Ministry of Agriculture, Livestock and Food Supply

Brazilian Agroenergy Plan

2006 – 2011

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Secretariat for Production and Agroenergy

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Foreword

The second edition of the Brazilian Agroenergy Plan focuses on the strategic actions of the Ministry of Agriculture, Livestock and Food Supply arising from its institutional mission, namely, “to promote the sustainable development and the competitiveness of Brazilian agribusiness to the benefit of Brazilian society”, as well as on the government's general guidelines, particularly those set forth in the document *Agroenergy Policy Guidelines*.

Brazil is the acknowledged world leader in the generation and implementation of modern, tropical agricultural technology and has a robust agro-industry. A striking example is the ethanol production chain, recognized as the most efficient in the world, driven by a dynamic business sector accustomed to innovating and taking risks.

A series of advantages, such as the possibility of earmarking new lands to energy farming without having to reduce the food-crop farmed area or impose environmental impact beyond what is socially acceptable, have enabled Brazil to become the leader in energy agriculture and in the world’s energy markets. In addition, in many areas of the country it is possible to grow consecutive crops within a single farming year without irrigation. With irrigation this potential increases considerably.

The importance of agroenergy for the Brazilian fuel mix requires definition of national, medium and long-term, strategic objectives in order to achieve a covenant between the Brazilian society and the State to promote jointly the following benefits: reducing fossil fuel use; broadening biofuel production and consumption; protecting the environment; assuring it’s leadership in the international biofuel market; and, lastly, contributing to social inclusion.

Investments in research are the basis for the development of agricultural production technologies, enabling the identification of the most appropriate plant species, the most efficient production systems and the regions with the highest production potential. New industrial technologies constitute the essence of the transformation of agricultural products into biofuels.

The Brazilian Agroenergy Plan establishes both a framework and an orientation for the public and private actions involved in the generation of knowledge and technology that will contribute to the sustainable production of energy agriculture and the rational use of this renewable source of energy. The priority goal is to enhance the competitiveness of Brazilian agribusiness and provide support to public policies aiming at social inclusion, regional development and environmental sustainability.

All sectors linked to the agroenergy chain of production shall come together to face this huge challenge. To that end, we can count on the work of the staff of the Ministry of Agriculture, Livestock and Food Supply, rural producers and their leaders, teachers, researchers, and society as a whole in a joint effort to achieve our country's autonomy and development.

Luís Carlos Guedes Pinto
Minister of Agriculture, Livestock and Food Supply

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Executive Summary

The purpose of the Brazilian Agroenergy Plan is to organize and develop a technology research, development, innovation, and transfer proposal with a view to guaranteeing the sustainability and competitiveness of the agroenergy chains. The Brazilian Agroenergy Plan also establishes institutional arrangements to structure research: an agroenergy consortium and a new Embrapa unit, Embrapa Agroenergy. It indicates government actions in the international biofuel markets and in other spheres of interest.

The proposed strategy is linked to the overall policy of the federal government as set forth in the document Agroenergy Policy Guidelines.

The world energy demand is expected to rise 1.7% per annum from 2000 to 2030, when world consumption will have attained 15.3 billion TPE (ton petroleum equivalent) p.a. according to the scenario envisaged by the Institute for International Economics (MUSSA, 2003). Unless the world energy matrix is altered, fossil fuels will account for 90% of the increase. Current proven worldwide petroleum reserves, notwithstanding, total 1.137 trillion barrels, 78% of which are located in OPEC countries, an amount sufficient for approximately 40 years at the current rate of consumption. It is obvious that both reserves and consumption will increase in the intervening period, although the reserves will probably grow at a lower rate.

The economic viability of bioenergy necessarily depends on an evaluation of its cost when compared with the price of petroleum. At the present time (2006), tax-free alcohol and gasoline prices even out when the price of an oil barrel fluctuates from US$ 30.00 to US$ 35.00. Since bioenergy technology has yet to attain maturity, it is estimated that parity will only be achieved when the oil barrel price is US$ 60.00 in the case of biodiesel, although a sharp declining trend is foreseen for the near future. The economic conditions are right for the Brazilian agribusiness to include biodiesel as one of its most important components, in addition to ethanol and other types of agroenergy. Social (employment, income, migration flows) and environmental (climate changes, pollution) pressures reinforce and consolidate this position, as well as bring the timetables forward.

