scheme, it has the potential to create a new agriculture industry to provide low cost biodiesel feedstock for both southern Africa, and exports to markets such as the EU.

3.4 Economics

3.4.1 Economics of Ethanol Production

To determine the project economics and financial viability (through the IRR route), requires knowledge of investment costs, operations and maintenance costs, and production parameters of typical sugar factories in the region. Given in Table 3 is such information. From the table, it is clear that the size of typical sugar factories in the region ranges from 100 – 500 tonne/cane hour.

Table 3: Production Parameters

Typical Factory Size	Actual output (tonne/ cane hr)	Actual output (tonne/annum)	Molasses-cane output ratio	Molasses production (tonnes / hr)	Alcohol production, (litres per day)	Investment Cost Molasses to Ethanol (Anhydrous)		O+M % of investment or output related
						Installed capacity, kL/day	Investment, (US$m)	
100	95.69	462,294	0.04	4	21600	20	2.30	5
150	160.04	688,226	0.04	6	32400	30	2.93	5
250	250.84	1,007,183	0.04	10	54000	50	3.99	5
300	305.47	1,211,236	0.04	12	64800	60	4.45	5
350	356.10	1,655,682	0.04	14	75600	70	4.88	5
400	408.96	2,217,396	0.04	16	86400	80	5.29	5
500	492.86	2,193,737	0.04	20	108000	100	6.04	5

Source [Reference 10]

Results of financial analysis (IRR vs Ethanol Production Price) were obtained for three scenarios, based on consideration of credits via the Kyoto Clean Development Mechanism (CDM), as follows:

- BAU without CDM consideration
- CDM scenario spread over 21 years, at US$5 per tCO_2
- CDM scenario with 33% down payment from sale of carbon credits, and the rest being sold over the remaining crediting period US$5 per tCO_2

Given in Figures 4, 5 and 6 are the results of financial performance for scenarios described above.

Figure 4: BAU Scenario (Ethanol Financials) for varying factory sizes

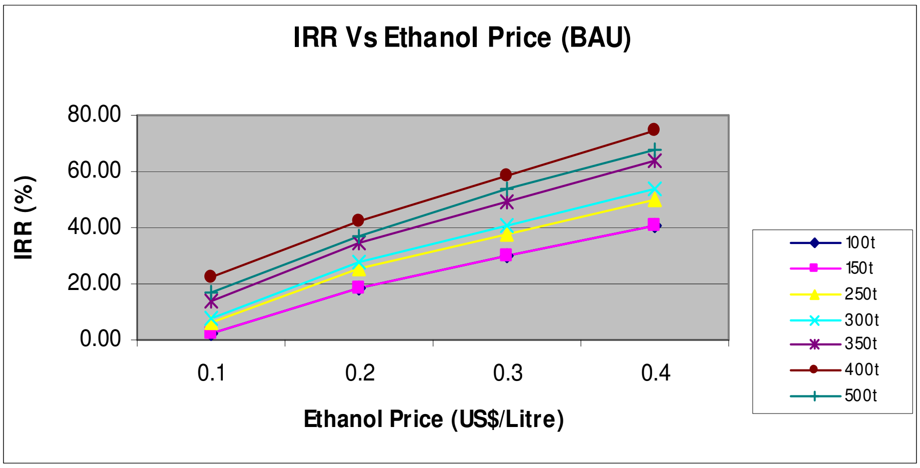


Figure 5: CDM (Spread) Scenario (Ethanol Financials) for varying factory sizes

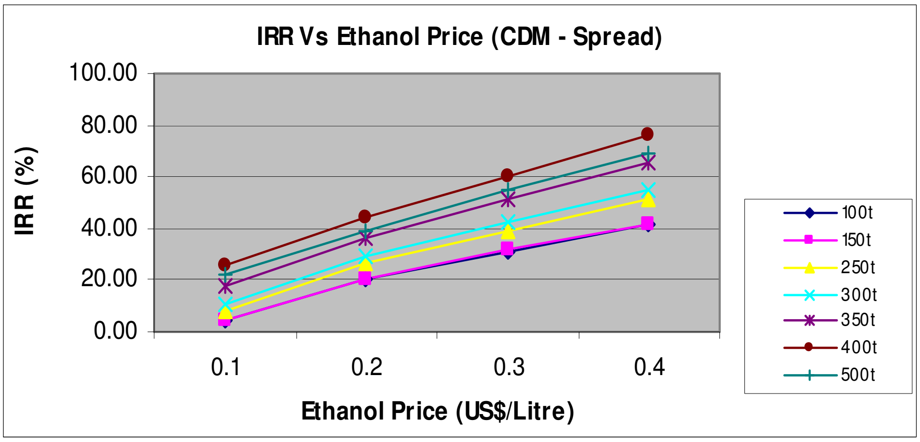
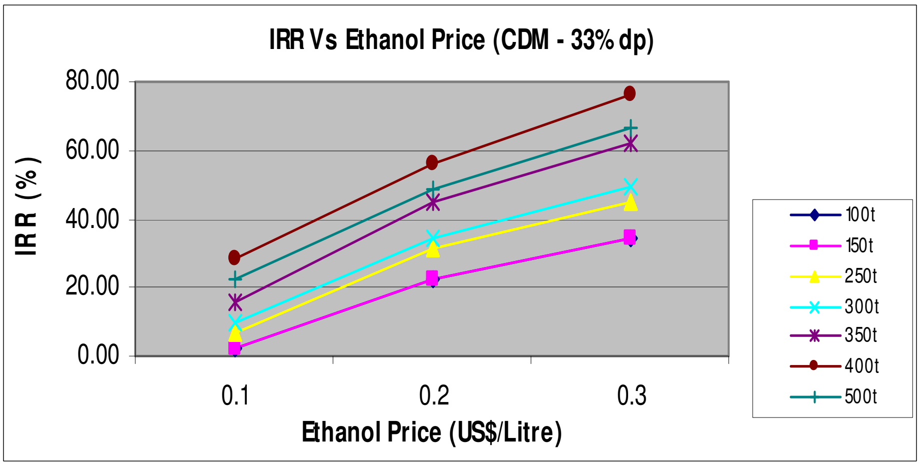


Figure 6: CDM (33% Down payment) Scenario for varying factory sizes



For each scenario, it is clear from the figures that larger plant sizes have a better financial performance due to economy of scale. Assuming an IRR of 20%, which is quite a reasonable return on investment, the ethanol production prices are given in the Table 4 below:

Table 4: Ethanol Production Prices for Different Scenarios at 20% IRR

Factory Size (tonne/cane hr)		100	150	250	300	350	400	500
Scenario	BAU (UScents)	21	21	17	16	13	10	12
	CDM Spread (UScents)	19	19	16	14	11	8	10
	CDM Advanced Payment (UScents)	18	18	15	13	10	5	9

It is clear from Table 4 that the ethanol price ranges between 10 and 21 US cents per litre for BAU. It ranges from 8 to 19 US cents for CDM spread, while it ranges from 5 to 18 US cents per litre for CDM advanced payment.

In case of Zambia, for example, the current gasoline price (ex-factory) is 40 US cents per litre [11], which gives an economic advantage to ethanol use as an octane enhancer. It is interesting to note from the above that CDM at US$5 per tonne CO_{2e} is not attractive to business. Unless the value of carbon credits is increased, it is unlikely that the business sector will be attracted by CDM.

Prices obtained from the local production compares favourably with Brazil, more competitive than U.S.A. depending on the feedstock (Table 5).

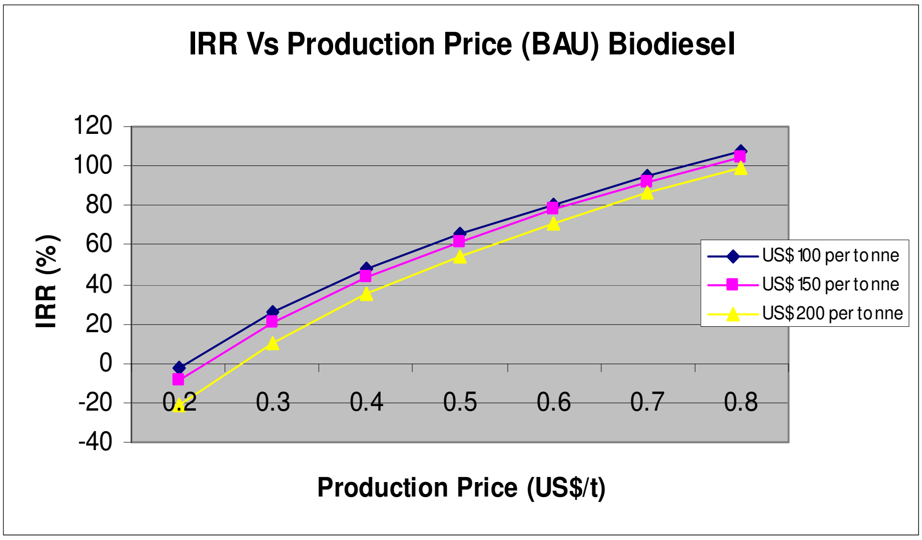
Table 5: Comparison of Local Ethanol Prices and Other International Producers

Country	Ethanol Price (Gasoline Equivalent) US cents	Feedstock
Southern Africa	20 – 25	Molasses Sweet sorghum juice
Brazil	20 - 25	Molasses Sugarcane juice
U.S.A.	40 – 50	Corn
EU	50 - 90	Cellusose

3.4.2 Economics of Biodiesel Production

Given in Figure 7 is the project economics for a 50,000-tonne per annum biodiesel plant with a capital outlay of US$20million, with an O & M cost of 60% of investment cost at different jatropha raw material prices.

Figure 7: BAU Scenario - economics for Biodiesel Production



NB: The curves show cost of raw material (i.e. 100, 150, 200 US$ per tonne)

The results above are for business as usual scenario. Using results from Figure 7, biodiesel price for different raw material prices at 20% IRR are given in Table 6.

Table 6: Biodiesel Prices for Different Raw Material Prices at 20% IRR

Raw Material Price (US$/tonne)	100	150	200
Biodiesel Price (US Cents)	28	30	35

From Table 6, the price of biodiesel ranges from 28 to 35 US Cents, which can be compared to 45 US cents for petroleum diesel [11]. The viability of biodiesel production depends largely on the price of the raw material and benefits accrued to farmers. Between the prices of US$100 to US$150, the economics of biodiesel production is relatively attractive.

As in the case of ethanol, biodiesel prices are equally comparative with other producers in Europe.

Table 7: Comparison of Biodiesel Prices

Country	Biodiesel Price (diesel equivalent), US cents	Feedstock
Southern Africa	30 - 35	Jatropha
EU	40 - 80	Rape seed Soy
EU	25	Waste oil

4. Regulatory, Fiscal and Policy framework

An important driving force for biofuels development is a conducive regulatory fiscal and policy framework. This is required to ensure that sustainable development benefits of increased biofuels development are properly reflected in holistic approach being proposed; including markets, distribution, production and economics.

Some of the policy issues that need elaboration include the following:

- Awareness and information programme
- Articulation on out-grower policy to enhance sustainable feedstock production and supply
- Articulation on land-use issues
- Articulation on policy of replacement of lead as an octane enhancer with ethanol
- Harmonisation of standards on biodiesel and ethanol
- Establishing organisational structures to transport or deliver biofuels product
- Assessment of socio-environmental impacts
- Tax incentives on technology and biofuels

5. Involvement of Stakeholders

No biofuels strategy can succeed without involvement of various stakeholders ranging from the public, policymakers, farmers and farmers organisations, technology suppliers and distributors, financial institutions, environment enforcing institutions, and last but not least, the private sector.

A critical issue of consideration is involvement and cooperation from automobile suppliers and distributors to ensure acceptable blending issues are agreed upon. This is essential for engine warranties to ensure public acceptability of use of biofuels.

For example, most countries are implementing blending ratios between E5 and E10 for ethanol, and B5 and B20 for biodiesel. However, with the advent of flex fuel car having a combustion engine with a flexible injection system, blends of fuel from E85 (85% ethanol and 15%) to 100% petrol can be used.

On the other hand, it is important to note that stationery compression combustion engines – in the diesel engine category including tractor engines can use up to B100/100% biodiesel without much concern.

6. Conclusions

Southern Africa has great potential to greatly benefit from the use of its natural resource endowment base to produce biofuels, and if implemented will go along way in achieving a sustainable energy path, and contribute significantly to poverty reduction through creation of numerous jobs from agriculture, processing and marketing.

To achieve such targets require a holistic approach, which requires considering the following:

- Markets
- Production processes/technology
- Feedstocks
- Economics
- Regulatory, fiscal and policy framework
- Involvement of stakeholders

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5
PAPER

Certification of Bioenergy from the forest: motives and means

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Under the Bioenergy Agreement, the International Energy Agency (IEA) has a number of Tasks dedicated to various aspects of the field of bioenergy. Task 31, *Biomass Production for Energy from Sustainable Forestry,* has been dealing with sustainability issues related to increased harvest of biomass for energy from silvicultural systems. The work is organised in three parallel themes:

- Environment; biodiversity, site productivity, carbon and nutrient budgets, water etc.
- Social implications; effects on rural and overall lifestyle, economy and development
- Economy; technology and efficiency incl. LCA of forest energy procurement systems

Based on leading-edge science and technology, the objective of Task 31 is to coordinate research, to compile and disseminate knowledge and promote the use of such information. The Task has a significant role in identifying research needs and opportunities, assimilating and synthesizing scientific and technical information, and identifying breakthrough technologies in relation to silviculture, forest management, harvesting and transportation in conventional forestry systems.

With the increased interest and urgency of developing new energy sources, mitigating climate change and environmental run-down, sustainability of such novel technologies has become an important issue for reasons of evaluation. With its expertise in the field of energy from forest biomass, Task 31 may make important contributions in this process.

Standardisation and certification

Standardisation is an important part of the industrial paradigm. In principle, it aims to minimise friction of transactions through common rules of measures, material properties etc. that have been agreed and described beforehand. Through standardisation, the customer is guaranteed that a product or service incorporates certain defined properties. Thus, these properties do not have to be independently investigated for every transaction. Certification serves the same aims as standardisation, but often relates to properties that are difficult or impossible to objectively measure on a specific product. As the use and international trade of biofuels increase, so will the need for relevant standards and certification, in order to simplify transactions and assure overall quality.

Currently, the European Committee for Standardisation (CEN) are developing a much needed technical standard for biofuels. Technical Committee 335 (Solid Biofuels), under leadership of the Swedish Standardisation Organisation, SIS, are preparing some 30 technical specifications for solid biofuels including classification, specification and quality assurance of solid biofuels. The classification will be based on origin and source. The specification and quality assurance includes detailed technical material characteristics of major traded forms such as briquettes, pellets, olive cake, wood chips, hog fuel, logs, sawdust, bark and straw bales. Significant properties such as calorific value, dimensions, mechanical durability, moisture, ash and sulphur content etc. are covered and classified by the standard. An interesting feature is that the standard will be coupled to CEN/TS 15234, a standard that covers fuel quality assurance and quality control. This means that traceability is guaranteed and that the full supply chain from source to end consumer is controlled and specified.

Certification has become an increasingly important factor in various situations. Different certification standards, address different needs; business, management, trade, environment and ethics etc. Some standards mainly concern technical specification and quality; others provide user safety assurance while others certify that specific rules of production have been adhered to for one or several tiers of the supply chain. The certification process includes

- the establishment of standards to be fulfilled by a party wishing to be certified
- certification, i.e. the procedure of checking that standards are met
- accreditation, which is the procedure of checking competence and credibility of the organisations undertaking to certify ('certification of the certifiers').

Forest certification and biofuels

There are several organisations that provide certification. A well-known example is the ISO (International Organisation for Standardization) with the 9000 and 14000 families of management standards. But the ISO standards are more concerned with the organisation and structure of environ-mental work, less with the setting and grading of performance. This, instead, is a focus of most certifi-cation systems for land-based products, which also normally emphasise sustainability and purpose-fulness of systems. Most of the accredited organisations for the significant systems of forest certification are NGOs. Governmental institutions and agencies have not had the needed credibility.

Certification of biofuels from forests should dovetail with the existing standards for forest management. Of twenty or so available standards for forestry and forest products, there is but a handful of international interest and importance, e.g. FSC (Forest Stewardship Council) and PEFC (Programme for the Endorsement of Forest Certification schemes). Both systems are resting on the three fundaments for sustainability: economy, ecology and social values and also apply the Chain-of-Custody principle, meaning that an agreed set of standards is certified for the entire supply chain throughout the forest sector.

The new CEN technical standards and a coupling of quality assurance of forest biomass for energy to the existing forest certification standards would represent major step forward. But this will not be enough. It is argued that evaluative measures, pertaining to the energy efficiency, fossil to renewable carbon quotas and other criteria that are needed to rank alternative energy options – also biomass of a non-silvicultural origin - against each other are also needed. Since the existing forest certification schemes are end product neutral, such modules must be developed within the biomass and forest energy sector.

Keywords: solid biofuels, forest fuels, certification, standardisation, sustainability, forestry

Introduction

Certification has become an increasingly important factor in various aspects of production: business, management, trade, environment and ethics are some of the issues that can be addressed through certification. The certification is normally audited by a separate, third-party organisation, that checks and verifies that the enterprise comply with the certification rules. There are several organisations that provide certification.

The basic idea behind certification is the same as for any standardisation and quality control through technical and economical standardisation, to minimise friction of transactions through common rules of measures, procedures, etc. that have been agreed to beforehand. Through certification, the customer is guaranteed that a product or service incorporates certain defined properties, and these properties do not have to be independently investigated for every transaction.

The most important areas for certification concern technical and administrative specification. ISO (International Organization for Standardization) is the world's largest developer of standards. Although ISO's principal activity is the development of technical standards, ISO standards also have important economic and social repercussions. There are two different, widespread types of ISO certification standards, the ISO 9000 and ISO14000.

The ISO 9000 family is primarily concerned with "quality management", i.e. what an organization does to fulfil:

- the customer's quality requirements, and
- applicable regulatory requirements, while aiming to
- enhance customer satisfaction and value added through logistic services, and
- achieve continual improvement of its performance in pursuit of these objectives

In the field of technical certification of biofuels, the European Committee for Standardisation (CEN) currently carries out some very important work. Technical Committee 335 (Solid Biofuels), under leadership of the Swedish Standardisation Organisation (SIS), is preparing some 30 technical specifications for solid biofuels including classification, specification and quality assurance of solid biofuels (Alakangas, Valtanen & Levlin 2005). The classification will be based on origin and source (woody biomass, herbaceous biomass, fruit biomass and mixtures). The specification and quality assurance is on detailed technical material characteristics of major traded forms such as briquettes, pellets, olive cake, wood chips, hog fuel, logs, sawdust, bark and straw bales. Significant properties such as calorific value, dimensions, mechanical durability, moisture, ash and sulphur content etc. is covered and classified by the standard. The specification will enable producer and consumer to make case-specific agreements on specifications that may be objectively controlled. The standard will be of utmost importance both to simplify transactions and assure overall quality as international biofuel trade increases. An interesting feature is that the standard will be coupled to CEN/TS 15234, a standard that covers fuel quality assurance and quality control. This means that traceability is guaranteed and that the full supply chain from source to end consumer is controlled and specified.

The ISO 14000 family is primarily concerned with "environmental management". This means what the organization does to:

- minimize harmful effects on the environment caused by its activities, and to
- achieve continual improvement of its environmental performance.

However, the ISO 14000 certificate mainly rates the structure and methods of environmental management in an organisation, and does not define and grade actual performance. For land based products, e.g. from forestry, certification has received a lot of attention in the last decades. But to other sectors, certification is not a new phenomenon. In the U.S., Underwriters Laboratories have been setting standards and certifying safety for electrical appliances for almost a century (Meidinger, Elliott & Oesten 2003). What is striking about forest certification is not the novelty of the idea itself, but that non-governmental organisations have replaced the public sector in performing the certification functions, largely to guarantee public credibility.

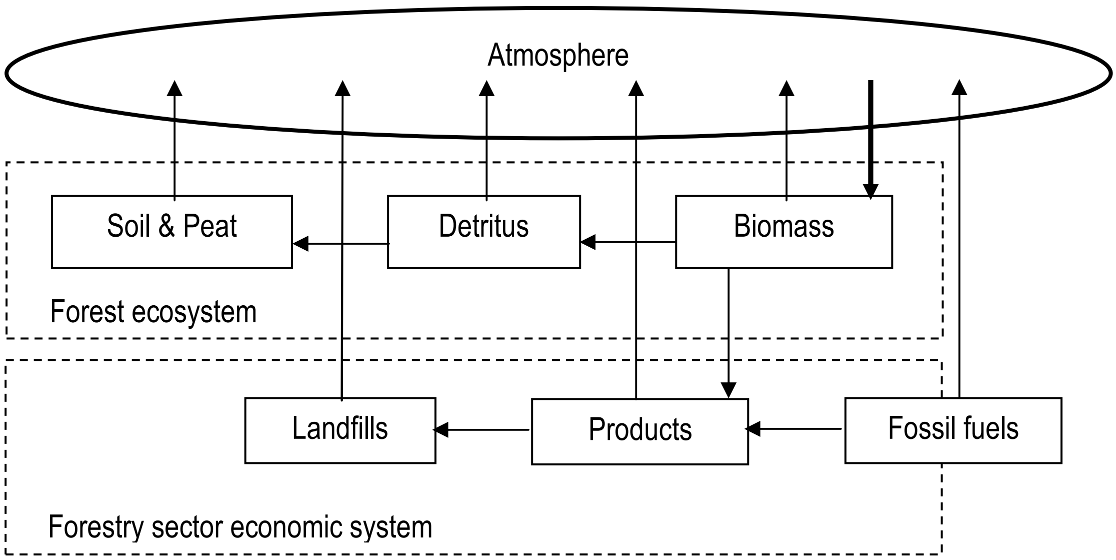
Obviously, it makes no sense to certify a forest as such. Instead, forest certification means that the people and organisations responsible for the management of a forest are doing their job properly. To achieve this, we must have a common understanding of what proper forest management means. Further the quality of forest management by the party applying for certification must be assessed by unbiased expertise who will certify that the forest is properly managed or withhold certification if this is not the case (Meidinger, Elliott & Oesten 2003). Thus, as compared to e.g. the ISO environmental standards, forest certification systems normally also define performance levels and achievements. That a forest product is certified as sustainable means that it has passed rigorous guidelines for responsible harvesting, ecosystem management and conservation, and long term sustainable management (Massachusetts Technology Initiative 2005).

Presently, there are around 20 different forest certification programs, of which only a few are affiliated with agencies and ministries (Meidinger, Elliott & Oesten 2003). There are three major standards for forest certification, SFI (Sustainable Forest Initiative of American Forest & Paper Association), FSC (Forest Stewardship Council) and PEFC (Programme for the Endorsement of Forest Certification schemes). Together, they are currently certifying around 250 million hectares of forestland as properly managed. From a European perspective, the two most significant systems are FSC (60 M ha) and PEFC (130 M ha). Both systems have basic rules that define sustainable forestry in general terms and then allows for specific national regulations.