A series of advantages make Brazil the worldwide leader of energy agriculture and the bioenergy market – the biomarket. The first advantage is the possibility of earmarking new lands to energy farming without having to reduce the food-crop farmed area or impose environmental impacts beyond what is socially acceptable. In addition, in many areas of the country it is possible to harvest several time a year without irrigation. With irrigation, the number of harvests increases considerably.

Brazil's location in the tropical and subtropical zones of the world ensures intense solar radiation year-round, the basis of bioenergy production. In addition, the country is blessed with a wide range of climates and an exuberant biodiversity, as well as one-fourth the world's fresh water reserves.

Brazil has successfully taken on the leadership in the generation and implementation of modern, tropical agriculture technology and has a robust agro-industry. A striking example is the ethanol production chain, known as the most efficient in the world, driven by a dynamic business sector accustomed to innovating and running risks.

Lastly, the consumer market is sufficiently large to enable scale gains that would reinforce competitiveness in the domestic bioenergy business and support its expansion into the world biomarkets.

In the short term, the environmental pressures to replace fossil fuels as the main source of energy will drive the demand for agroenergy. Atmospheric CO_2 concentrations in the atmosphere have increased by 31% in the last 250 years. Fossil fuel burning and cement production account for 75% of carbon emissions.

To establish a framework and provide orientation for public and private actions aiming at the generation of knowledge and technologies that contribute to the sustainable production of energy through agriculture and to the rational use of this renewable energy. Its goal is to ensure the competitiveness of Brazilian agribusiness and support specific public policies, such as social inclusion, regional development and environmental sustainability.

The overall purpose of the National Agroenergy Plan on the basis of the facts and premises cited above is:

Achieving the overall purpose implies realizing certain specific objectives, in conformity with Brazilian public policies, in order to meet the expectations of society and the demands of the clients:

• To increase the share of the renewable sources of energy in the National Energy Balance (NEB).

• To guarantee the development of the country's hinterlands and regions through an expansion of energy farming and adding value to the production chains linked thereto.

• To create opportunities for the expansion of employment and income generation within the scope of agribusiness, with increased participation of small farmers.

• To contribute to the fulfillment of the Brazilian commitment to the Kyoto Protocol and take advantage of the opportunities open to the country in said agreement in terms of obtaining carbon credits.

• To induce the creation of an international biofuel market and ensure Brazil's leadership in the sector.

• To optimize the use of areas affected by human action on natural vegetation (anthropic impact), maximizing the sustainability of the production systems, discouraging unjustifiable expansions of the agricultural frontier and encroachment upon sensitive or protected systems. To develop solutions that integrate agroenergy generation and eliminate health risks to agribusiness.

These objectives comply with the guidelines of the Research, Development and Innovation (RD&I) Agenda:

To ensure the sustainability of the energy matrix; job and income generation; rational use of areas affected by anthropic actions; Brazilian leadership in biomarkets; energy autonomy at the community level; support to public policies; energy savings along agribusiness chains; and elimination of health risks.

The reach of these objectives requires multidisciplinary technical teams, organized in scientific networks and organizational and strategic partnerships; mobilizing skills, entrepreneurship and training; and guaranteeing funding.

As regards the timeframe, the RD&I program encompasses short-, medium- and long-term goals. Its geographic scope is given by the technology required for the various ecosystems and environments. The environmental issues pertaining to the technology to be developed should comply rigorously with the principles of environmental protection.

From the social standpoint, the program takes into account the need to broaden job and income opportunities while ensuring the sustainability of the systems and the quality of life. The various disciplines involved should focus on developing the agronomic technology required to obtain adequate raw materials and sustainable, primary and agro-industrial production systems that comply with all standards and regulations. Due attention should also be given to the overall production chain, with special emphasis on coproducts, byproducts, wastes, and residues from agricultural and agro-industrial production.

The RD&I program should unfold along the four principal areas of the main agroenergy production chains: ethanol and the cogeneration of energy from sugarcane; biodiesel from animal and plant sources; forest biomass; and residues and wastes from agriculture and agro-industry.

In each of these areas, priority shall be assigned to the following topics:

- Agroecological zoning of species important for energy farming in traditional areas and in agricultural-frontier expansion areas in order to direct public and private funding and to detect environmental impacts.

- Traditional and biotechnological plant breeding in order to select plants species for the production of biofuels and improve significantly the productivity of the species currently used.

- Socio-economic and strategic studies to develop scenarios, strategies and geopolicies and to serve as input for public policies on energy and their link to environmental, economic, social, and business topics.

- Competitiveness studies on systems and production costs, market niches and opportunities, transportation and storage logistics, obstacles to production chain performance, non-tariff barriers, attracting investments, strategy, and geopolitics.

- Energy balances of the life cycles of the production chains in Brazilian agribusiness with a view to replacing fossil carbon sources with agroenergy sources, as well as progressively reducing the energy demand of the production systems.

- Topics linked to the Kyoto Protocol, greenhouse gas emissions, the clean development mechanism, and carbon credit markets and their relations with breeding programs, good farming practices, impact on biomass, nutrition management for ruminants in the context of sustainable development, all of which coordinated with other territorial, regional and global initiatives.

For each area of energy agriculture, the Plan also proposes strategic priorities to be analyzed thoroughly by the institutions and technical personnel involved in technological research, development and innovation activities in each of the agroenergy areas.

Background

The federal government has issued Agroenergy Policy Guidelines prepared by an interministerial team and approved by the President of Brazil. The document provides for the creation of the Interministerial Management Council to manage the agroenergy policy in accordance with the following general guidelines.

Development of agroenergy. Through the expansion of the ethanol sector, establishment of a biodiesel production chain using residues and development of cultivated energy forests throughout the country, focusing on efficiency and productivity and favoring less developed regions.

Agroenergy and food production. The expansion of agroenergy should not affect food production for domestic consumption, particularly staple food production. Instead, some biodiesel coproducts, such as soybean and sunflower cakes, would complement the human food and animal feed supply.

Technology development. Research and development (R&D) of appropriate agricultural and industrial technologies for the agroenergy production chains that ensure increased competitiveness, added value and lessened environmental impacts. At the same time, technological development should contribute to economic and social insertion, including the development of technologies appropriate to small-scale use of energy-producing biomass.

Community energy self-sufficiency. The idea is to enable individual farmers and farmer cooperatives or associations, in addition to land reform settlements, to generate their own electric power, particularly in the remotest regions of the country.

Job and income generation. The agroenergy policy should help develop the hinterlands and eliminate social exclusion. It should also help fix the local populations in their habitat and reduce regional disparities, especially by adding value to the production chains and integrating the various dimensions of agribusiness.

Optimizing the use of areas affected by anthropic action. In producing energy crops, the sustainability of the production systems should be of major import. Unjustifiable expansions of the agricultural frontier and encroachment upon sensitive or protected systems, such as the Amazon Forest and the Pantanal region, inter alia, should be discouraged. Bioenergy projects could also contribute to the reclamation of degraded areas.

Optimization of regional vocations. Encouraging the installation of agroenergy projects in regions where large extensions of land with intense solar radiation and plentiful manpower are available. These projects would provide advantages for both labor and capital and from the private and social standpoints when compared with even the most profitable crops.

Leadership in the international biofuel market. Brazil's comparative advantages enable the country to seek a leading role in the international biofuel market and promote energy products derived from agroenergy. An expansion of exports would bring in hard currency, consolidate the agroenergy sector and provide an added thrust to the development of the country.

Compliance with environmental policy. Agroenergy programs should comply rigorously with the Brazilian environmental policy and the provisions of the Clean Development Mechanism of the Kyoto Protocol, increasing the use of renewable sources of energy with diminished greenhouse gas emissions.

The position of the federal government as regards the future supply of energy from renewable sources has gone beyond a merely public administration issue and has become a State matter because of its comprehensiveness and consequences for the development of the country. The supply of energy at high prices compromises economic development, job and income generation and the welfare of the Brazilian people.

Agriculture is a viable alternative for the generation of renewable energy from the economic, social and environmental points of view. Alcohol production from sugarcane is a successful example worldwide, because it has enabled the replacement of a substantial part of the gasoline used in transportation with alcohol. It is possible to repeat the process with other types of biomass.