The objective of this paper is to analyze plausible certification regulations for utilizing bioenergy and especially for energy based on forest biomass. The FSC and PEFC certification schemes will be examined and a further look at how forest energy utilization may affect the general principles of sustainable will be made.

The overriding rationale behind substitution of fossil fuels for bioenergy is to reduce the risk of detrimental climate change. Further, the development of bioenergy technologies is part of a drive for increased sustainability. The aim is to end the dependence of limited resources and to develop technologies with as small negative impact on the environment, and on the liberty of action of future generations, as possible. Although any type of biomass may be used to this aim, forest biomass plays the dominating role. Great importance is attached to forests and forestry as a means of fighting fossil GHG emissions and in the development of sustainable bioenergy systems. The role of forests in this struggle is not only due to its' potential as an alternative energy source with the ability to re-circulate carbon, but also through its potential to store carbon either directly in the forest ecosystem or in wood-based products. The principal workings of the forest and forestry systems from a carbon balance perspective are outlined in Figure 1. As seen in the figure, the forest ecosystem contains three main pools of carbon; live biomass, detritus and soils. When forestry converts live biomass into products, additional carbon pools appear in the form of more or less durable products or in landfills. All carbon pools leak carbon to the atmosphere, but only live biomass assimilates carbon from the atmosphere. The use of fossil fuels introduces fossil carbon to the atmosphere in an extent that is not balanced by this assimilation (Vine, Sathaye & Makundi 1999).

Figure 1. Carbon cycles of forest systems (after Vine, Sathay & Makundi 1999)



Forest management practices may be used in three principally different ways to decrease influx of carbon dioxide into the atmosphere:

1. Management for carbon conservation (of existing carbon pools in forests including forest preservation, fire and pest control etc.)

2. Management for carbon sequestration and storage (increased area and carbon density of forests, increased use of durable wood-based products etc.)

3. Management for carbon substitution (transfer of forest biomass into materials and products that can replace fossil fuel based energy and products)

When biomass is used in place of fossil fuel, net greenhouse gas (GHG) emissions are reduced, as long as the carbon dioxide produced through combustion of biomass is assimilated by new, growing biomass. But bioenergy is not truly GHG neutral since more or less GHG intensive inputs of energy are normally needed for the production, handling and transport of the biomass. Thus, the GHG balance of alternative production chains needs to be audited to ensure efficiency in GHG savings. In light of the aim to increase sustainability, it would be counterproductive to promote development of such practices and use of bioenergy that involve serious risk for environmental damages or that may cause unacceptable social effects. For example (LowCVP 2005), production of bioenergy crops on cleared virgin forest land may 'have implications for both biodiversity and GHG emissions. Large monocultures of bioenergy crops may impact on local biodiversity or place unacceptable demands on water resources.'

In conclusion, certification is needed to ensure that we 'get things right' and, due to the likely imperfections of the emerging alternatives, to provide decision support for choice of technology and for perpetual improvement of the chosen alternatives. A certification system for bioenergy must cover carbon balance issues as well as wider sustainability issues such as biodiversity, sustained yield (nutrients, soil and water management) and social issues such as health and safety, fair pay and equal opportunities. This puts bioenergy in the same class of commodities as other land-based products. Although it is possible to construct accreditation systems for bioenergy per se, it would also be advantageous if for bioenergy from forestry, the certification dovetail with existing and accepted forestry certification schemes to prevent confusion and duplication. This approach is discussed further in the following section.

Forest certification

The two major international standards of forest certification, FSC (Forest Stewardship Council) and PEFC (Programme for the Endorsement of Forest Certification schemes) are fundamentally very similar. They are based on the basics of sustainable forestry as outlined at the Rio summit (United Nations 1992). They endorse the promotion of sustainable forest management resting on the three principles:

- economically viable management of forests for present and future generations
- environmentally appropriate
- socially beneficial

For Swedish conditions both standards state that the forest management should make sure that (the quotation is from FSC 2003, but similar regulations can be found in PEFC 2005):

- *Extraction of biofuels complies with the recommendations of the National Board of Forestry and the volume removed is documented on a stand level. Fertilizing/ash recycling to compensate for biofuel extraction, liming of forest land, and revitalization fertilizing is carried out in accordance with regulations, general guidelines and recommendations of the National Board of Forestry*

The forest owner should in addition keep records of biofuel extraction on stand level. In the FSC standard there is also a general paragraph (FSC 2000):

- *Extraction of biofuels should not be made in such ways that it impairs the conditions for biological diversity*

So the recommendations from the Swedish National Board of Forestry are of vital importance. The Forestry Act states:

- *Under regulations issued by the Government, or public authority designated by the Government, a forest owner is obliged to notify the Regional Forestry Board of:*
  (i) felling operations and removal of logging residuals for fuel, to be carried out on his land;

In the Board's recommendations the following sentences are the only ones referring to utilization of biofuels (Swedish National Board of Forestry 1998):

- *Leave the needles in the forest and do not utilize other parts than the stem wood more than once during a rotation*

or

- *Compensate by fertilizing with nutrients (primarily using pure wood-ash)*

There are also some statements about the maximum supply of ash during a rotation (3 tonnes dry matter per ha) and in what form (stabilised and slow soluble).

All in all, the certification standards do not in any way prohibit the utilisation of forest fuels.

Finland has similar certification rules. To some extent stumps are extracted in Finland for utilisation as fuel, which require more precaution as the risk of damages and other negative consequences are likely to be higher in comparison with when only above-ground biomass is extracted.

Effects of forest fuel utilisation on sustainable management

Possible effects of the utilisation of logging residues for energy may be examined through the consequences of the practice to sustainable forestry, for each of the three main criteria of sustainability; economy; ecology; and social values.

Economy

Forest fuel utilisation is primarily positive to the economy. An additional assortment means an additional income. However, another positive consequence is that the removal of the harvesting debris facilitates the subsequent operations of regeneration. Planting, and to some extent also soil scarification, is much easier and therefore less costly on an area cleared from harvesting residues.

The major concern to the economy is the long-term productivity of the soil, and hence the long term economy. The removal of branches and tops add to the drainage of nutrients from a stand that harvesting implies. As long as the natural long-term soil nutrient status is maintained, the long-term productivity is secure; if not it will be jeopardised.

Studies have shown that even on fertile sites there is a risk of over-utilisation (Sverdrup et al 2002). The recommendation to leave harvest residues for one season to let the needles fall off the branches is due to this reason. The needles contain relatively more nutrients than the lignified parts.

Ecology

The most positive ecological effect of using forest energy is found not in the stand or even within a region, but on a global scale. The substitution of fossil fuels is increasingly important as the effects of the green house gases to the climate change become more evident. Forest energy is almost carbon dioxide neutral. Just a small amount of fossil fuel (~4% of the produced energy) is required for procurement, handling and transportation of the forest energy (Hansson et al. 2003).

In the Nordic countries, removal of branches and tops from logging sites seem to be insignificant with respect to preservation of biodiversity. But at the same time studies have shown that the high degree of utilisation in harvestings in the Nordic countries has led to a lack of coarse dead wood in the forests, compared to natural conditions. Coarse dead wood in various degrees of decay is important to numerous different species, many of them rare in the north European forests. Different kinds of insects, lichens and fungi thrive on the decaying wood. Hence, it is of importance that the collection of forest energy not gets overambitious, but leaves a sufficient amount of dead wood on the site.

The nutrient balance of the soil has an implication for the biodiversity as well. If nutrients are depleted the biological conditions may change so that the species present at a site may not prevail. This is a slow process and may be very hard to detect.

Social values

Studies on forest recreation preferences have indicated that harvest residues to most people is perceived as very negative (Lindhagen & Hörnsten 2000). The removal of harvest residues will in fact increase the recreational value of a site. Beside the aesthetics, which are very important to many visitors in the forests, the absence of residues increases the accessibility to a site. Even if most forest visitors stay on tracks and pathways, berry and mushroom pickers as well as orienteering people, appreciate the increased ease of mobility over an area.

Another major concern related to socio-cultural values governing land use is that a depletion of nutrients may change the natural conditions in an unfavourable direction.

Conclusions

Standardisation and certification of forest biomass for energy is needed to

- ensure public acceptance.
- simplify and rationalise international trade.
- render GHG control more effective.

Since global biotrade will be increasing, linking potential biomass surplus with biomass deficient areas, such standards must be global. Furthermore, the problems addressed through forest energy and bioenergy are global: the depletion of fossil fuels and serious climate impacts resulting from the increase of GHGs to the atmosphere.

It is important to assure credibility of the processes leading towards a bioeconomy based on biomass production and biotechnology. A way of assuring this is certification. The United Nations should support sound certification as a means of simplifying the transition to a bio-based economy. If certification is based on the degree of sustainability, this will support beneficial development from economical, social as well as from ecological perspectives.

For forest energy, it will be efficient to base certification on existing, international certification standards such as the FSC or the PEFC. This is however not enough. These standards are end-product-neutral. This means that the forest biomass is certified only as far as the supply chain within the forestry sector is concerned. Thus, it must be complemented with measures pertaining to the suitability of forest biomass for different technical applications (Technical standards) as well as with instruments enabling prioritizing between different fuels from the perspective of energy efficiency and carbon cycles and other relevant criteria based on social, economical and ecological impacts of the transformations of biomass in the energy sector.

The utilisation of forest energy has a positive implication on sustainable forest management in general. However, the nutrient balance of the soil has to be taken in concern, as a depletion of nutrients may have a negative effect on all the aspects (economical, ecological and socially) of sustainable forestry. Furthermore, to improve the biodiversity, the utilisation of forest energy must not lead to a decline of the amount of coarse dead wood in the forests.

Considering these issues the utilisation of forest energy is mostly favourable to the promotion of sustainable forest management. This is also reflected in the existing forestry certification standards which put no hindrance to utilising forest energy, even if they do not promote it explicitly.

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Governance of Industrial Biotechnology: Opportunities and Participation of Developing Countries

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Abstract

Industrial biotechnology promises to improve significantly process profitability, future market share of products made from biomass and reduce the environmental impact of industrial activity. Developing countries, that already possess significant amount of biomass, could exploit industrial biotechnology to improve their productivity, diversify their exports and develop their industries. However, the global governance of technology and trade, and national biotechnology policies may influence the participation of developing countries in the emerging bio-based knowledge economy.

This paper explores the current trends in industrial biotechnology and the potential impact of industrial biotechnology governance regime on the ability of developing countries to participate in international trade and improve their living standards. It argues that the wider participation of developing countries in the emerging bio-based economy will require formulating responsive and inclusive governance regimes that promote partnerships and alliances, provide greater market access, encourage technology transfer and development of consistent and predictable policies.

Introduction

The global biotechnology industry was estimated to have generated about US$54.6 billion in revenues (compared to just US$ 8.1 billion in 1992) and employed about 184,000 persons in publicly traded firms in 2004. An estimated US$21 billion was invested in biotechnology-related research and development (R&D) activities in 2004 [1]. Most of the revenues are driven by health biotechnology product sales.

Agriculture is one area where biotechnology has made significant contributions. Biotechnology is estimated to have accounted for about 15% of the total crop protection market (US$32.5 billion) and 16% of the global commercial seed market ($30 billion) in 2003. Genetically modified crops were planted on 385 million hectares of farmland. [2]

Although health and agricultural biotechnologies have received significant public interest and attention, the application of biotechnology in industrial process and production management has also grown tremendously. Most of the development in industrial biotechnology has been fuelled by advances in enzyme technology and metabolic pathway engineering. These developments have enabled the development of more versatile enzymes and micro-organisms that could work well under varying conditions.

The global market for industrial enzymes alone is estimated to be about US$2 billion and is expected to reach US$2.4 billion in 2009. [3] Nearly half of this market is composed of technical enzymes (enzymes used in detergents, pulp and paper production, among others) while food enzymes make up 37% and the remainder is made up of largely animal feed enzymes.

There is growing optimism that this century may be driven by technologies that exploit renewable resources, life processes and their convergence with other technologies (e.g. the convergence of biotechnology with nanotechnology, information technology and materials technology). There is also the convergence of industries, such as agriculture, pharmaceutical and manufacturing, mainly influenced by new advances in technologies. Biotechnology application cuts across all sectors of the economy by providing inputs, transforming manufacturing techniques and developing new and alternative products and services.

This paper seeks to explore the role international and national governance could play in enabling developing countries to participate effectively in the new bio-based economy and suggest how some elements of such a governance regime could be made more inclusive and responsive. The paper first provides a snapshot of the new developments and trends in industrial biotechnology and then addresses the governance elements that are likely to influence wide use of modern biotechnology advances in developing countries. These elements include governance of intellectual property rights, biosafety regulations, and access to international markets as well as measures to assist developing countries build sound national technological and productive capacities.

2 Trends and some Factors driving Industrial Biotechnology

2.1 Trends in industrial biotechnology

Industrial biotechnology applications encompass two broad categories. One category involves the applications that use microbes and/or enzymes to create new industrial products and services from renewable resources; and the other is composed of applications replacing conventional chemical or mechanical processes with biological systems in industrial production [4]. Although this categorization may be useful, there are substantial overlaps in terms of technologies, products and services.

An increasing number of firms are investing in industrial biotechnology application to broaden feedstock, improve performance of products and develop new products. Currently, about 5% of all products from the chemical industry are produced using biotechnology processes. It is estimated that in the next 5 years, about 10 - 20 % of all products will be made using biotechnology applications. This ratio is expected to be even higher in the fine chemical industry.

For instance, sugar is expected to be a major feedstock for the chemical industry for the production of ethanol and a range of other new building blocks for new products (e.g. sweeteners, hydrogen, polyactic). Similarly, the development of biotechnology techniques to convert cellulosic material into fermentable sugar for the production of fuels is likely to reduce the cost of biofuels to below that of gasoline. Iogen Corporation's cellulosic ethanol pilot plant uses wheat straw to produce ethanol (700,000 litres annually) at about $1.08 a gallon. Other firms such as DuPont, Genencor, John Deer and Novozyme are investing in development of similar technologies.

The global market of renewable fuels and chemicals from biomass is estimated to reach $150 billion by the mid of the 21st century [5]. This may be driven by research in fuel cells that could use methanol, ethanol, biogas and hydrogen or combinations of them to generate electricity from a variety of materials (e.g. grass, garbage, agricultural remains). Some research seeks to bypass the costly fermentation process in the generation of biofuels by using genetically engineered organisms capable of converting biomass directly into alcohols.

The range of products (e.g. amino acids, acrylamide, indigo dye, methanol, ethanol, lubricants, polylactide and 1,3 propanediol) that could be produced from biomass using enzymes is likely to increase in the next few years. Major business houses with interests in specialty chemicals include BASF, DSM Dow and DuPont [6], most of which are pioneering their own technologies or collaborating.

For example, NatureWorksLLc, formerly Cargill-Dow, is working with plastic manufacturers to use their polymer, polylactide (PLA) to produce a variety of bioplastics from biomass. Metabolix also produces a wide range of polyhydroxyalkanoates (PHAs) [7] using microbes as biofactories. There is increasing interest in the conversion of biomass into bioplastics that could be used in many applications. For example, NEC Corporation announced in 2003 the development of a bioplastic that is substantially resistant to heat with possible applications in electronic devices [8] by reinforcing polylactic acid with kenaf fibre. The temperature for deformation of the bioplastic was raised from 67 to 120 degrees Celsius.

Another example is the Swiss biotechnology firm, 2B Biorefineries AG, which produces ethanol, protein concentrates and technical fibre from grass [9]. The protein concentrate is suitable in the preparation of animal feeds. Such developments offer developing countries that possess adequate biomass opportunities to diversify their product range and expand exports. They also present many opportunities for overcoming environmental challenges, creating employment and expanding business opportunities.

2.2 Favourable government policies

There are many factors that are driving the growth of industrial biotechnology. Among others, government policies, environmental concerns, economic benefits and new industrial opportunities are playing a prominent role. For instance, research in the bioenergy sector has been driven largely by favourable government policies. Governments have promoted bioenergy to reduce dependence on imported petroleum, create a market for excess agricultural produce and employment in rural areas, and develop new industries, among others.

The successful ethanol production in Zimbabwe and Brazil and the successful co-generation of electricity from bagasse (and coal) by sugar mills in Mauritius are just among many examples where government interest played a greater role in bio-energy sector. Several countries, including Brazil, Columbia, Cuba, India, Thailand, Mexico and the Philippines, provide incentives to their sugar industries to promote co-generation of electricity from bagasse, a technology that was pioneered in Mauritius and Hawaii.

Similarly, biorefineries in the US also benefit from government support. The Energy Bill passed by the US Senate in August 2005 is another example. The bill seeks to boost production of fuels, power and other products from biomass through an investment of about US$3.6 billion and requires U.S. gasoline suppliers to blend 8 billion gallons of ethanol annually into the domestic fuel supply by 2012. Such support will in turn stimulate investment in biofuels.

Public interests or concerns are also playing an important role in the biotechnology revolution. The increasing consumer concerns over antibiotics used in animal production and consumer interests in natural products are fuelling the growth of the market for bio-based products (e.g. probiotics and nutraceuticals). On the other hand, public concern on the use of genetically modified (GM) crops and animals is limiting the adoption of transgenic crops and animals for industrial use.

2.3 Economic and environmental benefits

At firm level, economic benefits play an important role on the decision whether to adopt a biotechnology application. A survey conducted by the OECD showed that firms are likely to adopt a biotechnology application if it at least some of the following conditions are met: reduce the cost of production, improve quality, lower investment, had an experienced partner(s) in the new technology and improved the quality of the working environment (See Table 1 below).

Table 1: Summary of main forces for adoption of a biotechnology process by three firms.

Company	Hoffmann La-Roche, Germany	DSM, Netherlands	Mitsubishi, Japan
Product	**Riboflavin (vitamin B2)**	**Cephalexin (antibiotic)**	**Acrylamide**
Economic	**Increased productivity; 50% reduction in cost**	**Efficiency and improved quality**	**Low investment in equipment**
Environmental	**Reduced emissions**	**Reduced waste and toxicity**	**Low energy consumption**
Process	**1-step instead of 6**	**4-steps instead of 10**	**Simple**
Length R&D	**7 years**	**5 years**	**9 years**
Determinant	**Science push**	**Competition**	**Economic factors**

Source: (OECD, 2001).

2.4 Science Push

Although science push alone is not sufficient to stimulate the adoption of biotechnology applications by firms, it plays a major role in technology adoption. For instance, estimates based on current and future technological developments that suggest the US farmers will make about US$5 billion in profits annually by 2025 and the US could save about US$20 billion per year by 2050 if it adopted an aggressive plan to produce 180 billion gallons of cellulosic fuels by 2050, [10] which may influence government policies and private sector interest. As the technology matures, more firms are likely to adopt biotechnology applications.

3. The Governance of industrial Biotechnology

3.1 Legal and regulatory policies

International and national policies influencing biotechnology vary widely between nations but broadly fall into two categories: (1) intellectual property rights; and (2) biosafety regulations. These policies affect technology development, dissemination and use as well as trade in biotechnology products and services. They also could be used to undercut development, limit access to potential markets and development of domestic innovative capacity.

Intellectual property rights

The extension of intellectual property rights to cover living forms is particularly significant, given the fact that historically, living organisms fell outside the scope of protection of most intellectual property systems. The biotechnology industry has argued that the absence of intellectual property protection for living organisms undermined innovations and funding prospects for biotechnology research [11].

Critics argued that such property rights are inconsistent with morality and are too wide [12]. In other words, the extension of intellectual property rights to cover living organisms is seen in some sections of society as being against the public interest [13]. Finding the right balance between public interests and private benefits remains the goal of many patent offices.

There are fears that intellectual property rights, especially patent monopolies, could also be used to block or stifle technology development and transfer. Peter Ringrose, Chief Scientist at Bristol-Myers, summed this as follows: "...There are more than 50 proteins possibly involved in cancer that the company [Bristol-Myers] was not working on because the patent holders either would not allow it or were demanding unreasonable royalties" [14]. Similar sentiments have also been expressed in stem cell research where the fees to access key materials and technologies are proving prohibitive and the conditions attached are restrictive. [15] Patent offices are faced with the challenge of establishing an adequate level of intellectual property rights protection that stimulates investment in R&D and also promotes innovation and technology transfer.

Experience in agricultural biotechnology suggests that the impact of intellectual property rights on the ability of developing countries to participate in the new bio-based economy depends on the nature of the research, level of technological development and enterprise size. Public sector research programmes remain particularly vulnerable to changes in intellectual property regime because of their traditional dependence on public domain technologies and lack of adequate knowledge of intellectual property practices. Although this situation is starting to change, many developing countries are still far from mastering the details of inventive activity.

Furthermore, most developing countries are still in the early stages of technological learning where access to technologies is essential for industrial development. First, developing countries will need to ensure that they meet the minimum requirements for intellectual property protection and create suitable environments for inventive activity. In turn, developed countries should help increase the level of trust in the intellectual property system by seeking to balance strong intellectual property protection with the need to broaden the base for technological partnerships with developing countries.

Agricultural biotechnology firms are exploring ways of sharing their patented technologies with developing countries under special institutional arrangements, including flexible licensing arrangements. For example, fourteen (14) leading public research institutions and foundations in the USA, [16] specializing in crop improvement and technology transfer, have requested free access to patented biotechnology advances to speed up crop improvement nationally and worldwide. Similar measures may be needed in the field of industrial and environmental biotechnology.

Biosafety regulations

Another major area of policy development is the emergence of new rules that seek to govern biological inventions on the basis of their presumed risks to human health and the environment [17]. These policy measures come under the general umbrella of "biosafety" and are the subject matter of the Cartagena Protocol on Biosafety to the Convention on Biological Diversity. The Cartagena Protocol provides a set of policy guidelines that have implications for the development of biotechnology [18].

One of the most significant features of the protocol is the promulgation of the precautionary principle as a tool for risk management in the face of uncertainty [19]. This is a contested field, because of the potential for the principle to be used as an instrument for market protection [20]. The critical policy issue here is how to establish an international standard that ensures human and environmental safety, and encourages international trade.

Another area that might require special attention is the use of environmental regulation to promote industrial sustainability. This regulatory field is relatively new, but it offers opportunities for expanding the adoption of environmentally sound biotechnologies. The main limiting factor is the low level of use of environmental regulations to promote the adoption of alternative technologies in developing countries. These include measures that seek to reduce the consumption of non-renewable raw materials and replace them with bioproducts.

3.2 Market access and trade policies

Agricultural products, that are likely to form the basis of the next revolution of renewable products, already face many entry hurdles on the international market. These include high tariffs, quota allocations, voluntary export restraints and non-automatic licensing, among others. Agricultural exports to developed countries suffer most from tariff peaks and tariff escalation [21].

Products that suffer from incremental applied tariffs by stage of production include leather, textiles, rubber, metal, wood and paper. Taken together, tariff peaks and tariff escalations discouraged vertical diversification into high-value products. Tariff peaks and escalations also discourage skills accumulation and technology development as they encourage export of raw materials.