There are various challenges to be met, including the development of agronomic technologies, which involves the selection of the best plants species and the most efficient production systems for this purpose, as well as the regions with the highest production potential. It is also necessary to develop new industrial technologies to transform the agricultural products into bioenergy.

The large-scale production of agroenergy not only would diminish energy costs when compared with petroleum, but also has environmental advantages, in addition to creating income and jobs in the rural sector. In other words, it would promote the sustainable development of the Brazilian hinterlands, particularly of the remote regions.

Since agriculture has been established as a viable alternative to face the challenges involved in producing agroenergy, the Ministry of Agriculture, Livestock and Supply should put together a program that meets the bioenergy needs of the country.

The government effort meets the expectations of society and the demands of its clients and complies with the public policies regarding energy, with strategic implications in the political, social, environmental, commercial, agricultural, industrial, and supply areas.

For the purpose of this plan, agroenergy is made up of four main groups: ethanol and energy cogeneration from sugarcane; biodiesel from animal and plant sources of fats); forest biomass and residues; and agricultural and agro-industrial residues and wastes. Energy forests yield various forms of energy, such as firewood, charcoal, briquettes, fines (small-diameter carbon fragments), and black liquor. The anaerobic digestion of organic matter produces biogas. Biodiesel can be obtained from plant oils, animal fats, or agro-industrial residues. Although ethanol can be obtained from other sources, sugarcane alcohol is unbeatable in terms of competitiveness. And agricultural and agro-industrial residues, as well as wastes from these processes, can be transformed into different secondary forms of energy, such as briquettes, biogas, biodiesel, etc. (Figure 1).

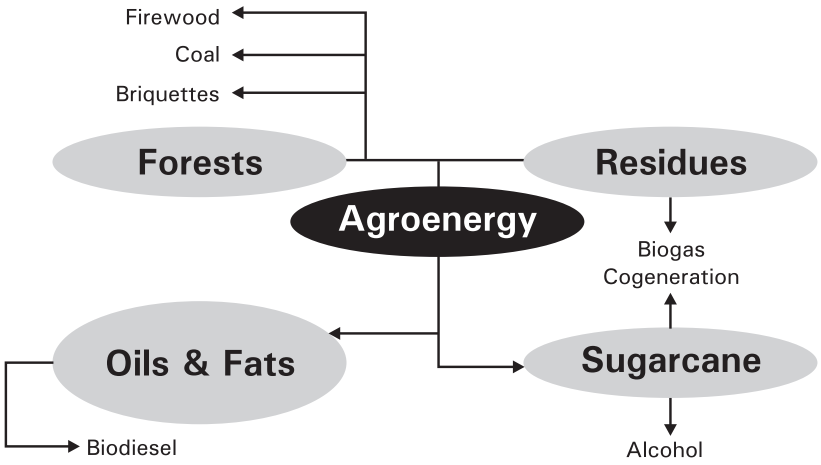

Figure 1. Agroenergy matrix.

RD&I should focus on raw-material technology development and process improvement (Figure 2). In either case, the vision of the final agroenergy form (heat, biofuel, or electricity) must be clearly defined in order to ensure raw material productivity and process competitiveness.

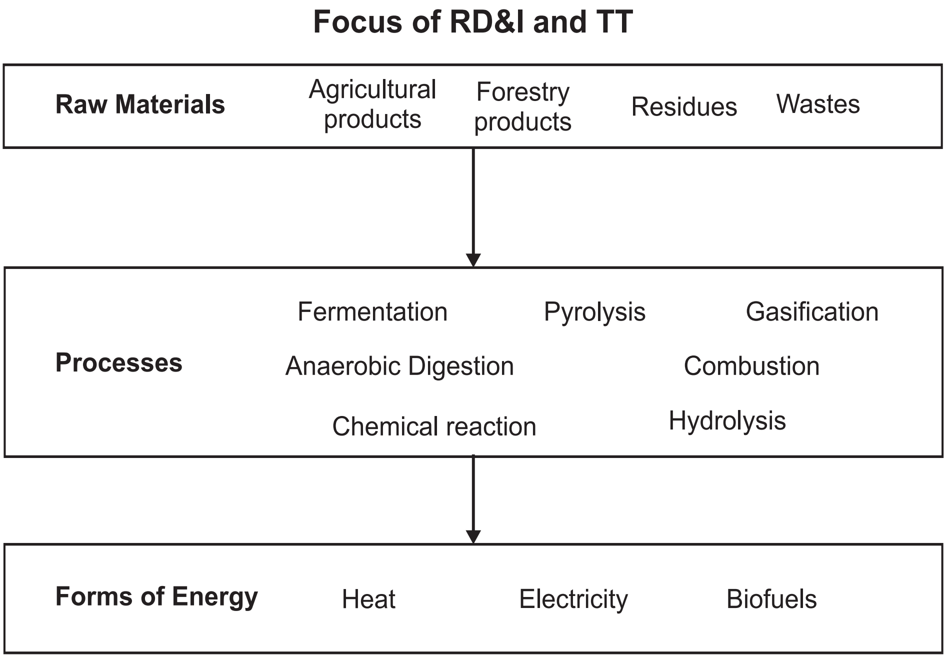

Figure 2. Agroenergy production chain.

The Plan directs the course of the strategic actions of the federal government as regards its overall policy, as set forth in the document Agroenergy Policy Guidelines. Its primary purpose is to provide the bearings for the efforts of Brazilian science, technology and innovation organizations, namely, projects that could be enhanced to provide, maintain, or increase the competitiveness and sustainability of the production chains linked to agroenergy. The Ministry of Agriculture, Livestock and Supply shall directly coordinate all efforts.

The creation of Embrapa Agroenergy, additional public/private partnerships and the organization of a consortium shall add a more dynamic dimension to the process. Other actions shall be undertaken with the participation of the Ministry of Agriculture, Livestock and Supply and the coordination of other agencies of the federal government, in addition to actions in the international markets.

The two annexes - Current Energy Scenario and Agroenergy Production Chains – were essential tools in the definition of the Agroenergy Policy Guidelines and in the conceptualization and design of the National Agroenergy Plan.

Agroenergy Research Program

This item focuses on a proposed common RD&I and TT agenda for the different agroenergy chains with a view to achieving the competitiveness and sustainability objectives.

Objectives

Main objective

To produce and transfer knowledge and technologies that contribute to the sustainable production of energy from agriculture and to the rational use of renewable energy for the purpose of ensuring the competitiveness of the Brazilian agribusiness and supporting public policies.

Specific objectives

- To support the change in the energy matrix in order to guarantee its sustainability.
- To create the conditions necessary for increasing the agroenergy sources' share in the energy matrix.
- To create the conditions necessary for the development of the country' hinterlands and regions through an expansion of energy agriculture and by adding value to the production chain.
- To create opportunities for increasing the number of jobs within the scope of action of agribusiness.
- To enable the broadening of income opportunities and its equitable distribution among stakeholders.
- To contribute to reducing greenhouse gas emissions.
- To help reduce petroleum imports.
- To increase biofuel exports.

RD&I and TT Guidelines

Agroenergy technology development and transfer shall be governed by eight major guidelines consonant with, and subordinated to, Brazilian public policies, the aspirations of society and the demands of the clients, namely:

a) Achieving sustainability of the energy matrix, developing environmentally appropriate technologies that ensure long-term livelihoods to farmers and farm workers participating in agroenergy projects, with profitability rates that ensure competitiveness in the energy market, and helping fulfill the country's commitments in international arenas.

b) Accomplishing energy self-sufficiency and sustainability at the community level, herein understood as the development of sustainable technologies that enable isolated communities, individual farmers, farmer cooperatives or associations, and land reform settlements to generate energy to meet their needs independent from external commercial sources.

c) Generating jobs and income, a way to add momentum to the development of the hinterlands, reduce regional disparities and help fix rural populations in their habit, particularly by adding value to the production chain and integrating the various dimensions of agribusiness.

d) Enhancing the use of areas affected by anthropic action, maximizing the sustainability of production systems, discouraging unjustified expansions of the agricultural frontier and preventing encroachment upon sensitive or protected systems.

e) Achieving and maintaining leadership in the international bioenergy market.

f) Supporting the design of Brazilian public policies and providing input to Brazilian officials in international negotiations involving topics such as energy, the environment and global climate changes.

g) Attaining sustainability, competitiveness and the rational use of energy in the national agribusiness chains and maximizing the use of the production factors.

h) Eliminating health risks to agribusiness through the formulation of solutions that integrate agroenergy generation.