This is compounded further by the high levels of subsidies to agriculture and export products in developed countries [22]. Subsidies undermine the comparative advantage of poor farmers by supplying cheap products on the local and international market. In the absence of 'fair' market regulations, it is not surprising that developing countries do not invest heavily in export industries linked to the processing of raw materials.

Industrial biotechnology may also expand or provide an alternative domestic market for farmers. For instance, biorefineries in developing countries could utilize maize to produce a variety of products such as syrup, gas (carbon dioxide), alcohol, feed additives and flour and represent a big market for maize farmers. Such activities could stimulate the development and transfer of advanced technologies. Current initiatives that turn grass into fuels, protein cakes and fertilizers may fuel livestock production and facilitate national development.

Although the global biotechnology industry is dominated by firms from developed countries, it is quickly becoming global. There are several private firms in developing country that are involved in industrial biotechnology. Asia's biotechnology industry is growing fast and Asia is also the fastest growing market for feed additives. While their share of industrial biotechnology products is small, they present an emerging market for enzymes as they expand their productive base, fuelled by the fast pace of economic development.

Therefore, efforts to reduce market entry barriers of products from developing countries produced using industrial biotechnology may encourage its wide adoption and provide a win-win situation.

3.3 International alliances and partnerships

The development of complex interlinkages involving a wide range of enterprises designed to reduce the risks associated with the development of new products define biotechnology industry relations. These networks seek to facilitate access to and transfer of technology and information exchange, and reduce risks associated with product development, production and marketing.

There are at least four factors that promote the development of collaborations and partnerships in biotechnology: 1. the multidisciplinary nature of biotechnology R&D activities; 2. increasing complexity of biotechnology R&D; 3. uncertainty of commercial success of biotechnology R&D products and; 4. the cost of biotechnology R&D activities. [23] These factors are further compounded by growing restrictive and/or lengthy regulatory regimes or requirements that increase the cost, risk and uncertainty.

Although these arrangements are concentrated in developed countries, partnering arrangements could, potentially, play a key role in the development of technological capabilities in the firms and institutions in developing countries. Such capacity would be specialized and related to specific products and services. Furthermore, such partnering would also be useful in promoting the adoption of good management as industrial production standards in developing countries.

The evolution of Biocon India, a company established in 1978 in Bangalore as a joint venture between Biocon Biochemicals of Ireland and local interests, illustrates the importance of international alliances [24]. The company started with the production of simple fermentation products and later embarked on its own R&D programme, becoming a major player in the fields of modern biotechnology.

One of the first efforts was to develop a method of producing amylases and proteases from a carefully cooked soybean meal and roasted wheat and then sold its enzymes to Biocon Ireland. Biocon India has become the owner of new fermentation technologies, and two manufacturing plants that were commissioned to meet demand for food enzymes by their clients in the United States and European markets.

The story of Biocon India is an example of the importance of international partnerships. Biocon Ireland provided the market for the resulting products, enabling the newly formed firm to have a steady flow of income as well as eliminating marketing costs of products. In 1989, Biocon Ireland and its 30 per cent share in Biocon India were acquired by Unilever. Unilever's financial muscle and global standing gave Biocon new linkages and access to funds, global operating procedures, standards and financial methods. This model carries with it the attributes of inclusion that should be encouraged in the development of industrial and environmental biotechnology.

4. Biotechnology Development Strategies

National policies play an important role in the development and use of new technologies. There are some common features of successful biotechnology development strategies. These include:

- Clear Government plans to develop a biotechnology industry with benchmarks (e.g. number of scientists to be trained, products or firms to develop and technologies acquired) on activities to be attained by each stage of development (The Republic of Korea is a good example).
- Establishment of biotechnology-related programmes (research, development and marketing) in universities and national research institutions.
- Involvement of the private sector in planning the biotechnology development agenda through matching funds, sharing facilities and technologies.
- Establishment of international collaboration and partnerships for research and development, production and marketing e.g., technical cooperation.
- Provision of public venture capital to fund small start-up firms and commercialization of research products.
- Policies and programmes that stimulate entrepreneurship in public institutions and investments. These include policies on commercialization and ownership of knowledge and allowing scientists to interact freely with industry.
- Incentives for public-private partnerships. These include government contracts, directives on publicly-funded projects and international strategic partnerships.

4.1 The need for clear and consistent energy policies: the case of bioenergy in Africa

Following the oil crisis of 1973 and the fall in sugar prices, some African countries considered production of bioethanol to reduce their dependence on imported oil. The case of Zimbabwe and Kenya highlight the need for clear and predictable policies to allow corporate planning.

In Zimbabwe, Triangle Ltd, a private sugar production firm, decided in 1975 to use surplus molasses to produce ethanol. A Germany firm agreed to supply only a "turn-key" facility [25]. By the mid 1990s the plant was producing about 40 million litres per year and a blending ration of 13:87 (ethanol to gasoline) had been attained, slightly lower than the target ratio of 15:85. Ethanol production increased incomes of about 150 cane farmers, facilitated acquisition of advanced technologies and consumed molasses, formerly a waste product. This success was partly based on a ready and influential customer- National Oil Corporation of Zimbabwe - which bought the ethanol and sold it to various oil distribution firms. [26]

In contrast, Kenya's success was short lived even though its 60,000-litres per day ethanol plant created employment for about 1,200 people. Although the failure was partly blamed on drought and pricing, the lack of government commitment and clear production, blending and marketing policies is thought to have accounted for much of the failure.

A sound government policy should at least:

- Seek to maintain stable supply and, indirectly, prices especially in the initial stages;
- Provide predictable regulatory and fiscal incentives;
- Set clear, quantifiable and verifiable targets;
- Encourage diversification, investment and efficiency and;
- Promote innovation and technological upgrade and development.

The need for policy stability and clarity is more important especially following the current liberalization of energy markets developing countries and in keeping with their trade commitments enshrined in international agreements.

4.2 Encouraging public-private-partnerships

Public-Private Partnerships (PPP) could facilitate technology development, transfer and diffusion. Such partnerships facilitate the development of friendly regulatory policies, public support for technology and reduce costs of technology development. Such teams identify areas of interests, challenges and opportunities, and could also serve as a lobby group for the biotechnology industry development, create awareness and promote co-development of business ventures.

Some of the technological niches that industrial biotechnology may provide will require favourable government policies, such as tax and financial incentives, to succeed at least in the initial stages. Even when governments do not fund the projects, they could provide credibility and guarantees to financial and technology suppliers. In general, such teams may be formed around technological and market niches.

These teams also play an important role in the development of technology and business incubators or business accelerators. National Government, municipal councils, industry and academia could work together to establish incubator facilities or business accelerators where scientists, industrial experts and students could develop their ideas into concepts and concepts into products and services by providing working space, and access to administrative, professional, technical and managerial support services. University incubators may be cheaper to develop especially in poor countries.

4.4 Utilizing international agreements to acquire technology

Developing countries wishing to acquire advanced technologies could enter in bilateral science and technology agreements, utilize multilateral international agreements and identify developed country initiatives (home country measures) that could benefit their firms. In particular, international science and technology agreements (ISTA) could facilitate the formation of international R&D collaboration and alliances between institutions of partner countries. R&D agreements, such as memorandum of understanding (MOU), mutual recognition agreement (MRA), cooperative research project (CRP) and implementing arrangement, among others, could help leverage national financial resources for large or expensive projects, tap expertise and natural resources located in other countries, and promote scientific and industrial relations. Currently, most of the ISTA are between developed countries. [27]

For instance, the agreement between the Republic of Korea and Russia of 1990, created the Korea-Russia Scientific and Technological Cooperation Centre in 1991. The centre was established to utilize Russian R&D expertise in areas where Korea was weak. The goals include: acquisition of technologies that are difficult to acquire from other countries, utilize Russian experts to facilitate development of small and medium enterprises, develop joint ventures and to manage the Venture Technology Incubation Centre.

There are also several multilateral agreements, such as TRIPS, GATS, SPS and TBT[18], and multilateral environmental agreements which contain clauses that seek to facilitate transfer of technology to developing countries. Although making these agreements operational remains a complex issue, several developed countries have adopted measures that directly or indirectly facilitate technology transfer. A survey by UNCTAD of 41 agencies revealed that only 7 support direct transfer of technology to developing country partners. [28] About 19 support training of industrial workers. The majority provide FDI-related incentives and matchmaking services to their enterprises [29].

For instance, the Canada-Brazil and Southern Cone-Canada Technology Transfer Fund (TTF) supports Canadian enterprises and organizations that wish to transfer their expertise and technology to partner organizations in Argentina, Brazil, Chile, Uruguay and Paraguay[19]. The Fund, which is administered by the Canadian International Development Agency (CIDA), provides grants to enable the successful transfer and adaptation of Canadian technologies in partnership with local organizations. About CAD$18 million was used to support 27 projects during the first phase of the TTF (1996-2001).

Similarly, Biopower - a 20-megawatt plant that will convert rice husks into electricity for sale to the Electricity Generating Authority of Thailand (EGAT) - benefited from investment by Finnfund [20], as one of the major shareholders. Other major investors include Al Tayyar Energy Ltd., Private Energy Market Fund, Flagship Asia Corporation and Rolls-Royce Power Ventures.

These measures, however, could play an important role in development of industrial biotechnology at institutional and firm level. In particular, measures such as matchmaking, partnership requirements, training of workers and financing of technology transfer could help knowledge flows, skills accumulation, create familiarity with the technology and adoption by firms. Developing countries could stimulate the emergence of many such measures and improve their effectiveness.

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[18] TRIPS- Agreement on Trade Related Aspects of Intellectual Property Rights, TBT- Agreement on Technical Barriers to Trade, SPS- Agreement on Sanitary and Phytosanitary Measures, GATS- General Agreement on Trade in Services.

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[20] http://www.atbiopower.co.th/indexe.html

Conclusion

Industrial biotechnology, if harnessed and used responsibly, could help developing countries diversify their product range, increase production and promote exports. Many developing countries have abundant renewable sources. These resources could be used in sustainable manner to build new industries and create employment. Industrial biotechnology could also help to prop up local industries, minimize environmental pollutions and provide a ready market for local products - providing additional sources of income and improving the quality of life of their people.

The realization of these opportunities may depend on the global and national governance of technology and trade. Measures that will promote transfer and diffusion of industrial biotechnology in developing countries' economies may be effective in ensuring the inclusion of developing countries in the bioeconomy. These measures include international partnerships and alliances, national investment in technology development and participation in international science and technology projects. Developing countries that improve their domestic technological base and intellectual property rights may benefit from such cooperation.

However, the diplomatic and scientific skills of developing countries to negotiate ever increasingly complex market and technology access issues will be required to enable their wider participation. These will include negotiations to reduce tariffs on finished biotechnology based products, moulding responsive intellectual property rights and establishing levels of safety that promote industrial and technological development as well as trade.

National government will also have to provide consistent policies to enable investors plan and incentives to stimulate R&D and uptake of industrial biotechnology alternatives by firms. In the early stages, governments may have to provide financial incentives, including tax rebates, in areas of interest and friendly regulatory environments that permit learning and adoption of these technologies.

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7
PAPER

The forgotten waste biomass; two billion tons for fuel or feed

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Demographers have revised scenarios of population growth down from a predicted 12-14 billion mouths to around 8 billion [1], predominantly middle class people who will desire a diet containing animal products, and will wish to travel in motor vehicles. The same amount of grain is needed for these 8 billion people and their animals as for 12 billion impoverished human grain eaters. With almost all arable land under cultivation, and more land leaving production than entering, where will the food needed to feed expanding humanity come from?

About half of the above ground biomass of grain crops is wasted: the straw that bore the grain. Most of the ca. two billion tons of the rice, wheat, and maize straw produced annually in the world has a negative economic value. Much of it had been burnt after harvest to kill pathogens; after burning was banned, fungicide use increased. Straw temporarily binds mineral nutrients after being ploughed-under, often requiring additional fertilizer in the following crop, with negative economic and environmental consequences. Note that the straw of maize and sorghum is often termed "stover". Small amounts of straw are fed to ruminants as roughage or as an extender to animal feeds, but very little caloric value is derived from it. Similarly, industrial projects to enzymatically degrade straw and produce ethanol from the sugars have about a 20% efficiency, due to much of the polymeric carbohydrates in the straw remaining undigested. Earlier, the sugars and amino acids digested from polysaccharides and proteins are exported from the leaves and stems during grain filling, leaving straw with highly indigestible material. Most of what remains in straw by harvest time is hemicelluloses (mainly xylans) and cellulose, but their biodegradation by ruminant bacteria is prevented by a smaller component of lignin. Very small amounts of lignin intercalate into and around the cellulose and prevent biodegradation due to asteric hindrance of the cellulolytic enzymes [2].

Breeders have tried to breed straw with higher digestibility, within the limited variability of the genomes of the various crops. Brown mid-rib mutations in maize and sorghum have been isolated that have lower lignin and higher digestibility. They have been used to breed forage (silage) maize and sorghum, invariably with somewhat lower yields, which can be economically compensated for by the greater digestibility[3-6]. The brown midribs are the result of mutations at various loci in lignin biosynthesis, which lead to slightly less lignin as well as a modified composition. These modifications lead to the signature brown midribs, allowing for easy mutant screening. There may well be mutations in lignin composition/quantity that do not have this signature, but they would be too hard to discern as there would be no visual phenotype to be detected. There are always often unclear correlations between brown midrib and lodging, the propensity of stems to buckle over in high winds. For example, in a multiple variety sorghum field test the brown mid-rib variety had a high frequency of lodging, but so did one of the conventional varieties [5]. It remains unclear whether it is the total lack of a critical enzyme in the brown midrib varieties (instead of a genetically engineered modulated level) or a yield reduction that will always be present, or a linkage disequilibrium.

Possible biotechnological solutions to the lack of digestible carbohydrates

The basic solution to the environmental problem of straw waste and the future needs for grain to feed people, as well as a potential solution to long range predictions of food shortages is to transgenically modify straw so that it can be utilized by ruminants [7-9], as ruminant animals can digest cellulose and hemicelluloses, unlike mono-gastric animals. The same enzymes used by ruminants are used to produce the sugar for bioethanol production. Plant material containing more cellulose or less lignin, or with modified lignin composition is more digestible by ruminant animals. For each percent less lignin, 2-4 times more cellulose is available to ruminants. Wheat and rice have very little genetic variability in straw composition, so it is doubted that classical breeding can provide a solution. Chemical and physical treatments to enhance digestibility (e.g. [10] have not been cost-effective. Increasing ruminant digestible material by 20% would upgrade the nutritional value of straw to that of hay, and meat could be produced using straw as a major carbon source, considerably decreasing the amounts of feed grains that must be used to feed cattle. The same straw could be used for more efficient bioethanol production. This can be achieved transgenically, creating lines with increased cellulose having a more open (biodegradable) structure using the CBD gene, and separately or together using RNAi techniques to modulate the lignin content.

Rice straw will require further modifications than those discussed below as the general case, because rice straw typically contains silicon inclusions, which can render the straw unpalatable, and possibly undesirable.

State of the art

Considerable efforts have been expended to decrease chemical wastes during paper pulping by transgenically reducing the lignin content or composition of trees [11]. Affecting the genes controlling biosynthesis of lignin monomers has led to a beginning of understanding of lignin biosynthesis and its relationship to cellulose availability. Yet there are many basic compositional differences between tree and other dicot lignins and those of grasses, and it is thus not clear how much one can extrapolate from dicots to grasses. Genetic modification/reduction of lignin by classical breeding using the brown midrib types enhanced digestibility of some forage crops. Mutants that would allow breeding decreased lignin have not been identified in small grains such as rice, wheat and barley, probably because the genes for lignin biosynthesis are in multigene families in grains, which are not amenable to modification by single mutations. Furthermore, most sources of variability would probably be quantitative, where more than one isozyme may have to be suppressed, requiring extensive breeding to modify lignin without modifying other grain quality characters. Partial (but not major) reduction or change in straw lignin composition should leave dwarf and semi-dwarf wheat and rice with sufficient strength to resist lodging. It is a general misconception – totally without proof, that lignin is singularly responsible for the structural stability that prevents lodging. A comparison of lignin content in straw and the susceptibility to lodging showed no significant correlation [12]. Indeed, it is not easy to understand the chemical and structural factors involved in lodging, but attempts are being made, both genetically and physically.

Lodging is typically precipitated by wind combined with rain or irrigation and may result from buckling or partial breaking of the lower stem, or from the roots twisting out of the soil. The latter should be more correctly termed “dislodging”. The driving force of both is the drag exerted on the grain head. In practice, wheat varieties with short stiff stems are often more resistant to stem buckling while wheat cultivars with compliant stems may be less susceptible to root lodging in wet or water-saturated soils. Breeders and agronomists as well as genetic engineers must balance the competing constraints imposed by stem rigidity and flexibility to select the best varieties for wet vs. dry environments to deal with stem buckling vs. anchorage. We have not seen where varieties that are susceptible to lodging have been divided between these two very different physical reasons based on lignin content. Whereas dwarf and semi-dwarf varieties have less stem to lodge, they have larger grain heads, acting as bigger sails in the wind. As drag is presumably a function of sail size, some if not much of the drag should be on the awns that spread out from the heads, unless they act as some sort of damper due to their spiky structure. We have seen no comparisons of lodging resistance between awnless vs. awned isogenic lines of wheat or barley. The question of awns has not been addressed by the physicists and breeders dealing with lodging.

There is another potential cause for lodging that was not widely discussed; corn borers. Corn-borer damage to a stem renders the stems far more susceptible to damage by wind due to the structural damage, just as termites weaken a house. There have been claims that low/modified lignin maize varieties are more susceptible to lodging. Is that because the plants are inherently less strong, or that the more digestible plants are more appetizing to corn borers? An analysis of QTLs for lignification show that many co-localize with those of resistance to corn-borers [13]; i.e. borers are not stupid; indigestible cell walls are probably less appealing. Rootworm damage is also highly correlated with susceptibility to root lodging, especially under environmental stress, but this was not correlated with lignin content or composition. The problems of corn-borers and root worms can only be ignored when modifying lignin at the risk of not coming up with a useful, highly digestible crop.

Transgenically enhancing straw digestibility

The solution to increasing digestibility without affecting important varietal traits is to transform elite material to have modified lignin and cellulose contents. Partial silencing of the phenylpropanoid pathway enzymes leading to lignin is encoded by gene families (Table 1). Partial silencing can be achieved by antisensing or other RNAi strategies using small interfering RNAs (siRNAs) that conform to consensus sequences of a gene family. Most of these genes have already been partially silenced in dicots [14], changing monolignol levels, increasing cellulose levels and digestibility [7, 8]. Decreasing transcript levels of gene families may suffice, but inhibiting more than one gene type may be necessary because of biochemical compensation by parallel pathways producing monolignols. A decrease in function of a single gene type provides sufficient down-regulation and modification of lignin structure and enhances digestibility in maize (cf. [4], sorghum and pearl millet [3], poplar [15] and pine [16]), but there has been little published evidence that affecting more genes can increase digestibility with fewer side effects.

Partially suppressing shoot lignification by ectopic antisense (RNAi) based on the desired phenotype is unlikely to affect mechanical strength. The compressed internodes of semi-dwarf and dwarf wheat and rice should maintain structure integrity with somewhat less lignin. As discussed above, no correlation was found between normal variations in lignin content in wheat and barley varieties and the ability to withstand lodging [12]. It is unlikely that selected modulation of lignification would affect defence mechanisms derived from phenylpropanoid intermediates, as the gene encoding (at least one) isozyme involved in defence lignification was different from the isozyme for xylem lignification [17]. Still, the task will not be easy as it is still unclear which lignin modifications / reductions will do so without affecting yield [18].

The typical gene jockey who performs the transformation, regeneration, and greenhouse analyses might think that a good product has been achieved because no growth or yield differences were observed with the small number of regenerated plants. The statistics of yield reduction require multiple field testing, over a few growing seasons at many locations. It is unlikely that farmers will cultivate a grain crop with even a 5% average yield reduction to gain a more digestible straw. This is why the brown midrib maize and sorghum mutations are used only in developing varieties to be specifically used for forage or silage, and is not found in varieties to be used for grain production. Thus, it will be essential to incorporate many lignin reducing/ modifying gene constructs with different tissue specific and expression level promotes into nume-rous genetic backgrounds, and have agronomists and nutrition specialists evaluate the lines [18].

A courageous attempt has been made with maize to define the ideal ideotype with optimal digestibility, which should be of use to both the breeder and the genetic engineer, as well as to facilitate their interactions [19]. Twenty-two inbred lines of maize were sectioned and stained for different properties. The microscopic results were correlated with lignin and p-hydroxycinnamate contents as well as cell wall degradability. Various combinations of the results could then genetically define 89% of the results. The ideal ideotype contained less lignin with a higher ratio of syringyl to guaicyl subunits, which were preferentially located in the cortex and not the pith tissues of the maize stems [19]. They modelled in vitro digestibility based on the two histological and two biochemical variables and were able to obtain a highly significant regression correlation with observed digestibility of 13 inbreds. But for the issue that interests us most—what will happen with mutants and transformants—the model is most inadequate. The brown midrib bm3 mutant maize was actually far more digestible than the model predicted [19]. Their results must yet be correlated to lodging in isogenic material. The results should also be econometrically correlated with added/reduced yield and the added value of the digestible stover. Despite there being so much more wheat and rice straw than maize stover, there are few publications dealing with modified lignin in these crops. If the reason is that maize is sold as hybrids, with economic advantages to seed companies, then it is time for the public sector to change its involvement with these most important crops.

Another interesting challenge has been raised to the molecular biologists from a study of 12 lodging resistant and susceptible varieties of wheat. In the analysis of all their data, it appears that a higher fibre (including lignin) content in the second and third internodes correlates with resistance to lodging (with a correlation coefficient of ca. 0.6) [20]. Would it be possible and invaluable to increase the fibre and lignin contents of these two internodes and lower it in all other ones using tissue specific promoters?

In generating more digestible cereals, one must not forget the corn-borers and possibly rootworms , who prefer the digestible lines [13]. One must consider that Bt or some other transgenes that will control corn-borers and rootworms must be co-transformed with all genes chosen, or that genes of choice be transformed into lines that already contain the Bt (or other insecticidal) gene(s).

Genes affecting lignin composition in dicots and their cereal orthologs

Lignin is a matrix of co-polymerized hydroxyphenylpropanoids (monolignols) covalently linked via a variety of bonds. The monomeric composition and the types of bonding vary among species, with a high content of p-coumarate and ferulates covalently linked to monolignols in grasses. Genes encoding the shikimate and phenylpropanoid pathways are activated during cell wall lignification, along with up-regulation of transcription factors [21, 22] having an unclear role in cereals. Ferulate and diferulates cross-link cell wall components to xylan α-L-arabinosyl side chains during grass lignification, leading to further co-polymerized lignin complexes [23].