Strategy and program proposal

The strategy of the program calls for:

Integrating efforts, valuing Brazilian talents and skills, taking advantage of strategic associations with international scientists and keeping all actions focused on the development of the agroenergy production chains.

The main aspects to be considered are:

• Multidisciplinary technical team. The numerous fields of knowledge that make up agroenergy require complex research networks constituted by diverse disciplines and professionals with distinct training, such as physics; chemistry; biology; biotechnology; agronomic, chemical, environmental, electric, mechanical, and civil engineering; sociology; and economics, among others.

• Management of the RD&I and TT Plan. The participants will be organized into formal institutional partnerships in charge of executing the National Agroenergy Plan.

• Organizational partnerships. Identification of the actors in RD&I, agribusiness, or the energy chains for the purpose of setting up the closely and firmly integrated, long-term institutional and organizational partnerships required for the success of the activity. The objective of these partnerships is to systematize agroenergy research. The partners will be private or public entities known to be involved in S&T research, even when the main focus of their business is not research and development.

• Strategic partnerships. The strategic partners will collaborate in specific activities of certain programs or projects and make discrete contributions to technological development. Both organizational and strategic partnerships will be tightly articulated in order to support the agroenergy RD&I activities.

• Mobilization of skills. Networks should be organized so as to ensure the success of the RD&I program. Such networks should reach beyond the boundaries of academe to find research partners that can actually contribute to the overall effort with their management skills, installed industrial base, market knowledge, etc.

• Entrepreneurship. The RD&I program should consider its contribution to the development of the national production chains. It should also enable the return of research funding resources as royalties, or some other type of remuneration for technology production, technical assistance, consultancy, or others as contemplated in the Innovation Law.

• Training. The agroenergy research networks will require formal and informal training because of the dynamic nature of the research areas involved. The networks will also receive recent graduates for specialized training and preparation for the RD&I activities, with strong emphasis on specialized manpower to be supplied directly to the production sector.

- Funding sources. The RD&I activities will be funded by various sources, namely: regular National Treasury budgets; the National Agroenergy Research Fund; partners' budgets; resources obtained by the projects; sectoral or research funds; voluntary donations; compulsory funds established by law; proceeds from the sale of services, studies, projects, technical assistance, royalties, technology charges, financial profits and other; loans and grants from financial institutions; transfers from non-governmental organizations; and funds from foreign institutions under the heading of technical cooperation.

The program guidelines are divided along three main lines: agronomic technology development; industrial technology development; and sociological, economic, market, management, and public policy studies.

Agronomic technology will especially focus on sugarcane, oleaginous plant species and energy forests.

Industrial technology will focus on the development of forms of energy, non-power use of products and coproducts, uses and impacts of biofuels.

The remaining studies will be transversal in nature and distributed along time and space; they will percolate through the various chains.

Scope of RD&I in Agroenergy

The RD&I Program contemplated in the National Agroenergy Plan covers various different dimensions in order to meet the needs of the sectoral public policies, the aspirations of society and the needs of the clients.

In terms of the timeframe, the program encompasses short-, medium- and long-term goals.

Geographically, the program includes appropriate technology for the various ecosystems and environments in the country.

Environmentally, the technologies to be developed must meet environmental protection and damage reduction requirements.

From the social standpoint, the RD&I program will consider the need to increase income and job opportunities and ensure their equitable distribution, as well as guarantee system sustainability and quality of life, mitigating strenuous physical exertion and assuring the independence of rural workers and their organizations.

The disciplinary dimension should focus on the development of agronomic technology to obtain appropriate raw materials, the development of sustainable processes, and compliance with the standards and regulations, as well as become integrated into the production chain, especially coproducts, byproducts, wastes and residues of agricultural or agro-industrial production.

In terms of the technological development framework, the RD&I program will consider carbon market opportunities as a part of the production systems. The process will include studies and development of scenarios of a social, economic and environmental nature that modulate the technological demands.

Brazil should be prepared for the post-Kyoto negotiations ensuing the renewed global effort to reduce global warming. The country will certainly not receive the same condescension other countries extended during the current Kyoto protocol negotiations, particularly in view of the uninterrupted CO2 emissions from fires in the Amazon and the Cerrado.

Brazil must present a major clean energy program with world impact to counterbalance the negative effects of the fires and provide better negotiating conditions.

Some pinpointed actions in agribusiness could be undertaken in terms of an investment effort in agroenergy. There are two main considerations:

a) Rural producers and associated agro-industries - separately or in association - should seek energy self-sufficiency based on renewable sources, particularly agroenergy.

b) The agroenergy RD&I networks should review the energy demand of the production systems aiming at two goals: quantitative reduction of energy consumption and replacement of the energy sources of the production and processing systems.

RD&I Agenda

The RD&I Agenda is a macro strategic research agenda that takes into account the timeframe, social and environmental concerns, connections with Brazil's major objectives and commitments in international agreements, and inductions of the international agribusiness market and, particularly, the international biomarket.

Thus the importance of organizing a sectoral RD&I Agenda clearly based on complex, multidisciplinary, multi-institutional networks, anchored by international cooperation, guided by sectoral public policies, and closely linked to the aspirations of society and the demands of the clients.

Cross sectional actions

There are demands in all agroenergy chains, namely:

• Designing socio-economic and strategic studies, such as database compilation and maintenance, scenario development, prospective studies, ex-ante and ex-post evaluations, preparing input for public policy design in the energy area and its connection with environmental, economic, social, and business topics.

• Carrying out competitiveness studies, focusing on the obstacles to chain performance, market niches and opportunities, attracting investments, investments in logistics, strategy, and geopolitics.

• Evaluating the energy balances of the life cycle of the Brazilian agribusiness production chains, for the purpose of replacing fossil carbon sources with agroenergy sources and progressively reducing the energy demand of such production systems.

• Carrying out agro-ecological zoning of the most important plant species for energy agriculture.

• Developing cooperative networks to identify non-tariff barriers and find suitable solutions for the main markets on the basis of an evaluation of the conformity or nonconformity with international standards of measuring methods and techniques in the clean development mechanisms (CDM) projects.

• Incorporating into scientific and technological development programs new models of study, such as: CDM in breeding programs that focus on valuable crops, good agricultural practices, impact on biomes, ruminant nutrition management, and issues linked to reducing greenhouse gas emissions (GGE) in various production systems along the entire agricultural production chain, consolidating a database that permits forward analyses in the context of sustainable development, in coordination with territorial, regional and global initiatives. To that end, it would be necessary to train a technical-scientific corps on the topics associated with the clean development mechanism, to foster the development of new networks and to expand existing networks considering that the lines of research involved are very new, very dynamic and multidisciplinary in nature.

• Mapping and following up the various project portfolios and exploring carbon market issues as yet unsolved. Thus, S&T can generate and make available consistent data in a systematic fashion for the purpose of drawing the base lines of the CDM projects, as well as developing and perfecting methodologies associated with pilot projects, in partnership with the private sector with a view to taking advantage of market opportunities.

Actions in the production chains

The different challenges linked to each component of the energy complex help define the research priority agenda.

Ethanol

• Eliminating obstacles to the expression of the production potential of sugarcane.

• Increasing sugarcane productivity, sucrose contents, energy aggregate, and industrial yield.

• Developing technologies that save inputs and eliminate or mitigate environmental impacts.

• Developing sugarcane crop management and production system integration technologies.

• Developing alternative technologies to use all the energy of sugarcane mills by improving current processes and/or developing new ones.

• Developing new products and processes based on alcohol-chemistry and the use of sugarcane biomass.

Biodiesel

• Enabling energy densification of raw material having as reference 2,000 kg/ha of oil in the medium term and 5,000 kg/ha in the long term.

• Improving current biodiesel production paths by using ethanol as input and developing new productions paths.

• Generating technologies that enable the rational use of energy in the farms and the replacement of fossil carbon sources with renewable sources.

• Developing competitive, sustainable energy production processes from organic residues from the animal product processing chains.

- Developing technologies to add value to the production chain by using coproducts, residues and wastes.
- Developing technologies that use energy biomass for other purposes in the fine chemistry and pharmaceutical industries.
- Generating technologies that help farmers, agro-industries and remote communities achieve sustainable energy self-sufficiency.
- Integrating the concepts of agroenergy and carbon market into the processes.
- Developing processes for obtaining innovations based on oleaginous plant biomass, including oil chemistry.