Gradual elucidation of lignin monomer biosynthesis pathways and related genes resulted from efforts to decrease lignin content in trees and model dicots and from genomic projects. A high sequence homology (>70% identity) exists among gene families encoding enzymes of the phenylpropanoid pathway in dicots and cereals (Table 2). Cinnamate, the first phenylpropanoid pathway product is a precursor of lignin, but also of pigments, phytoalexins, and flavonoids, suggesting that its production must not be modified, and only later enzymes should be modulated.

Table 1. Biochemical specificities of the brown midrib mutants of maize in an isogenic line
ty[c]

Mutant	fibre in straw[a]	lignin in fibre[b]	digestibili	deficiency[d]
	percentage (% of cv)			
cv[e]	56.2 (100)	16.4 (100)	15.9 (100)	none
bm1	54.9 (98)	14.6 (89)	19.2 (121)	cinnamyl alcohol dehydrogenase (CAD)
bm2	51.3 (91)	13.6 (83)	20.2 (127)	no information
bm3	52.2 (93)	13.0 (79)	23.1 (145)	5-hydroxyconiferaldehyde O-methyltransferase (CaldOMT)
bm4	53.4 (97)	14.3 (87)	22.8 (143)	no information

[a] *measured as neutral detergent fibre;* [b] *percent of Klason lignin in neutral detergent fibre;*

[c] *in vitro neutral detergent fibre digestibility;* [d] *mutated enzyme where known;* [e] *cultivar F92, into which all brown midrib mutations were backcrossed, until near isogenicity.*

Source: collated from data in Barriere et al. 6, and references cited therein.

Table 2. Enzymes of the phenylpropanoid pathway in cereals are encoded by small gene families. Gene copy and nucleotide homology estimations are according to the rice and other cereal genome data currently available on the NCBI and Gramene websites.

Rice Gene[a]	type	No. copies identified	Sequence identity (%) barley	wheat	maize	dicot[b]
PAL (AK067801.1)	FL-cDNA	at least 5[c]	86	85	86	<76
C4H (AK104994.1)	FL-cDNA	at least 2	89	89	87	<80
C3H (AK099695.1)	FL-cDNA	at least 2	ni	89	79	<80
4CL (AK105636.1)	FL-cDNA	at least 3	83	ni	76	<80
CCoAOMT (AK065744)	FL-cDNA	at least 2	ni	93	90	<82
F5H (AK067847)	FL-cDNA	at least 2	ni	84	ni	LS
COMT (AK061859.1)	FL-cDNA	>1	71	86	87	LS
CCR (AK105802)	cDNA	at least 3	88	85	90	<75
CAD[d] (AK 104078)	FL-cDNA	at least 12	ni	ni	83	<71

[a]*Rice gene reference for homology comparisons.* [b]*Highest identity with a dicot ortholog.*

[c]*Number of copies as of December2005.* [d] *According to Tobias and Chow* [47]

FL=full length; ni=not identified; LS=low score

Source: updated from Gressel and Zilberstein [8]*.*

The brown midrib maize mutants have recently been biochemically characterized in isogenic backgrounds, which had not previously been done (Table 1). There is up to 45% greater digestibility of the fibre with bm3, which is now thought to be mutated in 5-hydroxyconiferaldehyde O-methyltransferase (CaldOMT) [6]. Yield or lodging information was not presented, but if acceptable, this is a good target, especially in other grass crops. It is hoped that mutant bm4, which also has a very high digestibility will also be characterized soon.

Engineering decreased/modified lignin

As discussed above, down regulating expression of genes encoding various enzymes of the lignin biosynthetic pathways decreases or modifies lignin, with preliminary evidence for enhanced digestibility without overly modifying structure [3]. Antisense repression of 4-CL in aspen lignin biosynthesis was compensated by increased cellulose [24]. Antisensing with dicot COMT cDNAs caused decreased tobacco COMT activity and altered lignin composition [25, 26]. Transgenic plants with dual antisensing of COMT and CCoAOMT had less lignin content, but each alone was ineffectual [27].

No field studies have yet been reported with transgenic annual plants (let alone dwarf grains) with decreased/modified lignin, where lodging was compared to the original variety. There are no reported lodging problems with decreased lignin transgenic poplars. Still, in some cases where lignin was heavily modified, the changes could be ultrastructurally visualized [28], but there is no need to engineer such vast changes. Minor modulations or down regulation may be sufficient to economically enhance digestibility.

A considerable amount of possibly useful information has been obtained from models such as Arabidopsis. Still, Arabidopsis is a dicot, and may have it wrong for cereals, which have totally different morphologies and needs. Puny Arabidopsis, growing among wind breaking trees near a forest floor is unlikely to have had a need to evolve resistance to the type of wind turbulences impacting a wheat field in the plains. The rice genome sequence and additional maize and wheat EST and genomic data have allowed identification of cereal orthologs of genes encoding lignin precursors, including sinapyl alcohol dehydrogenase (SAD) [29], which is highly homologous to CADs (Table 2). This fact, along with the ease which wheat, maize, and rice can now be transformed precludes the continued reliance on models, when the real targets can be used. This genomic information from the target species paves the way for extending dicot modifications to cereals, as a first step.

Modulating the quantity and structure of cellulose

Increasing the amount of cellulose (especially at the expense of lignin), or modifying its structure such that more is available to ruminant cellulases could also increase the feed value of straw. This has been done transgenically with two genes: CEL1 and CBD. CEL1 is an endo-1,4-β-glucanase gene from Arabidopsis thaliana. Transgenic poplar plants over-expressing CEL1 were taller, had larger leaves, increased stem diameter, wood volume index, dry weight and a higher percentage of cellulose and hemicellulose, than control plants [30, 31]. Transgenic poplar over-expressing the poplar endo-1,4-β-glucanase gene also produced more cellulose [32]. The CBD effect in transgenic plants was demonstrated in tobacco [33], Arabidopsis, potato, and poplar. CBD protein expressed in the cell wall of these species resulted in an increase in growth rate and enhanced biomass accumulation. Two-year old field grown poplar had a three-fold increased volume index over the non-transgenic controls, as well as an improvement in fibre quality [34]. There are no extant reports of modulating this gene in grains, but it would be advantageous if similar results were to be obtained with grains.

The unique problem in rice straw – silicon inclusions

Rice straw has an additional deterrent to digestibility, silicon (Si) inclusions. The Si content in plants greatly varies among varieties, ranging from 0.1 to 10% in dry weight. The difference in Si content has been ascribed to the ability of the roots to take up Si [35]. Rice accumulates Si in the stalks to levels of up to 10% of shoot dry weight, being the most Si-effective accumulating plant known. The ascribed benefits to Si accumulation in shoots include keeping the leaf blade erect, increasing pest and pathogen resistance, counteracting nutrient imbalances and other claimed beneficial effects [36-39]. However, this high percentage of silicon in rice is a major hindrance to ruminant digestibility, yet based on the inter-varietal variability, clearly not all the silicon is needed.

Some recent progress in elucidating the pathways and molecular mechanisms by which silicon is absorbed and deposited has been achieved through the use of rice mutants that are deficient in silicon uptake [38, 40]. The ability of rice roots to take up Si is much higher than that of other graminaceous species; a kinetic study indicated that Si uptake is mediated by a type of proteinaceous transporter [40]. A sequence homology search of the rice genome has not found any genes similar to the known Si transporter [41, 42] of the marine diatom (Cylindrotheca fusiformis). A single dominant gene encodes the unknown rice Si transporter [38].

The solution to overcoming the Si hindrance to straw digestibility is to reduce the amount of Si uptake by roots without affecting the benefits that this element has for the plant, achieving the minimum amount of Si in the plant needed for a healthy growth. Incomplete anti-sense gene silencing could be used to modulate this transporter function. Isogenic transgenic plants with decreased Si uptake can be compared with the original variety, with respect to the digestibility, lodging and pest disease resistance. As the transporter gene has yet to be identified, its elucidation may come from microarray analyses of rice varieties that have very low and very high silica contents. Once this gene, or other genes related to the synthesis of the inclusion bodies is found among the un-annotated genes of rice, then antisense/RNAi technologies should allow modulating silica to a desired level for the crops needs, as well as to deplete them to a level where the straw will be palatable. Indeed, total suppression of the Si level, without changing other factors, will allow researchers to ascertain what essential role, if any, Si has in rice.

Lignin and cellulose modification/reduction may not be enough - integrating approaches

Reducing or modifying the lignin content of straw would render far more carbohydrate available to ruminant animals, but this would still not be the equivalent of hay containing 10-20% protein, and animals must be fed proteins – or must they? Only some of the protein fed to ruminants is directly digested to amino acids. Much more is cycled through rumen bacteria, which die, releasing amino acids to the animal. Bacteria need not be fed proteins to make amino acids; they can utilize and reduce mineral nitrogen sources to amino acids. When Europe was severed from feed grain imports during World War 2, beef cattle were fed ammonified waste paper (cellulose)[43]. Ammonifying straw also separates some lignin from cellulose, ren-dering more cellulose digestible, even more so if done with heating. Urea, which releases ammonia under heat or water, has the same effect. Thus, there can be multiple e ffects of injecting wrapped bales of lignin reduced/modified straw with liquid ammonia or urea. If the bales are left in the sun, solar heating assists in delignification. Small-scale subsistence farmers can use solar heaters manufactured from old barrels, black paint and polyethylene sheeting to convert chopped straw and a handful of urea fertilizer into fodder [44].

If straw is to be heat pasteurized and a nitrogen source added, another biotechnology can add to the nutritional quality of the product; short term fermentation with preferentially ligninolytic microorganisms such as *Aspergillus japonicus.* Unlike ligninolytic Basidiomycetes, *Aspergillus japonicus* degrades straw lignin in the presence of nitrogen sources [45]. Ruminants can then utilize the lignin biotransformed into fungal biomass, instead of excreting the lignin in the manure. In the distant future, a second fermentation with a cellulolytic fungus could then convert the cellulose to utilizable biomass, good enough for supplementary feeding to monogastric animals such as pigs and poultry, and if with mushroom flavor, to humans.

Potential impact of the technology

A mixture of these transgenic with other technologies could yield two billion tons of inexpensive, high quality hay or silage from rice, wheat, maize and sorghum straws around the world, replacing about a billion tons of feed grain. The technology should somewhat replace concentrated feedlot cattle production where high feed value grain is brought to the cattle. Instead it should support a more diffuse, farm-based feeding operation, with the farmer receiving considerable value added from the straw, having to purchase less imported grain for feeding. The cost of the ammonia /urea for upgrading the straw is mainly offset by using the resulting animal manure as a slow release fertilizer that is superior to urea or ammonia used by themselves, and by not needing supplemental nitrogen fertilizer to offset that used by soil degradation of straw. Whereas feedlot operations cause considerable water pollution, the on the farm use, with the returning of the wastes to the fields or paddies will vastly reduce such problems. As the straw is not incorporated into the soil, there are none of the mineral binding problems during the initial microbial degradation of fast-degrading components when a new crop is planted, which requires additional fertilization in spring. As plant-disease carrying straw is removed from the field, there could be less need for fungicide application the following season. The soil improving humic compounds are not lost by harvesting the straw (as they were when straw was burnt); they are returned to soil as manure, although there may slightly less humic matter produced, to the extent that lignin content is reduced in the straw.

There has been a reluctance to deal with lignin in straws because of the present slight oversupply of grain and meat in the developed world. This does not consider future needs, nor the time needed to develop the biotechnologies. If the lignin reduction technologies develop rapidly, the straw could be used as a better source for ethanol production, far better than with the present technologies that utilize only a small proportion of the cellulose to produce ethanol. It will be necessary to allay public fears relating to scientific / technical issues, although it is likely that by the time the technologies are ready, transgenics will probably no longer be a public issue, as generating the ideal straw will take time.

Very poorly digestible straw with its very low nutritional value can potentially be economically converted into hay-quality material having both highly enhanced caloric value as well as being a nitrogen source using biotechnologies described herein, especially when used in conjunction with physical and chemical treatments. If successful, the Americas and Europe could produce another 200 million cattle a year, 35% more than at present, Asia 250 million cattle, 50% more than at present, Africa 170 million more goats per year (or 500 million goats per year if grain yields were increased to match world averages), 80% more to triple the present number, and Australia 30 million more sheep, 25% more than at present. This would free billions of tons of grain for human consumption or for non-ruminant animals. Genetic engineers should turn straw into milk and meat instead of feeding grain to animals while straw rots in the field. More of the digestible straw can be fed to (castrated male) steers than milk cows, as steers do not need to be grown intensively with as much concentrated feed as milk cows. Grass-fed ruminants produce a leaner, less fat and cholesterol-containing meat than animals fed on maize and soybeans. This should have a considerable positive impact on consumer health.

The redundancy of the monocot phenylpropanoid pathway in homologous small gene families with sequence homology to dicots (Table 2) indicates that RNAi/antisensing is the most feasible strategy for down regulating expression and changing the lignin/cellulose ratio and lignin subunit composition. Moreover certain highly homologous short sequences may serve as RNAi machinery initiators for down regulation of similar gene families in both monocots and dicots.

Carbon emission credits

The Kyoto carbon dioxide emission accords have most countries interested in obtaining carbon credits for not releasing or for delaying the emission of carbon dioxide into the environment. It is conceivable that when the technology described herein is in widespread use, it will be possible to receive Kyoto carbon credits for the differential period that the carbon is not released as carbon dioxide, between this process, and those processes presently in use. All manipulations of straw, natural or artificial, bring about return of the CO_2 fixed by photosynthesis back to the environment. The question is which process delays CO_2 return the longest, keeping the carbon fixed and not released as CO_2. The fastest return of CO_2 is burning after harvest, followed by the presently mandated soil incorporation and microbial degradation.

Using transgenic straw for ethanol production replaces petroleum that would be burned instead of the straw naturally degrading. Thus, all ethanol produced should be eligible for carbon credits. Feed for ruminants keeps carbon fixed for long periods, as part goes to animal products and is stored for long periods, and the undegraded lignocellulose is returned to the soil where it slowly degraded as humic material. Thus, there should be some eligibility for carbon credits based on these factors, and the low carbon consumption in fuel to process the straw vs. that required to produce grain. The only commercial use that might keep the carbon fixed longer is the use of straw in construction materials (a minor market nearly saturated at present) and possibly paper manufacture – which most experts feel is not feasible, and the paper industry of necessity produces other pollutants.

Concluding remarks

The best solution to the worlds' most abundant agricultural waste is to recycle it through bioethanol for fuel, or through ruminants producing more food. The technology has elements that render it ideal to demonstrate why / where genetic engineering can be of benefit to farmers, the manufacturing sector, the environment, and to humanity as a whole. It will require more than a decade to isolate the genes, transform the plants, analyze each series of transformants, and fine-tune the levels of expression such that sturdy, high yielding grain crops will result, with more digestible cellulose. It will take years more to either cross and backcross the genes into more varieties of the crop, or to transform each variety. The subsidiary technologies of processing and feeding the straw will also have to be developed. If the research would commence now, with luck it would be ready soon after there are perennial food shortages due to Malthusian overpopulation. Straw utilization will be environmentally beneficial, compared with present uses, but it will not provide feed value equal to grain yields. The best quality hay or silage, a viable target, has only a quarter the feed potential of grain, but a 25% increase in agricultural efficiency is also exceedingly valuable, especially when the environmental worth is added to the equation. Agricultural productivity in much of the developing world is half the world average. This 25% advantage will remain as productivity increases.

The final product will not be simple to obtain. It will not result from engineering a single gene with a non-specific promoter. It will surely contain a large number of cereal genes that are transgenically modulated, with tissue specific promoters, as well as the addition of genes, based on the needs documented above.

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8
PAPER

Global Markets and Technology Transfer for Fuel Ethanol: Historical Development and Future Potential

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Introduction

Until the mid-1990s, there was no real global market for alternative transport fuels; nearly all trade was regional and the only large markets at that time were for ethanol in Brazil and the U.S. Since the mid-1990s there has been a growing worldwide interest in alternative transport fuels. International trade was also increasing in the 1990s, although at a fairly slow pace. The interest in biofuels accelerated considerably in the early 2000s due to significantly higher oil prices, concerns about energy security, and a greater commitment within OECD countries to reduce GHG emissions in the transport sector, especially within the EU Member States.

The Brazilian ethanol programme in particular has received much attention as the only biofuels programme to achieve economic competitiveness; after many years of intense effort to build up the industry, Brazilian ethanol has in recent years become cheaper than petrol, without provision of subsidies. In other countries, ethanol has become competitive where it is taxed at a lower rate than petrol, or where it receives subsidies and/or import protection, as is the case in the U.S. Meanwhile, other developing countries have looked to expanded ethanol production as way to improve rural economies while at the same time reducing their oil import bill and improving environmental conditions.

The use of biodiesel has also been increasing at a rapid rate, although starting from a much smaller base. Although there are several other bio-based and alternative transport fuels that are available or can potentially become available, biodiesel and ethanol will likely remain the main biofuels in the medium-term. Biodiesel is generally not yet cost-effective compared to petroleum diesel, but is quite important because of the efficiency of modern diesel engines and the market dominance of diesel over gasoline in many parts of the world. Since the conversion processes and markets are quite different and since ethanol is more mature in terms of a global market, this article focuses on ethanol.

The long-term global ethanol production and market potential is reviewed in this paper, based on cane and cellulosic biomass as the major feedstocks that are likely to be cost-effective in the medium-to-long-term. Cane is already cost-effective in Brazil, whereas cellulosic conversion is not yet commercially mature. Other “first-generation” biofuel options such as corn-based ethanol are unlikely to be competitive without continuing subsidies and are thus of less interest for market development. Some key issues for market development are considered below, including international trade, technology transfer potential, and R&D.

The opportunity for South-South technology transfer in particular offers some useful routes for expanding the global ethanol market. Such expansion can take advantage of the productive biomass resources of the South and the growing market for transport fuels in many regions. The experiences in Brazil and other major developing country players in the ethanol market, such as India, can benefit smaller developing countries that need technical support, policy advice, and market strategies to get their ethanol programmes started.

Historical Overview

The use of ethanol as transport fuel goes back to the origin of the automobile industry itself e.g. Henry Ford’s Model T car built in 1908 was aimed at ethanol. Ford’s vision was to “build a vehicle affordable to the working family and powered by a fuel that would boost the rural farm economy.”[21]

There is an extensive literature on the history of fuel ethanol[22]. Contrary to general belief, fuel ethanol was used on a large scale already in the early 20th century, particularly in Europe (e.g., Germany, France, and Italy). In 1902 there was an exhibition in Paris dedicated to alcohol fuels, including automobiles, farm machinery, lamps, stoves, heaters, etc (Kovarik, 1998).

By the mid 1920s, ethanol was widely blended with gasoline in almost all industrial countries, except in the USA, where the combination of raising taxes, a concerted campaign by major oil producers and the availability of cheap gasoline, effectively killed off ethanol as a major transport fuel there in the early part of the 20th century. In the Scandinavian countries, a 10-20% blend was common, mostly produced from paper mill waste; in continental Europe, ethanol was obtained from surplus grapes, potatoes, wheat, and other feedstocks. (Kovarik, 1998; Rosillo-Calle & Walter, 2006).

Post-WW II era

Ethanol achieved some global prominence during the years of the Second World War, due to fuel shortages; when the conflict was over, the availability of cheap gasoline effectively eclipsed the use of ethanol as fuel for nearly three decades in most countries. In Brazil, however, the vital role of the sugarcane industry led to frequent government intervention, as ethanol production was seen as an instrumental policy to achieve the rationalization of the sugar industry ever since the early 20th century.

Although over 35 countries have some type of fuel ethanol programme, globally production and consump-tion of bio-ethanol is still dominated by Brazil and U.S.A. Of the three broad market categories for ethanol—fuel, industrial, and potable—the largest volume market today is for fuel, whereas the opposite was true just 30 years ago. In fact, since 1975, the market share of fuel ethanol (out of all ethanol) has increased from about 5% to over 75% (F.O. Lichts, 2006). The

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[21] Quoted in: History of ethanol production, Rural Enterprise and Alternative Agricultural Development Initiative, Report No.12, June 2002.

[22] For example, 152 popular and scholarly articles under the heading of “Alcohol as a Fuel” are mentioned in the Readers Guide to Periodical Literature between 1900 and 1921. See Kovarik (1998).

industrial market is generally associated with chemical and pharmaceutical industries that require ethanol as a feedstock for fine chemicals and various products.

Synthetic Ethanol and South Africa

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.[23] 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; consequently Table 1 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 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.

Table 1: Ethanol production[a] 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[b]	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[c]	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: [a]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.

[b]other Europe includes Russia and republics;

[c]other Asia includes Pacific/Oceania

Source: F.O.Licht's, 2006.

[23] Synthetic ethanol does not have the environmental benefits of bio-ethanol due to the use of fossil fuels in production; the contribution to GHG emissions is even greater than that of ordinary petrol.

Brazil

Brazil has long been the world's largest producer and consumer of fuel ethanol, largely due to the creation in 1975 of the Brazilian Alcohol Program (PROALCOOL)[24] with the purpose of producing anhydrous ethanol for blending with gasoline. In the mid-1980s production was expanded to include hydrated ethanol to be used as neat fuel in modified engines. This resulted in a rapid expansion of sugarcane production, e.g., from about 50 Mt/yr in 1970 to over 380 Mt in the 2004/05 harvest, as illustrated in Table 2. This continued expansion has accelerated due to high demand for sugar and ethanol, the rise of ethanol exports and improvements in productivity. In fact, Brazil is the world's most efficient producer of both sugar and ethanol, i.e. it has the overall lowest producing costs. Consequently, Brazil is the world's only swing producer between the two products, and can react based on market changes and thereby impact future prices as well.

Table 2: Sugarcane & ethanol production in Brazil 2000/01- 2005/2006

Year	***2005/06***	***2004/05***	***2003/04***	***2002/03***	***2001/02***	***2000/01***
Cane (10^6t)	383.74	381.40	357.30	316.12	292.34	254.92
Sugar (10^6t)	26.43	26.63	24.96	22.38	18.99	16.02
Ethanol (10^9l)	16.09	15.20	14.66	12.49	11.47	10.52
- Anhydrous	7.98	8.16	8.79	7.01	6.48	5.58
- Hydrous	8.19	7.04	5.87	5.48	4.99	4.93

Source: MAPA (2006)

Currently, Brazil has around 320 combined sugar mills and ethanol distilleries and over 50 under construction, including new plants and expansion of existing ones. Improvements include the whole chain system, ranging from better varieties, soil management, transportation, technical improvement in con-version, to end-use. For example, in the early 1980s the average productivity of sugarcane was 70 t/ha/yr, and 60 litres ethanol/t/cane. Average ethanol production in 1980 was 4,200 l/ha/yr compared to 6,350 l/h/yr in 2002/2003 harvest; thus, the overall productivity increase was more than 50% (UNICA, 2005; Macedo, 2005). Ethanol now accounts for nearly 40% of non-diesel motor fuel consumption in Brazil.

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 these support schemes and the recent rise in oil prices, U.S. production exceeded Brazilian production for the first time in 2005 (F.O. Licht, 2006). U.S. ethanol production is not cost-competitive with Brazilian ethanol made from cane. Not only does corn-based ethanol production have a poor overall energy balance, but furthermore much of the biomass in the corn is wasted, whereas with sugarcane, the fibrous bagasse residue is used for energy production at the factory. Only when cellulosic ethanol conversion is mature can producers in the U.S. and Europe begin to compete with cane-based ethanol.

Ethanol is sold in most States as an octane enhancer or oxygenate blended with gasoline, while in the Midwest there are also E85 or ethanol-only vehicles, including buses. Ethanol demand has been stimulated by the phasing out of MTBE in the U.S.A. as an octane enhancer in recent

[24] Although a major aim of PROALCOOL was to substitute imported gasoline with locally produced ethanol, there were other policy objectives, including: i) need to safeguard large investment committed by sugarcane industry (approximately US$3 billion) to modernise the sector; ii) generate employment; iii) encourage socio-economic development in rural areas.

years, due to concerns about ground water contamination from MTBE tanks. The main producers are the states of Iowa, Illinois, Nebraska, South Dakota and Minnesota, with over 80% of the production (RFA, 2006). The total production in the U.S.A. represents about 3% of the total domestic gasoline fuel market (EIA, 2007).

Feedstock Markets

Currently ethanol is produced from a large variety of feedstocks. However, from an economic point of view few raw materials can seriously be considered as feedstock, excluding sugarcane, maize (corn), sugar beet, cassava, sweet sorghum as supplement to sugarcane and some cereals, such as wheat. Of all these, sugarcane and corn are currently responsible for approximately 95% of bioethanol production (see Rosillo-Calle & Walter, 2006).

Alternative feedstocks for ethanol

There are a wide range of potential feedstocks and/or processes for ethanol production, ranging from sugar crops to waste streams such as municipal solid waste. Some examples within the various categories are listed below:

- Sugar crops: sugarcane, sugar beet, sweet sorghum;
- Starch or grain crops: corn (maize), cassava, wheat, sweet potatoes;
- Waste streams: municipal solid waste, black liquor (from pulp/paper);
- Cellulosic Biomass: wood, bagasse, grasses;
- Fischer-Tropsch: a by-product of gas-to-liquids processes.

A comparison of the costs and environmental impacts of these feedstocks is beyond the scope of this paper. In general, the feedstocks of greatest interest in the near-to-medium term are sugarcane and cellulosic biomass, due to their cost-effectiveness, superior energy balance, and prospects for large-scale deployment (Fulton et al, 2005). Consequently, only these two options are reviewed below.

Sugarcane

Sugarcane is the world's most economically significant energy crop, is currently the most important feedstock for ethanol production and is likely to remain so in the future even if cellulose becomes a major feedstock, for a number of reasons:

- It is produced in over 100 countries;
- Infrastructure is well-developed due to the long history of sugar agro-industry;
- It is a very efficient crop, e.g., has a very high photosynthetic productivity;
- It is the most energy-efficient crop for fuel ethanol production, since it arrives at the sugar/ethanol factory with its own energy resource in the form of bagasse

The juice extracted from sugarcane can be used directly as feedstock for ethanol production, which is the case for so-called "autonomous" distilleries that produce only ethanol. In this case, only a cane juice preparation station is needed rather than a sugar factory, thereby saving a significant amount of investment cost where ethanol is known to be the key product. Sugarcane mills equipped to produce both sugar and ethanol (annexed distilleries) have flexibility over autonomous distilleries because they can respond to market demand between the two products more efficiently. Annexed distilleries are normally sized to able to vary the sugar/ethanol ratio (in sugar use) from 40 to 60%, and sometimes even more. The additional investment cost required are justified by the flexibility this option provides.

There are also some adjustments between the two products during a given season with respect to operating conditions. For example, production of ethanol over sugar is preferred during rainy days during crashing season because the higher impurities associated (e.g. mud) and when mechanical harvesting is involved (e.g. dust, small stones, etc). This is because production of ethanol is less stringent so far as the quality of the feedstock is concerned.

Molasses

Molasses[25], a by-product of various sugar-containing materials, remains at the core of ethanol production in many countries. Although sugarcane and sugar beet are the main source of molasses, it can be produced from any sugar-containing material. Molasses can be used as feedstock for ethanol; the yield decreases with the content of fermentable sugars it contains. Cane juice can also be mixed with molasses of different grades and used as feedstock. In Brazil, many producers have found that a mixture of juice and B-molasses can be optimal for their operations in terms of cost and performance (Macedo, 2005).

The world production of molasses from all sources amounted to about 50 Million tonnes in the crop season of 2005/06; outside of Brazil, only modest growth has occurred globally since 2000/01 (Table 3). In temperate climates such as Europe and the U.S., nearly all molasses is from sugar beet; since beet production has generally not increased significantly due to competitive pressures, molasses production has decreased or only increased slightly in these regions, as shown in Table 3.

Table 3: Molasses production[a] by year and country or region (million tonnes)

	2000 /01	***200 1/02***	***2002 /03***	***2003 /04***	***2004 /05***	***2005 /06***	***Global Share, 2000/01***	***Global Share, 2005/06***	***Annual Average change***
Brazil	7.9	9.3	10.8	11.6	12.4	12.0	18%	24%	8.7%
U.S.A.	2.4	2.1	2.2	2.3	2.0	2.0	5%	4%	-4.0%
other Americas	6.6	6.7	6.5	6.7	6.4	6.2	15%	12%	-1.3%
EU	4.7	4.5	4.8	4.3	4.4	4.7	10%	9%	0.0%
other Europe[b]	2.2	2.1	2.2	2.3	2.5	2.5	5%	5%	2.6%
Africa	3.3	3.3	3.3	3.4	3.4	3.5	7%	7%	1.1%
China	2.0	2.6	3.3	2.7	2.4	2.3	4%	5%	3.0%
India	7.8	8.1	8.9	5.9	5.5	8.6	17%	17%	1.8%
other Asia[c]	7.9	9.1	10.8	9.8	8.6	8.5	18%	17%	1.3%
World	**44.9**	**47.8**	**52.7**	**48.9**	**47.6**	**50.2**			**2.3%**

NOTES: [a]The table shows total estimated world production for all types and applications. In addition to uses for ethanol production, molasses has many other applications, e.g. animal feeds, biochemical products; molasses is also sometimes wasted due to lack of market, high transport costs, etc.

[b]other Europe includes Russia and republics

[c]other Asia includes Pacific/Oceania

Source: F.O.Licht's, 2006

[25] There are three main types of cane molasses at most sugar factories: A-molasses is the by-product after the first centrifugation process to crystalline sugar; B-molasses is the by-product after the second such process, and C-molasses is the final molasses, i.e. that which remains after all the crystallised sugar that can be economically extracted has been removed.

There are advantages and disadvantages of using juice, A, B, or C for ethanol production, depend on the specific physical circumstances and the market value of both sugar and ethanol. If the main aim is to produce mainly sugar, the preferred option is to use A and B molasses because of the higher sugar content. This is not necessarily the case if ethanol is the major product because it can be produced from lower and poorer quality feedstock such as B and C molasses.

In some countries C molasses is not economic to produce ethanol e.g. in some South African mills, extraction of sugar is high and thus makes C molasses use uneconomic. In Australia, extraction of sugar is lower due in part to greater mechanisation, and thus ethanol production can only be justified if C molasses is used, i.e. higher molasses grades would defray valuable sugar production. Brazil is unique in using combinations of A, B and C molasses and cane juice.

Cellulosic Biomass

The separation of cellulosic material from woody or plant biomass for use as ethanol feedstocks has very high long-term potential. A considerable and attractive advantage of large-scale ethanol production from cellulose is that it is very abundant and available around the world. For temperate countries, where crop productivity is much lower, cellulose is particularly attractive for large-scale ethanol production.

Among the most promising feedstocks are short rotation coppices and grasses because of their high yields, low costs, suitability for low-quality land, and the fact that they can be harvested annually and in most cases with the same machinery as food crops, at potentially low environmental impacts (Hamelinck et al., 2005). Many countries are investing heavily to competitively produce ethanol from cellulose material, particularly USA and the EU. However, the result so far has been rather disappointing as costs have remained high and will probably remain so for years to come.

In the mid to long-term scenarios, 2020-2050, ethanol production from cellulose material is considered by many authors as the most promising alternative (Hamelinck and Faaij, 2006). Nevertheless, its long-term feasibility will strongly depend on technological developments in various areas such as pre-treatment, micro-organisms for higher conversions, integration of processes, scale economies, reduction of capital investment costs, and lowering cost of feedstock. Hamelinck *et al.* (2005) indicates that ethanol production costs can reach 13 Euro/GJ by 2015-2020 and even less than 9 Euro/GJ after 2025. To put these costs in perspective, gasoline costs about 8 Euro/GJ (excluding distribution costs, excise and VAT) at crude oil prices of 35 Euro/barrel (Hamelinck and Faaij, 2006).

Sugarcane bagasse has been a prime candidate for ethanol production via hydrolysis for cellulosic conversion, but with disappointing results so far. Nevertheless, the potential of bagasse for ethanol remains high in the medium-to long-term for two main reasons:

1 the cost of bagasse is essentially its opportunity cost; i.e. it is readily available at the factory; and

2 the fact that existing mill infrastructure can be used.

However, if bagasse were used on a large-scale for ethanol production, other sources would have to be found to generate heat and electricity. An alternative being considered is to complement bagasse with sugarcane trash.

The Brazilian equipment manufacturer, Dedini, and the Sugarcane Technology Center (CTC), have an R&D program aiming at developing the DHR process (Dedini Rapid Hydrolysis) to produce ethanol from bagasse. A pilot plant, with capacity of 5,000 l/d, was installed in the

State of Sao Paulo. The process uses ethanol and diluted acid as solvent; the separation of fibres components and hydrolysis of cellulose and hemi-cellulose materials take place in a single tank. The company states that the hydrolysis yield is close to 82%; in addition, 11% of sugars (mass basis) are added to the flow that goes to traditional ethanol production through fermentation.

Competition for feedstocks

As biofuel markets, and especially ethanol markets, have expanded, one issue that has arisen is the potential for competition for feedstocks between food and fuel uses. Where the feedstock has major food applications in developing countries, such as is the case with corn, the food vs. fuel issue arises directly. Such effects have been observed in the form of increasing corn prices in North America, and similar effects have been noted in the case of South Africa, which has a considerable surplus of corn that may be used for ethanol production (BEAP, 2007). Such interactions can also arise indirectly where there is competition between food and fuel production for land, water, and other inputs. In the case of sugarcane, the impacts appear to be minor or non-existent, due to the less vital role of sugar in food systems and the high efficiency of ethanol production that is based on sugarcane. In the case of cellulosics, such impacts would also be lower, due to the plentiful availability of cellulosic materials in wood, plants, and organic materials.

World fuel ethanol production potential

As with most energy-related scenarios, estimates of the long-term potential for fuel ethanol markets are complicated by a number of uncertainties, related to technical development, feedstocks, and market changes. Most scenarios have assessed the technical potential, but are weaker when it comes to evaluating the social, economic and political drivers and implications.

Most estimates relate to the share of gasoline that fuel ethanol can displace. Some studies suggest that world demand could be in the 65-75 B/l range by the end of this decade. Berg (2004), for instance, estimates that fuel ethanol consumption can reach 75 B/l in 2010. To put this in perspective, a consumption of about 65 B/l by 2010 would represent approximately a 4% share of fuel ethanol vis-à-vis gasoline use; in 2005 fuel ethanol consumption represented somewhat less than 3% of gasoline use (IEA, 2006).

Ethanol from sugarcane

The medium and long-term estimates of production potential can be based on sugarcane and cellulosic biomass on the supply side, as these are likely to be the most economical feedstocks. From sugarcane alone, the medium-term potential in 2030 could be about 240 B/l, which is equivalent to about 10% of projected global gasoline consumption (Johnson, 2002). Alternatively, one might include feedstocks such as sweet sorghum, which could potentially provide nearly as high annual yields of ethanol at much lower capital investment costs. Sugar production from sugarcane are unlikely to forego sugar production altogether, but sugar production requires capital-intensive factories, whereas production of ethanol alone from a crop like sweet sorghum would involve considerably lower costs and would be accessible to small farmers, thereby providing additional benefits for rural economic development. Such co-cropping strategies may be feasible in southern Africa, where there is a considerable amount of suitable and available agricultural land (Johnson and Matsika, 2006).

In the long run, looking out to 2050, Fulton (2005) estimated the potential from sugarcane as 633 B/l/yr, which is 14.5 EJ/yr, or about 20% of the estimated projected world gasoline demand. This scenario considers a maximum of 10% of cropland area to be used for sugarcane, except for Brazil, which would account for nearly half of the estimated total ethanol production from sugarcane, as shown in Table 3[26]. This scenario would require building 3,460 new industrial plants worldwide, of which 1,720 would be in Brazil; the cumulative associated investment is estimated at US$215 billion. A significant increase in demand will have to be met by increase in productivity to avoid serious supply problems, as there are few countries in the world capable of becoming major exporters while at the same time meeting growing domestic demand.

Ethanol from lignocellulosic biomass and other feedstocks

Fulton's (2005) second scenario includes total capacity of ethanol production with other feedstock (e.g., grain and beet), and ligno-cellulose; these results up to 2050 are summarised in Table 3. The total production of ethanol ranges from 5% in 2010 to 54% in 2050 of the estimated gasoline demand, in energy basis (about 70 EJ). In the long-term, it is probable that a global mix of alternative fuels may emerge in the transportation market and thus ethanol could be just one of the available alternatives.

From 2020 onward ethanol production could be considerably increased as the technology for producing ethanol from ligno-cellulose material is expected to be commercially mature. This will further increase production capacity worldwide, making ethanol fuel a truly global commodity.

Other short to medium-term estimates for Brazil and USA have different results due to different assumptions. For example, Oliveira (2005) has estimated domestic demand for ethanol in Brazil will grow about 9% annually over the next 5 years, reaching 21 B/l in 2010 (anhydrous + hydrated). In addition, a further 5 B/l could be produced for the export market. Thus, the Brazilian production in 2010 would be 24% higher than Fulton (2005) estimates. Nastari (2005) has estimated that up to 2013 the Brazilian domestic demand could be around 34 B/l in 2020, which is just 55% of the production presented in Table 4.

Table 4: Ethanol production potential (Billion litres per year)

Country/region and feedstock	***2010***	***2020***	***2030***	***2050***
Brazil – ethanol from sugarcane	21.0	61.3	121.2	309.6
Other LA – ethanol from sugarcane	4.4	24.2	42.7	59.8
India – ethanol from sugarcane	5.9	23.6	49.7	100.6
Africa – ethanol from sugarcane	1.6	16.6	35.6	65.9
Asia, except China – from sugarcane	5.6	19.8	31.2	54.4
China – ethanol from sugarcane	1.9	7.6	16.0	38.6
Middle East– ethanol from sugarcane	0.3	1.2	2.0	3.7
World – ethanol from sugarcane	***40.7***	***154.3***	***298.4***	***632.6***
EU – ethanol from grain + beet	12.1	27.3	27.3	27.3
North America – ethanol from grain	28.9	68.2	68.2	68.2
Rest of the World – ethanol from grain	4.6	10.6	10.6	10.6
Ligno-cellulosic ethanol	0.0	21.2	203.0	1,036.4
Total from all feedstocks	***86.3***	***281.7***	***607.6***	***1,775.1***
Share of estimated gasoline demand	*5%*	*13%*	*25%*	*54%*

Source: Fulton (2005)

[26] The ethanol yield in Brazil was estimated to increase from 6,000 l/ha/yr to 9,000 l/ha/yr between 2005 and 2050. For other countries ethanol yield is assumed to increase from 4,500 l/ha/yr to 8,500 l/ha/yr.

European Union Market Drivers

The EU Directive on biofuels came into force in May 2003, under which Member States shall ensure a minimum 2% share for biofuels by 31 December 2005 and 5.75% by December 2010 (EC, 2003). 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.

Ethanol production in the EU is very uneven, concentrated in just a few producing countries, particularly Spain and France. Currently only a small fraction of ethanol has been destined for fuel, as opposed to industrial uses.[27] One of the limitations has been the fact that the auto industries prefer to make ETBE for use in petrol engines rather than blending ethanol directly (EurObserv'ER, 2006). Another limitation is the fact that diesel autos are more popular with a number of major automakers and national markets, so that diesel consumption is much higher than gasoline consumption in most European countries. Nevertheless, several other EU countries have initiated new investments for ethanol production; in the UK, Czech Republic, Poland, and elsewhere, various bioethanol plants are under construction or planned.

The integrated energy-climate package that was put forth by the Commission retains biofuels as a major component of strategies aimed at the goals of energy security, competitiveness, and sustainability (EC, 2007). A further goal of 10% has been set for 2020, and it is expected that as much as 50% of this will be met with imports. Due to the policies and programmes in place, the EU market for fuel ethanol is estimated to be between 10 and 14 B/l/yr by 2010.

China

Although China cannot be regarded currently as a major player on ethanol this could change dramatically in the near future as the country is potentially a hugely untapped vehicle market and needs alternative transportation fuels and is pursuing a diversified policy towards this end. The Chinese automobile industry has been growing faster than in any other country; annual production has more than tripled during the past five years, and China is currently the world's third world largest auto producer (OICA, 2006). Fuel ethanol could become a more attractive alternative, either from domestic resources or imports, particularly if oil prices remain high. In the case of fuel ethanol, the current installed capacity is nearly 3.7 B/l and is expanding rapidly (Xiberta Bernal and Rosillo-Calle, 2005).

There are of course many other potential ethanol producers and consumers worldwide but the global impact would be on a smaller scale, although the impact on their domestic markets could be large (Rosillo-Calle & Walter, 2006). Other countries, such as India, could become major producers, but only for their domestic market, and would therefore not have a major impact on international trade.

Policy framework

The ethanol industry has entered a dynamic new phase in recent years, with global markets expanding at unprecedented rates. As an agro-industry, the policy framework for ethanol that lies behind these changes is complicated by differences in agricultural and industrial sector policies around the world. Although the general policy framework is beyond the scope of this paper, some key dimensions that are strongly impacting global market development are reviewed below: end-use innovation, technology transfer, international trade, and support for R&D.

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[27] The statistics generally do not distinguish between uses. Less than 20% of total ethanol production is estimated to be destined for fuel use.

Technology transfer

Although technology transfer issues are often cast in a North-South perspective, in the case of bioethanol, South-South technology transfer is arguably more important, given the pivotal role of Brazil, the importance of sugarcane, and the significant potential for expansion in developing countries. In fact, the sugarcane industry has long experienced South-South technology transfer, such as various types of harvesting equipment between the Brazilian and South African sugarcane industries. However, since this technology transfer has focused on sugar and has generally not extended to the whole processing and management aspects, it has not yet had significant impacts on ethanol production outside of Brazil.

Among the key developments in the Brazilian market development has been the flexibility to produce either sugar or ethanol, which has many advantages:

- Full use of all sugars in the sugarcane and not only sucrose;
- Since final molasses need not to be exhausted, a sugar of better quality can be produced, with less energy use;
- The beginning of the crushing season can be anticipated since the lower sucrose content of the cane is partially compensated by higher inverted sugar content (i.e. inverted sugars can be used for ethanol production, but not for sucrose);
- All sugars recovered (as sugar or ethanol) is sold at sugar prices, while the molasses (in sugar only mills) are sold at much lower prices;
- The flexibility of producing more sugar or more ethanol with the same cane milling allows to adjust the production to the market prices;

Although few countries would have the large national market in which to create such highly competitive conditions, regional cooperation among groups of countries could achieve such higher scales to create market volume and reduce production costs.

Brazil can also provide considerable first-hand expertise in improving the cost-effectiveness and yields of ethanol through a combination of feedstock preparation and optimisation of process conditions. Brazil has extensive experience in the utilization of by-products e.g. use of bagasse in cogeneration, use of stillage as fertilizer, harvesting and transport, and above all in ethanol fuel engine modifications (discussed below).

End-use Innovation: Flex-fuel vehicles (FFVs)

One of the key facilitating mechanisms for the recent surge in ethanol markets has been the development of the Flex-fuel vehicle (FFV) and its widespread use, first in Brazil, and later in U.S.A. and elsewhere[28]. In the USA the FFVs vehicles incorporate a modern microprocessor that continuously monitors the engine's operation and fuel-air ratio, making it possible to adjust automatically to ethanol/petrol blends containing up to 85% ethanol (E85). For E85 vehicles, power, acceleration, payload, and cruise speed are comparable with those of conventional fuels[29].

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[28] The idea was first developed in Europe and USA in the late 1980s, but the technology was improved in Brazil to allow the use of higher compression ratios. The availability of the improved technology starting in 2003 coincided with higher oil prices, and in combination with a small excise tax reduction, the market for flex-fuel vehicles was considerably accelerated, such that by January 2006, 73% of all passenger-vehicles being sold were FFVs.

[29] This comparison refers mainly to U.S.A. (see www.afdc.doe.gov/afv/; www.ott.doe.gov/biofuels/).

The FFV in Brazil is more advanced than its counterpart in the USA since this technology can cope with anything from 100% (neat) ethanol, to blend in any proportion. In Brazil, the development of the technology is due to the efforts of the parts industry – mainly the manufacturers of electronic management devices – rather than the car manufacturers.

Because of their higher compression ratios, close to the one of neat ethanol engines, Brazilian FFVs perform better than their US counterparts in terms of fuels saving, although compared with a neat ethanol engine the FFV presents slightly lower performance, but this drawback is compensated by its higher flexibility. Currently vehicle manufacturers concentrate in the production of FFV engines rather than producing both options, avoiding the need for multiple assembly lines and processes.

International Trade

For decades the sugar industry (both beet and cane) has both benefited and suffered from one of the most distorted international commodity systems in the world, with subsidies that have benefited some producers at the expense of consumers, as well at the expense of alternative products such as ethanol. Pressure from the WTO has led to a gradual market liberalisation, and therefore the sugar and ethanol markets are going through a period of transition to more open markets. Exports of ethanol are expected to grow more than four-fold in the next five years, as shown in Table 5.

Table 5: Potential demand for fuel ethanol imports (Million litres)

Country/region	*2005*	*2010*
Japan	500	6,000
European Union	1,000	3,000
China		2,300
South Korea		1,900
India	600	1,500
USA (through CBI)	600	1,200
Thailand	700	1,000
Canada	400	600
Total	**3,800**	**17,500**

Notes: Japanese and South Korean markets estimated considering an E10 target for 2010 and that both countries depend on imports. Estimates for European Union are based on the directive that obliges the use of 5.75% of bio-fuels mixed to fossil fuels in 2010 and that 20-25% of demand will be met by imports. Chinese market was estimated assuming widespread use of ethanol + gasoline blends and that local production is able to reach about 50% of the total demand. For India it was assumed that local capacity would be unable to meet demand as a result of the E5 directive. The same assumption was made for Thailand. In the case of USA, imports were calculated as 7% of the estimated fuel ethanol demand.

Source: Rosillo-Calle and Walter, 2006

Currently, over 4 billion litres of ethanol are traded annually, with Brazil and USA as the main exporters, and Japan and EU as the main importers (F.O. Licht, 2006). Brazilian exports have increased rapidly in the past few years. Demand in 2010 for imports is likely to be driven by those countries and regions that have put blending requirements or targets in place, and have only small amounts of domestic capacity, especially the EU and Japan; the EU and Japan account for more than half of the expected demand in 2010.

The trade reforms will benefit countries such as Brazil that have a well-developed and competitive industry; other countries that have had preferential market access, particularly the African, Caribbean and Pacific (ACP) countries, are facing a more difficult transition. Diversification into ethanol and other products could ease this transition, provided that these markets are also open to competition. A number of trade and market barriers remain, including:

- Cautious attitude of the automobile industry toward alternative fuels;
- Ethanol classified as an agricultural good, for which import duties are imposed by U.S.A. and EU;
- Lack of internationally agreed biofuel standards;
- Certification of the production of ethanol to ensure its sustainability;
- Uncertainty in GHG reduction benefits, to be used for carbon financing.

Resolution of these barriers could result in even greater expansion of trade in ethanol as well as expanding trade in other biofuels.

Research and Development

The ethanol industry, with its strong connection to sugar commodity markets and to agricultural practices and policies, is more fragmented than other industries, in terms of presenting a common policy or R&D strategy. The industry is far behind many other industrial sectors when it comes to innovation, or introduction of new technologies. The low and/or fluctuating prices of sugar leaves little margins, while differences in agronomy practices, productivity, know-how, culture, etc. have also contributed to shrinking R&D budgets. The following is a summary of the main findings of a recent survey (Kochergin et al, 2003):

- Greater cooperation among international R&D centres is needed to share results;
- There is a strong need to innovate, to invest in new technologies to improve productivity and cut costs; this is fundamental as competition intensifies;
- There is a need for greater commitment of private involvement in R&D, since in most countries government agencies continue to do the lion's share of R&D;
- Industry needs to make environmental issues an R&D priority;
- current R&D is too short-focused and is hindering long term development;
- Industry participation must be a driving force, as is mostly the case in Brazil;
- Need to reduce delays due to harvesting, transport, logistics, etc.

There is a downward trend in R&D in the sugar industry, which, if not reversed, will lead to stagnation. This downward trend has had a direct and major impact on ethanol-related R&D when it comes to developing countries, since sugarcane is likely to be the most cost-effective option in the near-to-medium term, as they are mainly located in tropical and sub-tropical climates.

Conclusions

The introduction of fuel ethanol (together with other alternatives) offers good possibilities for greater fuel diversification, lower prices, cleaner environment, and better social benefits, particularly in developing countries where the bulk of ethanol production is expected to take place in the short to medium term. In the past, biofuels policies have been largely driven by agricultural rather than by energy and environmental concerns. However, imports from countries that can produce at lower costs will foster the market and even induce technology improvements. Due to mandates and targets for biofuels, import demand will be concentrated in a few OECD regions, especially the EU and Japan.

A truly international market for fuel ethanol will require more producing countries to be in conditions to export large surpluses. In the short-term, low cost ethanol can be produced mostly from sugarcane; in a mid to long-term scenario, ethanol from cellulose could be produced in large quantities. Agreed international standards will also have to be implemented if fuel ethanol is to become a truly international commodity. Certification of sustainable production will need to be defined in such a way as to ensure that it does not results in the imposition of additional trade barriers.

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9

PAPER

Coconut Industrialization Centers

By: Edmundo T. Lim - Philippines

1. Overview

The first step in rehabilitating the coconut industry in the Philippines, and perhaps, in the other coconut producing countries as well, is to process whole coconuts into more primary products such as coconut fiber products, coconut peat, fuel instead of just copra and desiccated coconut and to establish smaller processing plants within the coconut growing communities instead of urban centres.

1.1 The Potential of Coconuts

According to FAO 2002 statistics, the total world production of coconuts amounted to 53,090,561 MT or around 53 billion nuts. In terms of the biomass produced from the coconut, coconut husks, shell and water, new value added products can be produced equivalent to 5 billion kilos of fiber, 10 billion kilos of coir dust or cocopeat, 10 billion kilos of coconut shell and 10 billion liters of coconut water, annually. In the Philippines and Indonesia (where more than 50% of coconuts areas are located), more than 99% of the husks and water are discarded as wastes and left to decomposed in the farms, contributing significantly to the greenhouse emissions.

Coconuts are produced in 92 countries worldwide on about 10.6 million hectares (26 million acres). The current world production of coconuts has the potential to produce electricity and energy, fiberboards without chemicals or glue, organic fertilizer, animal feeds, coconut fibernets, fuel additives for cleaner emissions, health drinks, etc. (Details are in Annex A)

1.2 Background and Rationale for Coconut Industrialization Centers

India, Indonesia and the Philippines account for almost 75% of world coconut production. In the Philippines, the rural population of 68 of its 79 provinces is heavily dependent on coconuts as a means of livelihood. One fourth of the entire population or around 20 million people depend directly on the coconuts for survival. The coconut farmers are the poorest of the three major categories of farmers in the Philippines, earning roughly P10,000 (US$182 or 150 Euros) per hectare per year. This is less than US$1.00 per family per day!

Yet, the Philippine coconut industry has not changed its operating system over the past 50 years. Major copra crushing plants are located at urban seaports. They continue to buy poor quality copra produced in the crude fashion way by farmers. The farmers still depend on the dried copra as the main source of income from their coconuts. An insignificant amount of husks and shells, when not burned, are sold to small manufacturers of coir and charcoal, while the coconut water is hardly ever utilized.

Low productivity continues to plague the farms due to poor farm management and lack of financial resources. Moreover, most oil mills produce low-grade oil and copra meal that contains levels of aflatoxin unacceptable in most countries in Europe, Japan and the USA.

In summary, the coconut industry in the Philippines, and in other countries, is inefficient, underutilized, uncertain, and produce low quality products. For lack of other alternatives, the coconut farmers continue to harvest, and some prefer to cut the trees, without replanting, to be sold as lumber. The coconut industry is waiting and ready to be restructured!

The only way for the coconut industry to survive is to show the stakeholders that there can be a bright future for the industry. The coconut farms must be transformed into countryside industrialization systems, initially with the establishment of COCONUT INDUSTRIALIZATION CENTERS (Center or CIC) in every 2,000-hectare coconut area, to achieve the following advantages:

- Increased harvest of coconuts from replanting, fertilization and proper cultivation of the coconut farm
- Maximize oil content of the coconut through timely harvesting
- Processing of the coconut into multiple products instead of just copra
- Reduction of transport cost, by establishing the Centers in the coconut farming communities and retaining portions of the production for sale to the consumers in the CIC localities.
- Utilization of biomass wastes as fuel for power generation
- Utilization of better drying system for producing quality copra, which will eliminate aflatoxin and PAH (Poly-Aromatic-Hydrocarbon) as well as ensure hygienic production and higher recovery of oil and meal
- Production of coconut bio-diesel for farming and fishing machineries
- Utilizing the Centers as an engine for increasing coconut farmers' income by assisting the farmers in managing their farms to increase the productivity of the nuts and trees
- Planting new crops under the coconut trees, and creating new opportunities for land usage such as livestock raising, honey production and providing employment and entrepreneurial opportunities from downstream processing of new products from these activities
- Lowering prices of household and medical needs through the operation of a community commercial center and health facility within the Center's community, as well as provide

an outlet to sell locally produced items, access to the internet, leisure and entertainment

- Stem migration of coconut farmers and their children to urban centers through localized industrialization and community development
- Encourage preservation and increase acreage of coconut farms as a result of improved income of the farmers from their coconut farms
- Eventual ownership of the Centers by participating coconut farmers and other stakeholders, thereby promoting community spirit and interdependence

All of the above is attainable if we make the CIC operations:

Farm-Oriented

- All the coconut farmers will be enticed to participate as the raw materials suppliers, workers and eventual owners of the Centers
- Workers required for the Centers will be hired from the local communities. Training will be provided if the skills are not available
- Tenants, farm workers, landowners or other local investors can be stakeholders and eventually share in the profits of the Center

Business-Oriented

- Centers will be operated primarily as a business concern BUT with a true social responsibility imbued into it. Professional managers will manage the Centers while community-grown expertise is being developed.

1.3 Objective

To industrialize the countryside and generate employment in the community - The operation of each CIC can generate at least 1,500 jobs, from fertilization to harvesting to processing of downstream products. The troubled area of Mindanao in the Southern Philippines is capable of supporting more than 750 Centers, translating to over 1,000,000 jobs for the coconut farming communities. The Autonomous Region in Muslim Mindanao has 15% of the coconut farms in Mindanao; it can establish 100 Centers generating over 150,000 jobs. Potentially, the income of the Coconut Farmers can increase from the current P10,000 (150 Euros) to more than P100,000 (1,500 Euros) per hectare per year.

1.4 Project Description

One Coconut Industrialization Center will be initially set up in every 4,000-hectare coconut producing community to process around 50,000 whole nuts daily. Five of these Centers can produce enough coconut shells to supply the fuel requirements of a power-generating plant using technology and equipment presently available from European countries. The husks from the five Centers can also supply the yearly requirements of a Coir-Based Construction and Packaging Material Plant. The final report on this project is available from the Wageningen Institute of the Netherlands.

Each Center will have facilities for a 100,000 whole nut receiving area, de-husking, splitting and de-shelling area, coconut meat drying area, decorticating, fiber drying and baling machines and storage area, fertilizer/feed mixing and storage area, office and community store.

1.4.1 There will be six operating teams operating under a general manager

1.4.1.1 The Nut Buying Team is responsible for the procurement of whole nuts from coconut farmers by organizing the farmers as members of the CIC. Farmers will be provided with assistance and incentives to ensure continuous supply of whole nuts. Management of the CIC facility, consisting of Copra Processing, Decorticating, Fiber Production, Fertilizer Production and Other Services, shall be manned by professional managers.

This Team shall also be responsible for the scheduling/transport/delivery of the nuts from the farms to the CIC to ensure that the daily supply of whole nuts is synchronized with the marketing commitments of the processed coconut by-products. It shall negotiate and contract with coconut oil mills for the sale and delivery of the copra to the oil mills.

It shall calculate the buying prices of whole nuts based on the copra buying prices of the oil mills. This new buying system will increase the income of the farmers by at least P4.00 per kilo of copra (around 40% of their current income) while freeing the farmers from the laborious copra making process. The farmers' free time will be channeled to more productive work in the form of planting other crops under the coconut trees and raising livestock, poultry and honey production.

1.4.1.2 The Copra Processing/Shell Production Team handles the copra drying, charcoal production and supply of coconut husks and water for the Decorticating, Fertilizer and Fiber Production units. There will be 10 hot air driers built with a capacity to dry 4,000 split nuts per batch every 8 to 10 hours. The hot air needed to dry the copra will be supplied by the carbonizing and power-generating component using the coconut shells as fuel.

The de-husking of the whole nuts will be performed in a working area adjacent to the 100,000 whole-nut storage area. Splitting of the de-husked nuts will be done over a system of basins that will collect and channel the coconut water into a storage tank, which will be pumped immediately to the fertilizer production area for immediate use. The husks and coconut water will be transferred to the Decorticating and the Fertilizer production units. The dried copra will be pried out of the coconut shells and will be bagged for delivery to the coconut oil mills. The shells will be transferred to the power generation component of the Project, which will also produce charcoal during the carbonizing process.

The copra production team will be will have a staff of 84 people per shift (82 piecemeal workers and 2 monthly staff).

1.4.1.3 The Husk Decorticating team must ensure that the husks are processed within two days from the time the nuts are de-husked to prevent the drying out of the husks. The decorticating machine will have a minimum rated capacity of around 5,000 husks per hour and will be powered by a diesel engine to ensure against inadequate power supply or fluctuating voltage, which is common in the rural areas. The machine is operated by a group of 8 people. Six workers bring the husks from the piles to the machine. Two workers ensure regular feeding of the machine and regulate the speed of the engine. Eight workers move the fiber and peat to the designated areas after decorticating. A production supervisor will organize and train this group of 14 workers, who are to be paid on a piecemeal basis.

1.4.1.4 The Fiber Production Team will oversee the production of long fibers for export and for twinning. The raw fibers delivered from the decorticating area will be combed and dried in preparation for baling. The drying of the fibers will utilize the low heat piped from the shell carbonizing unit of the project. Baled fiber for export has to be standardized according to the moisture and foreign matters specifications. Bulk density per bale is essential to maximize stuffing of containers to minimize shipping costs.

Fibers for twinning need not be dried nor baled, however, quantities delivered to farmers' households for twinning and weaving must be accounted for and controls on deliveries of raw materials and finished products have to be implemented strictly to discourage pilferage.

Four people are needed to man the drying process. Another group of 4 people load the dried and cleaned fibers to the baling machines, strap the bales and transfer the bales to the warehouse. The group of 8 piecemeal workers report to a production supervisor.

The baled fiber must have less than 20% moisture and less than 3% foreign matter. The baling machines must be able to produce 25 to 50-kg bales with dimension of 70 x 50 x 40 cm. This is crucial so as to fit not less than 18 tons per 40-ft container.

A quality controller will be in charge of quality control of the final product, the fiber balers, and organizes the storage of the bales to assure the principal of first-in first-out. Twice a month he organizes a team of 20 people to load the container(s).

Another product that can be produced from the fiber is coconet or geo-textile. This is produced by first twinning the fiber at a specific weight and length and woven into nets with specific weights per square meter. There is a huge potential market for coconets and coir logs to be used in controlling desertification, a UN-recognized significant threat to our environment. However, there is must be a determined effort to inform and promote the coconet for this purpose.

Once the product potentials are recognized, countries affected by the desertification menace can reverse the threat at minimal costs while the supplying countries will be able to generate millions of jobs that can reverse their poverty situation significantly. Entry into these markets cannot be achieved overnight.

Production of coconets requires hand-spun fiber yarns that are hand-woven into nets. This process requires training and organization to establish a network of households to be engaged in this activity. Coconets production is labor intensive and requires an organized and systematic effort in capability building to ensure consistent productivity. Processing equipment is very inexpensive and can be fabricated by and in the local community. Also, after training a few households by expert trainers, further training and capability building can eventually be locally generated.

Twining and weaving will be introduced on a very small scale initially. It basically entails training of trainers and building up the experience and expertise to produce the desired quality of twines and coconets in anticipation of future demand. The Nut Buying and Management Project will be in charge to further develop this project.

This Project will be employing 14 people (2 monthly staff and 12 piecemeal workers). However, when all the fibers are processed into coconets, 1,200 workers will be needed per Center.

1.4.1.4 The Organic fertilizer Production Team shall utilize the coconut peat from the decorticating project, coconut water from the copra processing project and special inoculants developed by the University of the Philippines biotech scientists to produce Biomanure and organic fertilizer components using only coconut-sourced materials. It shall operate a mixer designed to handle the special characteristics of the coconut peat.

Management will pre-arrange with the UCPB-CIIF Finance and Development Corporation for fertilization loans to be granted to the farmers-members of the CIC covering the cost of the fertilizers and for fertilizer application fees. Ingredients such as copra meal and inoculants will be purchased from the coconut oil mills and the biotech companies.

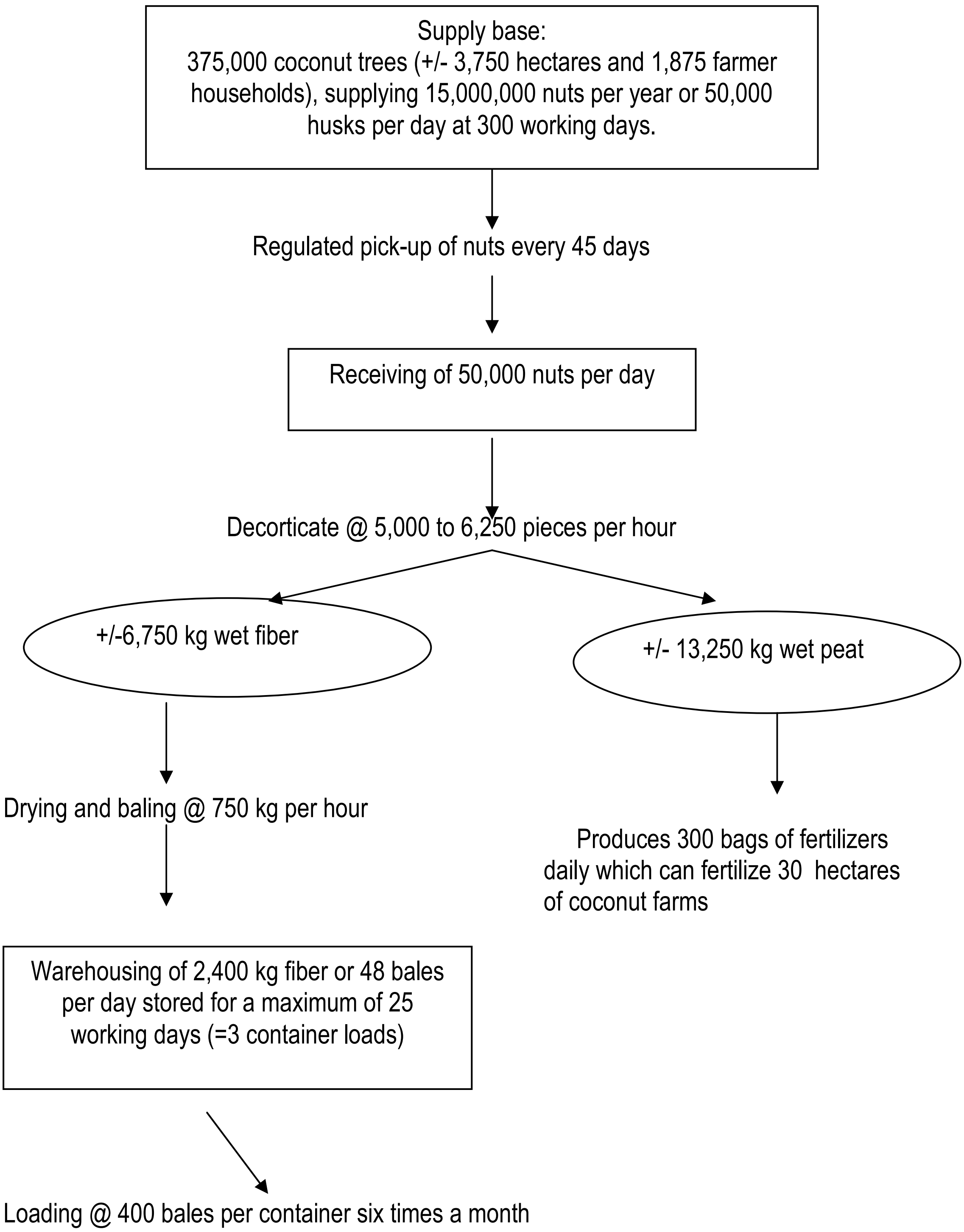
Production of Bio-manure will be the first step using the technology and inoculants provided by University of the Philippines biotech scientists. This Bio-manure will then be mixed with the coconut peat and water and specially developed inoculants to do away with the traditional method of aerating the materials during fermentation over a period of 3 to 4 weeks.

The CIC may subcontract to farmers' wives to provide the labor and storage in the production of the organic fertilizers, thereby providing new opportunities to the farmers' families to earn additional income. This team will be employing 10 people (one monthly staff and 9 piecemeal workers).

1.4.1.5 The Special Services Team will operate a mini-commercial area that will house a community store, computer training, internet access and entertainment area for the community. The lack of accessible road network in the villages creates the opportunity to introduce banking and communications using cellular phones.

It will also operate a small coconut oil-based bio-diesel plant when the prices of copra drops to a level that will make it economical to produce the coco diesel to replace diesel fuel. The current farm gate price (February 2006) of copra in the Philippine rural areas already warrants the production of coco diesel.

2. Material balance and process flow



3. Socio-Economic Aspects

Around 1,500,000 coconut farms, of 2 hectares per farm, will benefit directly from increased prices for their coconuts. With the financial and technical support from the Centers, the productivity can be increased three times, from 40 nuts to 120 nuts per tree per year; the income from the coconuts will also increase by at least 40% from the sale of the by-products; land productivity of the coconut farms through intercropping and livestock raising/fattening will add another 3 to 4 times to their current basic income.

Moreover, over 300 family members of coconut farmers/workers can be employed directly by the Centers. An additional 1,200 family members can earn extra income from twining and weaving of the coconut fiber to produce coconets suitable for erosion control and desert recovery projects.

Each Center can service a community of 2,000 families owning or working an area of 4,000 hectares. As the family income increases, the local communities start to benefit from more commercial activity, lower prices of goods produced in the community, like cooking oil, meat products, aquatic products from coastal coconut areas, vegetables and fruits from under the coconut trees, vinegar, flour, soap, organic fertilizer, cheaper feeds, and other coconut products.

Environmentally, the project will be processing whole coconuts with no waste whatsoever, husks into fiber and peat, coconut water for fertilizer and feeds, coconut shell to dry copra and produce charcoal, and clean copra with no aflatoxin. The processing of the biomass parts of the coconut will also reduce very significantly, the greenhouse emissions, which are currently produced from the rotting husks and the water, which has a 6% sugar content, being thrown away.

The use of organic fertilizers enriches the soil and eliminates harmful residues from the run off of chemical fertilizers and saves hundreds of millions of US Dollars for the Philippines. Organically grown coconut products can have a higher consumer value.

4. The Challenges

4.1 Establishing a commercially operating demonstration plant in a major coconut producing area with the support of the developed countries to fund, monitor and document the establishment and operation of a fully Integrated Coconut Industrialization Center consisting of five supply processing facilities, power generating plant, fiberboard manufacturing plant and a coconut diesel processing plant.

4.2 The promotion and generation of demand for fiber products, particularly the coconets is a significant component in maximizing the benefits that can be generated by the Coconut Industrialization Centers. Without a sustained demand, fiber products from 53 billion nuts per year may not be produced, and the over 2 million jobs, just in the Philippines alone, that can be generated will not materialize. It is therefore crucial that international markets for coconets be developed.

4.3 The potential markets for coconet are the countries in the world that are threatened by the phenomenon of desertification. Countries such as China, Saudi Arabia, Africa, Australia and parts of North and South America. These countries have signed up with the United Nations Convention to Combat Desertification (UNCCD). The recovery or reclamation of the desert into arable, or at least, greenery areas may provide the solution to a serious global environmental concern.

4.4 The need for governments of both the producing and the importing countries, to provide incentives to encourage private investors and stakeholders to participate in the program to industrialize the coconut rural communities. For the producing countries, this is a significant program to lessen poverty in the rural agricultural sector and solve the problems of poor education, urban migration, technological famine, poor delivery of social services, lack of local government funds due to non-payment of taxes, etc., and creation of wealth.

4.5 Generation of interest from international investors and technology providers and the conversion of this interest into actual investment in the Coconut Industrialization Centers.

4.6 Standardization of product specifications and removal of tariffs and non-tariff barriers for coconut fiber and coconut peat products

Annex A

From 53 billion coconuts harvested annually, the following can be produced:

1. Electricity and Heat from Coconut Shells

R.V. Siemons Holding b.v. of The Netherlands, an investor in the Dutch Carbo Group b.v., owns a shell carbonizing technology that can covert a feed of 110,000 coconut shells daily to over 74 megawatt hours per day plus 54 gigajoules of usable heat to dry coconut meat, fiber, peat, etc. This means that the annual world production of 53 billion nuts can produce over 36 million kilowatt hours per year plus 27 million gigajoules of heat.

The above figures are based on the following tables provided by R.V. Siemons:

Clean Fuels for a Sustainable Energy Economy

The energy conversion routes:

<u>Charcoal route:</u>

Yield 30 mass % (= 70 energy %), by- product: heat 15 energy % (if that heat to electricity, conversion at 15- 25%)

<u>Process heat route:</u>

Yield 80 energy %. No by- product.

<u>Heat for electricity route:</u>

Yield 15- 30% (combustion + steam cycle), No by- product

<u>Bio- oil (pyrolysis oil) route:</u>

Yield 70 energy %, by- product: heat 15 energy % (if that heat to electricity,

conversion at 15- 25%)

Elaboration of the Charcoal route:

Intake	Whole coconuts	40,000,000	nuts/yr
	or		
	Shells	10,000	t/yr
Carbonizing	Charcoal	3,200	t/yr
	=	99,200	GJ/yr
	=	27,556	MWh/yr
	Usable heat	20,400	GJ/yr
	=	5,667	MWh/yr
Heat Utilisation	Drying (copra, coir, peat, etc.)	5,667	MWh/yr
	=		
	water evaporation	6,327	t water/yr
	or		
	Electricity	1,417	MWh/yr
	=	0.65	MW

2. Construction fiberboard panels from coconut husks:

266 million panels of 6mm x 4ft x 8ft of fiberboards

or

Combining Coconut Peat with coconut water:

15 million tons of organic fertilizer

or

30 million tons of cattle feed

and

5 million tons of coconut fiber which can produce 10,000 square kilometers (1,000,000 hectares) of coconets per year

3. From the Coconut meat:

6 million tons of coconut oil

or

6 billion liters of cocomethyl ester which when blended at 2% cocomethyl ester with diesel fuel can produce 300 billion liters of cleaner-emission diesel fuel

plus

3 million tons of copra meal for use as protein source in animal feeds

PART THREE

Summary of Plenary Sessions

Summaries of Plenary Sessions

The transformation to a bio-based economy

This session considered the various driving forces, technical platform, and policy frameworks behind the bio-based economy, and identified potential challenges and opportunities that could arise. Biomass feedstocks, now largely discarded, could provide sustainable carbon sources to meet increasing energy demands and generate added-value products.

Technology Platforms as a tool to develop a bio-based economy

The representative of EuropaBio stated that Industrial or White Biotechnology - the modern use and application of biotechnology for the sustainable processing and production of chemicals, materials and biofuels – was expected to play an important part in the future success of the European economy and society. Industrial Biotechnology was increasingly gaining ground due to its potential to reduce pollution and waste as well as save energy, raw materials and water. It would also lead to better quality food products, create new products, materials and biofuels from biomass and provide a sustainable alternative to some conventional processes.

Technology Platforms were essential as they brought together stakeholders to define a Strategic Research Agenda (SRA) including, *inter alia*, major research and technological advances in the medium- to the long-term. The Technology Platform on Sustainable Chemistry (SUSCHEM) was highlighted as an example of a tool to develop a bio-based economy, addressing materials technology and reaction and process design.

Although most developing countries did not currently have resources to develop and use industrial biotechnology on their own, many of them had a large agricultural base which could become much more productive in the future. There was an opportunity for developing countries to provide biomass feedstock for a range of new industries, completely by-passing the way industry developed in Europe, thus avoiding related environmental problems. Extra world demand for agricultural produce – driven by population growth, increasing affluence and greater use of biomass by industry – could also tend to increase commodity prices and directly benefit developing country farmers.

Opportunities and challenges for industrial biotechnology in South Africa

The representative of AfricaBio, South Africa, underscored a need for sustainable solutions for South Africa that had great potential for further developments. She highlighted the status of the use renewable resources and the current status of the biotech industry in the country. Some of the inhibiting factors included lack of cohesion in research programmes, lack of investment and development of technology platforms and a lack of foreign investments. For industrial development, adequate funding for South Africa and African biotechnology was essential. In addition, stronger international partnerships, the elimination of trade barriers and public acceptance of biotech products were important. Currently, the large South African industries developing biotechnology included the forestry, sugar, starch, seed, energy and mining industries. The potential impact of renewable energy systems on the country, including the rural community was highlighted. There was need for more co-ordination in the development of a bio-economy, sustainable development, rural empowerment and poverty alleviation, new market opportunities and balance of trade and energy independence.

Relevance of biomass based products for the Indian economy

The representative of Biotech Consortium India Ltm, put forward a case study that focused on the relevance of biomass based products for the Indian economy. The biomass economy was largely agrarian, dependent on agriculture and made a significant contribution to GDP. Policies and incentives included new technology development and commercialization, energy crop plantation and subsidies and other incentives. The example of the biodiesel procurement policy of the Government of India was explained as a major incentive for a bio-economy. The biodiesel policy addressed the concerns of using agricultural crops as feedstock, the deployment of arable land, energy costs for cultivation, competition from large companies, sustained market demand and sustained consumption. The potential for biogas production was also described.

Chemical industry and white biotech renewables

The speaker from ‘Degussa’, a multinational speciality chemistry corporation in Germany, highlighted the link between the chemical industry and white biotech renewables. He underscored that the driving forces for renewables and white biotechnology were the ecology (1997 Kyoto Protocol), the economy (limited crude oil resources) and innovation (based on the growing chemical industry). A demand for certain products, e.g. for sphingolipids for high end skin care products or amino acid L-lysine as a feed additive, led to the need for ongoing research and new technologies. Degussa, since 1 January 2006, has established a ‘science to business bio centre’ that closely combines innovation with a strong customer focus.

Industrial biotechnology – experiences and comparisons

The session focused on recent or ongoing industrial biotechnology initiatives. Different platforms, geographical regions and lessons learned in large-and small-scale production systems for local, regional and international trade were discussed.

Biorefining and biorefineries – a potential way to establish a biobased economy

A representative from Biorefinery.de.Germany, focused on the significance of biorefining and biorefineries which were key to developing biobased industrial products and fuels. Biobased industrial products could only compete with petro-chemical based products if raw materials were optimally exploited and a variety of value-creating chains developed and established. He discussed four current biorefinery systems within research development and practice: the Whole Crop Biorefinery, the Green Biorefinery, the Lignocellulose Feedstock biorefinery and the two-platform concept.

Opportunities for bio-based products in the Brazilian sugar cane industry

The representative from Centro de Tecnologia, Canavieria, Brazil, stated that for many years, attention had been paid to the production increase of sugar and ethanol, the two main products in the Brazilian sugarcane industry. Recently, its contribution to generate electricity for sale to power distribution utilities had made it clear, that other co-products were also capable of increasing the industry's income. These included yeast and its derivatives from alcoholic fermentation or waxes extracted from filter-cake. Other co-products could also be recovered and transformed into added-value products depending on the market and technical and economical feasibility.

The low sugar production costs in Brazil and the supply of bagasse energy made sucrose very attractive for several other products. As a result, there was also commercial production of amino acids, organic acids, sorbitol and yeast products as well as developments for bioplastic.

The production of compounds obtained from ethanol returns were affordable alternatives for substituting products from the oil-derived industries. After providing a brief overview about the most common co-products, two products were highlighted: yeast and its derivates as a co-product from the ethanol fermentation and a PHB (polyhydroxybutyric acid) and related copolymers, which could be advantageously produced when integrated into a sugarcane mill.

Opportunities and barriers for biofuels markets in southern Africa

An expert from the University of Zambia stated that due to a realisation that biofuels could be used for heating, power generation and transport purposes, a heightened interest was recorded, especially among small- and large-scale farmers in Africa. For example, large resources of agriculture biomass in Africa could be converted into a variety of biofuels such as ethanol and biodiesel. At the same time, a number of challenges needed to be considered.

The key driving forces for biofuels in the EU were the Directive for Promotion of Biofuels and the Directive on Fuel Quality. The former, required member states to set indicative targets of biofuels sales in 2005 (2%) and 2010 (5.75%) motivated by the need to cut GHGs and increase energy security by reducing dependence on imported fuels. As a result of this Directive, it was estimated that a market demand of 10.5 billion litres of biofuels will be created.

With reference to the EU Directive on Fuel Quality, biodiesel had useful properties that it released fewer solid particles than conventional diesel and contained no sulphur and released no SO_2, which contributed to acid rain. Due to limited land availability, and relatively high cost of the feedstock rape seed, it was unlikely that the anticipated demand of 10.5 billion litres of biofuels in the EU would be met by domestic supply. This market was of significance to creating a biofuels industry in Africa.

Apart from high world petroleum products, two other factors had an impact on biofuels development in Southern Africa: the EU Preferential Trade Agreement Sugar Reform and the Africa Dakar Declaration on replacement of lead as an octane enhancer for gasoline fuels. In the medium term, most countries in Africa were seriously considering the use of ethanol as a substitute for both lead and MMT. Many sugar industries in the African, Caribbean and Pacific regions were likely to cease the opportunity to diversify to other core products (ethanol and surplus electricity generation) because of the EU Sugar Reform and low world market value of crystalline sugar.

Southern Africa had great potential to greatly benefit from the use of its natural resource endowment base to produce biofuels. If implemented, a sustainable energy path could be achieved contributing significantly to poverty reduction through the creation of jobs from agriculture, processing and marketing. Reaching such targets required a holistic approach and therefore a need to consider markets, production processes/technology, feedstocks, economics, regulatory, fiscal and policy framework, involvement of stakeholders.

The forgotten waste biomass – two billion tonnes for fuel or feed

Two experts from the respective Departments of Plant Science of the Weizmann Institute of Science and the Tel Aviv University, Israel, stated that the best solution to the worlds' most abundant agricultural waste was to recycle it to bioethanol for fuel or through ruminants to produce more food. The technology had elements that rendered it ideal to demonstrate why / where genetic engineering could be of benefit to farmers, the manufacturing sector, the environment, and to humanity as a whole. It would take more than a decade to isolate the genes, transform the plants, analyze each series of transformants, fine-tune the levels of expression such that sturdy, high yielding grain crops will result, with more digestible cellulose. It will take years more to either cross and backcross the genes into more varieties of the crop, or to transform each variety. The subsidiary technologies of processing and feeding the straw will also have to be developed. Thus there was an urgency to start research as soon as possible.

Straw utilization would be environmentally beneficial, compared with present uses, but it will not provide feed value equal to grain yields. The best quality hay or silage, a viable target, has only a quarter the feed potential of grain, but a 25% increase in agricultural efficiency is also exceedingly valuable, especially when the environmental worth is added to the equation. Agricultural productivity in much of the developing world is half the world average. This 25% advantage will remain as productivity increases. The final product will not be simple to obtain. It will not result from engineering a single gene with a non-specific promoter. It will surely contain a large number of cereal genes that are transgenically modulated, with tissue specific promoters, as well as the addition of genes, based on the needs documented above.

Bioethanol, Sustainable Development and International Trade: Opportunities and Challenges for North-South-South Cooperation.

The paper, presented by an expert from the Stockholm Environment Institute (SEI) on behalf of a representative from the Imperial College Centre for Energy Policy and Technology (who was unable to attend due to unforeseen circumstances), explained the work of the Cane Resources Network for Southern Africa (CARENSA), funded by the European Commission Fifth Framework Research Programme and coordinated by SEI. He highlighted the significant increase in world ethanol production in the last 30 years, due mainly to programmes in Brazil and USA. He also described cost reductions in the case of Brazil, as well as the capacity to expand production and market projections. He indicated the opportunities for North-South trade in bio-ethanol and the need for South-South technology transfer between Africa and Brazil and also between Africa and India.

Lessons learned for Africa from the ProAlcool Programme in Brazil included the need to avoid land concentration, but included the involvement of small farmers, large employment generation, rural economy development and social development. In that context, the focus should be on reconciling social development with economics, competitiveness, distribution and logistics.

Experiences in Cuba with industrial biotech and bio-processes

The speaker from Centro de Gerencia in Cuba described the co-products obtainable from field, intermediate and final streams of the agro-industrial cane sugar production. There were four main streams: the sugar itself, the sugar cane crop residues, the sugar cane industrial residue - the sugar cane bagasse - the filter cake - and the final molasses. It was possible to produce different co-products from this agro-industry for: animal and human food, bio-fuels, industrial productions and agricultural uses, by use of physical, chemical and/or biological processes. About 89 related products could substitute products currently made from petrochemical industries (based on research projects of National Research Programs managed by the Center for Management for Priority Programs and Projects (GEPROP) of the Ministry of Science Technology and Environment of Cuba). It was pointed out that the Ibero American Science and Technology for Development Program (CYTED) had edited a catalogue with some of these products and technologies that could be used as a way for the promotion of its use.

Product development for bio-waste

An expert from Wageningen University, Netherlands, stated that the use of suitable biomass residues from food and feed production needed to be expanded to value added products that would result in new economic agro-industrial activities for export markets and local consumption. Opportunities for commercialization of innovative products based on ligno-cellulosics and biopolymers had been explored for biomass residues derived from tropical and sub-tropical commodity crops (oil palm, coconut, banana, rice, etc.). Bioconversion and biotechnology would play key roles in the transition from a fossil-based to a bio-based society and were essential for the development of sensible uses of renewable resources.

The presentation reviewed project concepts related to technology development for value addition of bio-based products and gave examples of promising transfer of know-how to developing countries. Various aspects of organization of supply chains and drivers for project development were addressed. Forward integration of the marketable products required raising public awareness and the close involvement of farmers or cooperatives. There would be a need for commodification or the organization and regulation of trade in biomass feedstock. This implied the installation of mechanisms for quality control (grading systems / tracking and tracing) and certification for the sustainable use of biomass resources.

Mechanisms/incentives for expanding bio-based products and services

This session considered specific action or platforms that could stimulate expansion of biomass-based industries in developing countries, while simultaneously advancing policy goals at different levels: local (e.g. income generation); national (e.g. competitiveness); regional (e.g. trade and technology transfer), and global (e.g. climate change mitigation and sustainable development). Techno-economic and policy/institutional prerequisites for GHG co-crediting of biomass-based products and services under the UNFCCC Kyoto Protocol were assessed.

Certification of Bioenergy from the forest – motives and means

An expert from the Växjo University explained that under the Bioenergy Agreement, the International Energy Agency (IEA) had a number of Tasks dedicated to various aspects of the field of bioenergy. Task 31 - *Biomass Production for Energy from Sustainable Forestry* and its triennial predecessors dealt with sustainability issues related to increased harvest of biomass for energy from silvicultural systems.

Based on leading-edge science and technology, the objective of Task 31 was to co-ordinate research, to compile and disseminate knowledge and promote the use of such information. The

Task had a significant role in identifying research needs and opportunities, assimilating and synthesizing scientific and technical information, and identifying breakthrough technologies in relation to silviculture, forest management, harvesting and transportation in conventional forestry systems.

Standardisation was an important part of the industrial paradigm. In principle, it aimed to minimise friction of transactions through common rules of measures, material properties etc., that have been agreed and described beforehand. Through standardisation, the customer was guaranteed that a product or service incorporates certain defined properties. Thus, these properties did not have to be independently investigated for every transaction. Certification served the same aims as standardisation, but often relates to properties that were difficult or impossible to objectively measure on a specific product. As the use and international trade of biofuels increased, so would the need for relevant standards and certification, in order to simplify transactions and assure overall quality.

Currently, the European Committee for Standardisation (CEN) was developing a technical standard for biofuels. Technical Committee 335 (Solid Biofuels), under leadership of the Swedish Standardisation Organisation, SIS, are preparing some 30 technical specifications for solid biofuels including classification, specification and quality assurance of solid biofuels. This meant that traceability is guaranteed and that the full supply chain from source to end consumer is controlled and specified.

The new CEN technical standards and a coupling of quality assurance of forest biomass for energy to the existing forest certification standards would represent major step forward. It was argued that evaluative measures, pertaining to the energy efficiency, fossil to renewable carbon quotas and other criteria that are needed to rank alternative energy options – also biomass of a non-silvicultural origin - against each other were also needed. Since the existing forest certification schemes were end product neutral, such modules must be developed within the biomass and forest energy sector.

Bio-energy, bioproducts and the CDM

The representative from Joanneum Research, Vienna, stated that the Clean Development Mechanism of the Kyoto Protocol provided an additional income stream through the sale of greenhouse gas emission reductions, from bio-energy and bio-products. Even though that income might be small in comparison to the primary product, the additional income may make some projects economically viable.

The presentation provided a brief overview of the important steps in creating a CDM project and discussed methodologies that have been approved or are under consideration by the CDM Executive Board. Unfortunately the CDM project pipeline was limited to specific project types during the first commitment period of the Kyoto Protocol (2008-2012). Those limitations might not be suitable to least developed countries where biomass is the major source of household and industrial energy. The presentation focused on these limitations and discussed potential project types in the Post-2012 era.

The role of venture capital in developing a bioeconomy

The representative from Bioventures, South Africa, described the role of venture capital in developing a bioeconomy. While venture capital could provide a boost for the bio-economy in developing countries, it was not going to solve all the problems of creating a bio-economy in these countries. The time frames and return requirements of venture capital funds were not conducive to certain sectors of biotechnology. In addition venture capital operated in a broader economic environment that must be conducive to growing small business and allowing investors to cash out of those businesses. Policies such as exchange control and specified ownership requirements made venture capital an unattractive asset class in many developing countries.

Despite those difficulties, there were many positive features of venture capital that could facilitate the growth of a vibrant bio-economy in developing countries. A positive step forward would be to use development and government funding alongside private sector venture capital to promote venture capital in developing countries. The development agencies or governments could reduce the risks for the private sector by requiring a limited or capped return. Countries such as India, Russia, Singapore, Scotland and Korea were using such a model. These venture capital funds would then be mandated not only to make returns but also to play a development role in growing the bio-economy.

Experiences and challenges in developing industrial biotechnology: a South African perspective

The representative of BioPAD, South Africa, pointed out that the South African policy environment with respect to Science and Technology provided for the establishment of a National System of Innovation (NSI) to promote the development of a knowledge-based economy. Within the biotechnology sector the establishment of three regional innovation centres had been an integral component of this system. Some of the technology products developed through the auspices of the BioPAD BRIC by its investment in consortium based projects were outlined. These included environmental biotechnology process solutions for the treatment of Acid Mine Drainage, value adding to indigenous *Aloe Ferox* processing, and probiotic and flavour products developed from existing liquid and solid state fermentation platforms. The rationale for the establishment of a Seed Fund and its incubation model was also briefly discussed. Some of the experiences and challenges of technology development and seed funding from a public funding perspective were presented as a possibility for future development.

Programmes, policies and institutions

The market introduction of biofuels and feedstock derived from biomass depended on cooperation between agriculture, energy and chemical industries sectors. The session aimed at identifying the intersection of interests of the different stakeholders as well as tasks at government and industry levels to remove bottlenecks and promote the adoption of bio-industry as a sustainable alternative.

Governance frameworks for industrial biotechnology in developing countries

A UNCTAD (United Nations Conference on Trade and Development) representative focused on governance frameworks for industrial biotechnology in developing countries. The importance of consistent, clear and predictable policies was underscored, including clear communication of benefits/risks. The importance of IPR to facilitate TOT, innovation and investment was underscored as was the need for inclusive market and technology policies.

Managing the transition to a biobased economy

The OECD (Organisation for Economic Co-operation and Development) representative pointed out that an OECD survey of country-based activities in the biobased economy showed that in all 25 countries surveyed action was underway in using biotechnology, biobased feedstocks and bioprocessing in industrial production as part of a broader transition towards more technologically-advanced use of bioresources, as an alternative to reliance on fossil-based resources and moving towards a biobased economy. Those activities covered a range of areas, substituting for conventional processes in energy and manufacturing.

Bioeconomy – Perspectives of a developing country

A UNIDO consultant factored in perspectives of a developing country and against that background made specific suggestions for topics for working groups including: Social, economic, environmental and technical impacts were described as part of the biomass process.

Working Groups

Working group on programmes, policies and institutions

The session aimed at elaborating the components (such as structure, expected participants, and mode of operation) for an organisational platform addressing the concerns of key stakeholders in the development of new bio-products and markets. The role of platforms in designing and/or promoting programmes, policies and institutions for advancing industrial biotechnology in developing countries was also discussed.

Industrial biotechnology in developing countries involved different development issues, including health, environment, energy, security, trade, and investment. Actors or stakeholders concerned with industrial biotechnology comprised a diverse group spanning many different economic sectors and scales were also implicated. Therefore, the development of technical and organisational platforms for industrial biotechnology needed to have broad representation. A multi-stakeholder platform on industrial biotechnology would most likely include participants from industry, government, NGOs, trade groups, and community groups.

In that context, the following questions were addressed:

- Which useful functions could a multi-stakeholder platform fulfil?
- What would be the mission and scope of activities under this platform?
- Who should participate in this forum and why?
- How and in what manner might the participation of different groups be arranged in different ways (i.e. members, partners, supporters, etc.)?
- How should the forum operate (i.e. through some combination of working groups, internet dialogue, workshops, etc.)?

As a result, project proposals for three continents were discussed, including an Africa Biorefinery – Demonstration Plant; the use of biomass waste in the form of husks, shells and water from coconuts in Asia; and, a sugarcane biorefinery complex for fuel, food and feed production in Latin America. In all three cases, issues such as market access, environmental issues, standards, certification, monitoring, financing, investment, risk management, as well as promotion and dissemination were broached.

Working group on demonstration projects and initiatives

It was discussed that the emerging bio-based economy would require novel biomass feedstock for conversion into energy and products. Specially grown non-food crops for production of 'green' energy was one possibility, while another was discarded residues from established agro-industrial production that might find value added as a CO_2-neutral energy source or as the basis for renewable consumer products.

The use of biomass residues from food and feed production needed to be expanded to value added products resulting in new agro-industrial activities. Bioconversion technology and biotechnology would play key roles in the development of sustainable use of renewable resources.

However, in the developing world, the adoption of new bioconversion technologies would not only be dependent on whether new technologies could be accessed and adapted to local conditions. The application of biotechnology in industrial processes was likely to be determined by other considerations such as, the logistics of transportation and storage, the requirement for investment for setting up new facilities or conversion of existing obsolete production plants market, for example, competing products, distribution and pricing, regulatory issues.

The working group reviewed demonstration projects, actions and initiatives intended to fill information gaps and/or assess the potential impacts of industrial biotechnology on social, environmental welfare and economic development. The group also debated how bio-mass residues, often considered as waste, could become of economic value. The most promising concepts would be selected for further development and initiation as demonstration projects.

Participants presented proposals for demonstration projects, actions and initiatives, including project objectives (immediate and long term), project scope (national, regional, global) and end of project outcomes. Problem description, suitability of proposed technologies and the estimated resources required were also addressed.

Further, a proposal was made for the establishment of an International Forum for Industrial Biotechnology (IFIB) with the objective of assessing the impacts of new technologies on local economies, examining technology management issues, fostering technology alliances and knowledge networks and facilitating implementation of regulations.

Meeting closing remarks

Participants expressed their satisfaction with the discussions at the meeting despite its broad range of topics. Essential issues discussed included the need for bio-based industry as an opportunity for developing countries, the need for new technologies for transforming agro-products into industrial products as well as needs integration of agro-business and bio-/chemical industry.

It was also noted that some key concerns were yet to be addressed. For example, key parameters for competition in a global market as well as the demand and prices of bioenergy that were growing in parallel to the increasing cost of oil. Further, it would be pertinent to discuss decreasing costs for the production of bioenergy with the increasing demand as well as the price of bio-renewable feedstock for energy production.

The main purpose of the meeting had been to establish issues related to industrial biotech and biomass utilization. An attempt was made to give an overview of all the issues that would need to be addressed in a more thorough analysis. At the meeting, it was recommended that an Industrial Biotech Platform be set up to concentrate on the identified key issues and aim at providing thorough analyses to assist policy makers in developing countries in the decision-making.

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Biographies of selected participants

Below are the biographies of participants and/or authors that were submitted for this publication.

ROLF BJÖRHEDEN

Rolf is a professor of Forest Operations at the School of Technology and Design, Växjö University, Sweden. In the last five years, Växjö University has built a unique research program, aiming at the study of the complex, integrated problems of managing the supply chains of solid wood products from harvesting to final product. The basic funding for this 11 M€ programme is put up on a equal basis by the Swedish government, by the university and by the wood and forest industry. Rolf is director of this program and conducts research especially in the interface between forest operations and sawmills. Current research questions include harvesting and procurement of forest biomass for energy, improved management and control of wood inflow to sawmills and also product allocation strategies. Also he Co-ordinated the ongoing EU project CHRISGAS, aimed at gasification of biomass into synthesis gas, a base for liquid or gaseous automotive fuels.

Prior to his involvement with Växjö University, Rolf has spent time working with the sawmill-joinery interface for Dalarna University and for the Swedish University of Agricultural Sciences where he worked mainly with thinning machine development and with integrated harvesting of conventional wood and forest energy. Rolf has also held a research professorship in Denmark and has had a number of short-term employments with forest industries both in Sweden and in other countries.

DIRK CARREZ

Engineer in Chemistry and Agricultural Industries of the Ghent University (1984), Dirk CARREZ holds a PhD in Agricultural Sciences, which he prepared at the Laboratory of Molecular Biology of Prof. Dr. ir. Walter Fiers (Ghent University - 1989).

Since September 2004, he is Public Policy Director at EuropaBio (The European Association for BioIndustries), where he is also in charge of the Industrial Biotech Council.

Between 1999 and 2004, he was Secretary-general of BelgoBiotech representing the most important Belgian biotechnology companies, and also Director Innovation & Product Policy of Fedichem (Federation of the Belgian Chemical Industries).

He has been Responsible Care® and Product Stewardship Manager (Chemicals Sector) at SOLVAY S.A. (1997-1999), Senior Research Assistant at SOLVAY Research & Technology at the Department of Industrial Fermentation (1990-1997), and (Senior) Research Assistant of the National Fund for Scientific Research (FNRS, Belgium) in the Laboratory of Molecular Biology of the Ghent University (1984-1990).

Dirk Carrez is born in Oostende (Belgium) the 20th of Mai 1961, is married and has two children.

DAVID NEIL BIRD

David Neil Bird (Neil) joined Joanneum Research in August, 2005 where his main areas of interest are: Influence of changes in surface albedo on environmental benefits of LULUCF projects; Methodologies related to reduction in emissions from avoided deforestation; Evaluation of emission reductions from LULUCF that result from improved fuel wood use; and Development of unique CDM A/R projects. Prior to this, Neil worked, since 1995, for Woodrising Consulting Inc., his own consulting firm. Here he developed and assessed international and domestic projects that reduce greenhouse gas emissions. Initially this work focused mainly on forestry-related initiatives but has expanded to include waste management and industrial and municipal projects that reduce greenhouse gas emissions (energy efficiency, fuel switching, and renewable energies).

Neil continues to work part-time as Woodrising Consulting Inc., where he provides technical support (assessment of emission reducing activities particularly in biofuel use) for projects that are part of Canada's Technologies for Early Action Measures programme and greenhouse gas emission inventories and management strategies for Canadian corporations. In the past Woodrising's corporate clients were nominated for or won awards from Canada's Voluntary Challenge and Registry for their efforts. Neil has co-authored papers on forestry related issues for the Australian, Argentine and Canadian governments. Specifically, Neil has been involved with Canada's National Climate Change Secretariat by co-authoring a paper on the rates and causes of deforestation in Canada, and *Benefits of Afforestation Programs in Ontario, Quebec, and the Atlantic Provinces* both with ArborVitae Environmental Services Ltd. He also produced a study of the impacts of various methods for accounting for harvested wood products and authored *An estimation of the impact on net carbon sequestration of forest management including wood products storage,* both for NRCAN – Canadian Forest Service.

YUSUF CHRISTI

Yusuf Christi is Professor of Biochemical Engineering at the Institute of Technology and Engineering, Massey University, New Zealand. Professor Chisti holds a MSc (Biochemical Engineering) degree from the University of London, England, and a PhD in chemical engineering from the University of Waterloo, Canada. He is a Chartered Engineer, CEng, and Fellow of the Institution of Chemical Engineers (FIChemE), UK. His previous appointments were with the University of Almería, Spain; Chembiomed Ltd, Edmonton, Canada; the University of Waterloo, Canada; and The Polytechnic, Ibadan, Nigeria. Professor Chisti has produced nearly 200 publications including a highly cited book (*Airlift Bioreactors*, Elsevier, 1989). His work addresses many aspects of biochemical and chemical engineering, industrial biotechnology, biomass utilization, and environmental technology. Christi's research involves extensive international collaboration, most recently with partners in Spain, Thailand, Malaysia, New Zealand, Cuba, Iran, Canada and several other countries. He is editor of the Elsevier journal *Biotechnology Advances* since 1992. In addition, he sits on the editorial boards of the *Journal of Biotechnology* (Elsevier), *Biotechnology Letters* (Springer), *Journal of Applied Phycology* (Springer), and *Environmental Engineering and Management*.

See further details at: http://www.massey.ac.nz/~ychisti/~yc.html.

JONATHAN GRESSEL

Prof. Jonathan Gressel born in Cleveland, Ohio, in 1936 and immigrated to Israel in 1950 where he attended an Agricultural Secondary School. He received a B.Sc. in plant physiology from Ohio State University in 1957 and an M.Sc. (1959) and Ph.D. (1963) degrees from the University of Wisconsin. In 1962, he joined the Weizmann Institute as a post-doctoral fellow in Biochemistry and later became a research associate in the Plant Genetics Department, now called the Plant Sciences Department. He was promoted to associate professor in 1979 and full professor in 1985 and became Professor Emeritus in 2005, while still leading an active research group. He has been a visiting scientist at a number of institutions around the world, including Purdue University, Australian National University, U.S. Department of Agriculture, and Iowa State University.

Prof. Gressel develops scientific solutions to agricultural problems, especially for developing countries. His areas of expertise include genetic engineering of crops and new biotechnological methods for chemical and biological control of weeds. He has for many years been working on bio-utilization of agricultural wastes such as straw, first by developing fungal technologies, and most recently by proposing to transgenically modify the grain crops such that their straw will be a better substrate for ethanol production or ruminant utilization. In addition to serving on the editorial boards of a number of plant science journals in plant science, Prof. Gressel is active in international organizations in plant sciences and agriculture. He has registered 14 patents or patent applications and authored more than 260 scientific papers and book chapters, and authored or edited five books dealing with the above issues.

FRANCIS X. JOHNSON

Francis X. Johnson is a Research Fellow in the Climate and Energy Programme at the Stockholm Environment Institute, where he conducts policy analysis on energy and environmental systems, with special emphasis on bioenergy. Previously he was Senior Research Associate with the Energy Analysis Program at Lawrence Berkeley National Laboratory. His educational background includes Systems Science, Operations Research, Energy Analysis and Policy, and Geography. He has been a visiting researcher at the International Institute for Applied Systems Analysis in Austria. He has worked with a number of international organizations, including UNIDO, IEA, and FAO and has served as expert evaluator for the European Commission on international energy cooperation projects. During 2001-2005, he served as Scientific Coordinator for the Cane Resources Network for Southern Africa (CARENSA), a thematic research network with thirteen partners supported through the European Commission. He is also the manager of an international cooperation programme on energy, environment, and development, which is supported by the Swedish International Development Cooperation Agency (Sida).

BIRGIT KAMM

Birgit Kamm studied chemistry at the Technical University of Merseburg, Germany where she obtained her Diploma in 1986, and received her Ph.D. in Organic Chemistry in 1991 at the Institute of Organic Chemistry (with Prof. M. Schulz and Prof. E. Fanghänel). After receiving a grant from the German Federal Environmental Foundation in 1997, she joined the Institute of Chemistry (with Prof. E. Kleinpeter and Prof. M.G. Peter), University of Potsdam, where she finished her Habilitation in Organic Chemistry in 2005. She founded the Biorefinery Association Berlin-Brandenburg, Germany, in 1997. Since 1998 she has been a member of the board of the Research Institute of Bioactive Polymer Systems (biopos e.V.), and since 2001 she has been scientific director of this institute. Birgit Kamm is one of the three editors of the book 'Biorefineries –Industrial Processes and Products' (Wiley-VCH, 2005).

MICHAEL KAMM

Michael Kamm studied organic chemistry at the Technical University of Merseburg, Germany where he graduated with his Diploma. After a research assistantship in Halle-Wittenberg he moved to Potsdam University, co-founded the research institute biopos e.V. where he was involved in the material utilization of renewable raw materials. Since the foundation of biorefinery.de GmbH in 2001 he has been President of this company with its headquarter in Potsdam, Germany. He authored and co-authored more than 60 scientific publications and is the holder of 15 international patents.

Michael Kamm is one of the three editors of the book 'Biorefineries –Industrial Processes and Products' (Wiley-VCH, 2005).

VICTOR KONDE

Victor Konde is the founder of the African Technology Development Forum and an Economic Affairs Officer with UNCTAD. He is a former research fellow of Harvard University's Belfer Center for Science and International Affairs programme on science, technology and innovation. He founded the Zambian Society for Biochemistry and Molecular Biology and has been a lecturer at University of Zambia. He also worked in industry and holds a PhD from Brunel University, UK. His current research areas include international policy in technology transfer and commercialization and national innovation systems, and the promotion of entrepreneurship in Africa.

KARL HEINZ LEIMER

Dr. Karl Heinz Leimer holds a diploma in chemical engineering (1976) and a doctoral degree (1980) from the Vienna University of Technology, Vienna, Austria. From 1976 to 1977 he spent two semesters on the Colorado University, Boulder, USA on a Fulbright Scholarship with activities in the Chemical and Chemical Engineering Department.In 1980, he immigrated to Brazil where he started working at the Copersucar Technological Center, Piracicaba, São Paulo State, dealing with research, consultancy, engineering and training concerning the production of ethanol and yeast from sugar-cane. In 2004, the research center was changed to Cane Technological Center (Centro de Tecnologia Canavieira).

EDMUNDO T. LIM

In the past 10 years, Mr. Lim has devoted a considerable amount of time helping various poverty sectors in the Philippines. As a Special Adviser to the Governor of the Autonomous Region in Muslim Mindanao, he was tasked to formulate the Economic Development Framework Plan for Muslim Mindanao. Representing the Philippine Presidential Commission on Good Government as a member of the Board of Directors of four corporations, namely: Legaspi Oil Corporation, UCPB-CIIF Finance and Development Corporation, UCPB-CIIF Foundation, Inc., Niyog (Coconut) Tulungan (Cooperation) Center Philippines, Inc., four of the Philippine coconut levy-owned corporations which the Philippine Supreme Court declared in 2001 as a publicly-owned fund belonging to the coconut farmers of the Philippines, he was able to develop a farmers' income enhancement program, which was subsequently approved by the Board of Directors of the four corporations and funded with Three Hundred million Philippine Pesos (US$5.5 million).

Mr. Lim also formulated programs for education: for technical training such as the Scholarship-to-Jobs program, now being implemented by the UCPB-CIIF Foundation, college scholarships for children of coconut farmers/workers at the Mindanao State University. In his forty years of working experience, starting as a farmer and cowhand in the mountains of Mindanao, Philippines, the poverty in the rural areas had a marked impression on him. He subsequently joined the government service and became a Senior Trade Promotion Officer under the Philippine Department of Trade and the RP/UNDP Export promotion Project and later on as Head of the Trading Department of the only state trading company in the Philippines, with the objective of opening up new markets for products that can be sourced from rural communities.

Twenty years after graduating from college, he was back in the Philippines as an investor and Chief Executive Officer of two companies involved in multi-product trading and distribution.

DELON MUDALY

Delon possesses a Masters degree (MTech) in Biotechnology obtained at the Durban Institute of Technology (South Africa), and a Diploma in Business Management (Damelin Business School). His research interests involved the molecular detection and *in situ quantification* of micro-organisms implicated in advanced biological wastewater treatment processes.

He has been involved within the South African National System of Innovation for the last four years, first as Professional Officer: Biotechnology within the Innovation Fund (National Research Foundation), and is presently Portfolio Manager at the BioPAD Biotechnology Regional Innovation Centre where he has been for the last two years. This role focuses on research and technology management with a view towards supporting the commercial development and application of the Bio-sciences within the region.

PURNIMA SHARMA

Dr. Purnima Sharma has a doctorate in Microbiology. She has to her credit many awards for excellence in academics including a gold medal for best scientific publication during Ph.D. She is presently the Executive Director with Biotech Consortium India Limited (BCIL), New Delhi, India. BCIL is a public limited company promoted by the Department of Biotechnology, Ministry of Science & Technology, Government of India and all India financial institutions to provide the necessary linkages for facilitating biotechnology commercialization. She is coordinating all operational activities of the company which includes consultancy, technology transfer, information services and manpower training. She is also directly coordinating all the technology transfers activities and was instrumental in transferring many technologies to leading companies during the last few years. Incidentally BCIL was conferred with the National Award on “Biotech Product and Process Development and Commercialisation” for the year 2001 for its outstanding contribution in the area of technology transfer.

She has coordinated a number of reports relating to commercial biotechnology such as market surveys, status studies and feasibility studies for various medical and agricultural biotech products. She is also actively involved in developing business plans for setting up biotechnology parks in India.

HEATHER SHERWIN

Heather Sherwin was instrumental in setting up and raising Bioventures, South Africa's first Biotechnology Venture Capital Fund while at Gensec Bank in 2001. Heather is currently the Fund Manager of the Fund and as such manages the day-to-day operations of Bioventures. She sources and evaluates deals and works closely with investee companies in developing their strategies. Bioventures has done eight investments in start up companies and Heather is looking to raise a second fund. Heather received her PhD in Cell Biology from the University of Natal (Durban) in 1995. She has five years research and lecturing experience post PhD. She set up her own research consulting company that did contract research for the agricultural and horticultural industries.

After completing her MBA (University of Cape Town) Heather joined Gensec Bank as a Strategist in their Internationalisation Division where she was involved in international acquisitions before moving to Private Equity and starting Bioventures.

JOCELYN WEBSTER

Prof. Jocelyn Webster, is the Executive Director of AfricaBio, the Biotechnology Stakeholders Association based in South Africa. This organisation is a non-political, non-profit biotechnology stakeholders association serving as a factual reference point and a forum for informed discussion on biotechnological issues in Africa. To date, Prof. Webster has many publications in international journals, contributions to scientific books and has presented over 70 papers at national, regional and international conferences and workshops.

Prof. Webster sits on several boards of agricultural and biotechnology based organisations and has more than 30 years experience in R&D in biological sciences with skills and experience in:

Medical and industrial microbiology

Medical immunology

Microbial genetics and plant biotechnology

Prof. Webster has also established her own biotechnology consulting business, ProBio, which provides services to industries, academia and research organisations both nationally and internationally.

SONI SOLISTIA WIRAWAN

Mr. Wirawan studied in Brawijaya University, Malang, Indonesia for his Bachelor Degree in Mechanical Engineering and in Nagaoka University of Technology, Japan for his Master Degree in Mechanical Engineering. He currently works at The Center for Design Engineering & Technology System and Agency for the Assessment and Application of Technology (Engineering Center – BPPT). He has recently worked on Engineering, Procurement and Construction" of Pilot Biodiesel Plant , 8 ton/day capacity.

FRANCIS YAMBA

Prof. Francis. D. Yamba has extensive experience spanning over a period of 33 years in the fields of Energy, Climate, and Institutional analysis. He has more than 65 academic and professional publications in the area of energy, environment, and engineering and industrial applications for sustainable development. These experiences include energy modeling, planning and analysis, and energy for productive use, biofuels development, investigation in improved methods of charcoal production and utilization, household energy surveys, development and modeling of combustion and gasification systems, studies on climate change, and project development under CDM.

Prof. F. D. Yamba has also extensive general management and project management experience. He has served as Executive Director- INDECO (Industrial Development Corporation), Managing Director- Engineering Services Corporation. He has also served as Director and Board member for key energy institutions namely: National Energy Council of Zambia, TAZAMA Pipelines, and ZESCO (Zambia Electricity Corporation). He is currently chairman of the Board of Directors for ECZ, (Environmental Council of Zambia), and Director- CEEEZ (Centre for Energy, Environment and Engineering Zambia). He has supervised and managed several projects in energy resource development, capacity building for Clean Development Mechanism (CDM), and CDM project implementation.

EGM Programme

WEDNESDAY, 14 December 2005		

9:00-9:30	Registration	
9:30-10:00	Welcome address by A.J.J. Rwendeire, Managing Director, PTC, UNIDO	
10:00-13:00	Plenary Session 1	Chairperson: A.J.J. Rwendeire
		Rapporteur: G.Tzotzos

THE TRANSFORMATION TO A BIO-BASED ECONOMY

10:00-10:10	Expert Group Meeting: Scope and Objectives	George Tzotzos, UNIDO
10:10-10:30	Industrial Biotechnology in the knowledge-based bio-economy	Mark Cantley, European Commission, Brussels
10:30-10:50	Technology Platforms as a tool to develop a bio-based economy	Dirk Carrez, EuropaBio, Belgium
10:50-11:10	Opportunities and challenges for industrial biotech in South Africa	Jocelyn Webster, AfricaBio, South Africa
11:00-11:30	Coffee break	
11:30-11:50	Relevance of biomass based products for the Indian economy	Purnirma Sharma, Biotech Consortium India Limited, India
11-50-12:10	Chemical industry and white biotech renewables	Manfred Kircher, Degussa, Germany
12:10-13:00	Discussion	
13:00-14:15	Lunch Break	

14:30-18:00	Plenary Session 2	Chairperson: J. Webster Rapporteur: J. Van Dam

INDUSTRIAL BIOTECHNOLOGY – EXPERIENCES AND COMPARISONS

14:30-14:40	Introduction	Jocelyn Webster, Africa Bio
14:40-15:00	Biorefining and biorefineries – a potential way to establish a biobased economy	Michael Kamm, Biorefinery, Germany
15:00-15:20	Opportunities for bio-based products in the Brazilian sugar cane industry	Karl Leimer, Centro de Tecnologia Canavieria, Brazil
15:20-15:40	Opportunities and barriers for biofuels markets in Southern Africa	Francis Yamba, University of Zambia, Zambia
15:40-16:00	Coffee Break	
16:00-16:20	The forgotten waste biomass; two billion tons for fuel or feed	Jonathan Gressel, Weizman Institute of Science, Israel
16:20-16:40	Use of biofuels for transportation and electricity production (using sugarcane residues – the case of Brazil	Frank Rosillo-Calle, Imperial College, UK * Did not attend
16:40-17:00	Experiences in Cuba with industrial biotech and bio-processes	Antonio Valdes Delgado, Centro de Gerencia, Cuba
17:00-17:20	Product development for bio-waste materials	Jan Van Dam, Wageningen University, Netherlands
17:20-18:00	Discussion	
Reception Hosted by UNIDO (7th floor, coffee shop)		

THURSDAY, 15 December 2005

9:30-12:00	Plenary Session 3	Chairperson: J. Philp Rapporteur: F. Johnson

MECHANISMS AND INCENTIVES FOR EXPANDING BIOMASS-BASED PRODUCTS AND SERVICES

9:30-9:40	Introduction	J.Philp, Napier University, UK
9:40-10:00	Certification of Bioenergy from the forest motives and means	Rolf Björheden, Växjö University, Sweden
10:00-10:20	Bioenergy, bioproducts, and the CDM: project eligibility, opportunities and future challenges	Neil Bird, Joanneum Research, Austria
10:20-10:40	The role of venture capital in developing a bioeconomy	Heather Sherwin, Bioventrues, South Africa
10:40-11:00	Coffee Break	
11:00-11:20	Experiences and challenges in developing industrial biotechnology: a South African perspective	Delon Mudaly, BIOPAD, South Africa
11:20-12:00	Discussion	
12:00-13:15	Lunch Break	

13:30-18:30	Plenary Session 4	Chairperson: M. Cantley Rapporteur: C. Linke-Heep

PROGRAMMES, POLICIES, AND INSTITUTIONS

13:30-13:40	Introduction	Mark Cantley, European Commission
13:40-14:00	Governance frameworks for industrial biotechnology in developing countries	Victor Konde, UNCTAD, Switzerland
14:00-14:20	Managing the transition to a bio-based economy	Chris Deane, OECD, France
14:20-14:40	Bioethanol, Sustainable Development and International Trade: Opportunities and Challenges for North-South-South Cooperation.	Francis Johnson, SEI, Sweden
14:40-15:00	Bioeconomy – Perspectives of a developing country	Seetharam Annadana, UNIDO Consultant
15:00-15:30	Discussion	
15:30-15:50	Coffee Break	

15:45-18:00	**WORKING GROUP SESSIONS**
15:50-16:15	Introduction to working group sessions (See Annex I)
16:15-18:00	Meeting splits up into working groups where a project concept is formulated

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9:00-12:00	WORKING GROUP SESSIONS continued	
12:00-13:20	Lunch Break	
13:30-14:50	Presentation of Working Group Reports	Chairperson: R. Vujacic, UNIDO
14:50-15:30	Discussion	
15:30-16:00	Coffee Break	