Energy forests

- Making available technologies that enable the full use of forest biomass for energy purposes and diversifying the matrix of energy products obtained from forestry products.
- Developing technologies that promote energy densification in reforested areas.
- Generating technologies to replace the coal used in various applications.
- Developing technologies that have a social impact and help insert low-income communities into the energy forest chain.
- Promoting the integration of the concepts agroenergy and carbon market.

Biogas

- Developing biodigester studies and models.
- Modeling biogas production systems.
- Evaluating the use of biofertilizers as organic fertilizer.
- Developing equipment to use biogas as a heat source.
- Developing biofertilizer transportation and distribution equipment.
- Improving biogas-fueled equipment to use for generating electric power.
- Developing biogas compression and storage systems.
- Developing biogas purification processes.

Use of residues and wastes

- Developing technologies that use agricultural, livestock, forestry, and agro-industrial residues as a source of energy.
- Developing technologies that use health-hazard organic compounds resulting from agricultural production for the production of agroenergy.
- Developing technologies that use residues from energy production for other purposes, such as correcting soil acidity.
- Networking with the research networks that focus on the use of urban wastes for energy purposes.

Lastly, it is necessary to face new technological challenges in the development of agroenergy within the context of Brazilian agribusiness.

It is also necessary to implement tactical actions that will induce the creation of multi-institutional and multidisciplinary networks and sub-networks in charge of the management and implementation of the research agenda.

The agenda should also serve as foundation and inspiration for the funding agencies and sectoral research funds to induce specific tenders or research commissions to overcome obstacles found in the agroenergy production arrangements.

In addition, the agenda will guide the activities of the various institutions and help develop or review strategic and master plans so that the confluence of objectives help drive the development of the research networks.

Lines of research

Once the priorities of each production chain have been defined, research should focus on, but not restrict itself to, the following:

Ethanol

Agronomic technology

- Using biotechnology techniques to introduce new characteristics (pest resistance, draught resistance, soil acidity and salinity tolerance, increased nutrient uptake efficiency).
- Developing studies on the life cycle and energy balance of sugarcane production systems, for the purpose of reducing the energy consumption

of the systems and replacing fossil carbon with renewable sources of energy.

• Promoting agro-ecological zoning for sugarcane in the new expansion areas.

• Developing technologies that increase the productivity and sucrose contents of sugarcane.

• Developing technologies that promote symbiotic nitrogen fixation.

• Developing technologies that use plant hormones in sugarcane production.

• Developing sugarcane rotation, multi-cropping and renovation techniques.

• Developing plant nutrition techniques for sugarcane.

• Using the vinasse or stillage from sugarcane juice fermentation in agriculture.

• Generating plant health technologies for sugarcane.

• Developing sugarcane management systems.

• Developing soil management systems in sugarcane plantations.

• Improving irrigation and water management techniques in sugarcane plantations.

Industrial technology

• Developing technologies that use sugarcane styles and green leaves.

• Increasing industrial alcohol yields.

• Improving processes through a more rational use of water and other inputs.

• Improving energy cogeneration processes.

• Developing new products and processes based on alcohol chemistry and the use of sugarcane biomass.

• Improving motors and turbines to maximize energy yield with the use of carburant alcohol.

Biodiesel

Agronomic technology

• Prospecting new oleaginous plant species with increased energy density and broad edafoclimatic adaptation.

- Setting up, characterizing and maintaining plant DNA (germplasm) banks of new oleaginous species and expanding existing DNA banks.
- Promoting agro-ecological zoning of conventional and potential oleaginous species.
- Developing cultivars, varieties and hybrids of conventional and potential oleaginous species.
- Making available plant nutrition technologies for oleaginous plants.
- Generating plant health technologies for oleaginous species.
- Developing oleaginous plant crop management systems.
- Developing harvesting and processing systems for the purpose of improving the oil extraction activities and the use of coproducts and residues.
- Using biotechnology techniques to introduce new characteristics (pest resistance, draught resistance, soil acidity and salinity tolerance, increased nutrient uptake efficiency).
- Developing studies on the life cycle and energy balance of oleaginous plant production systems, for the purpose of reducing the energy consumption of the systems and replacing fossil carbon with renewable sources of energy.

Industrial technology

- Improving oil extraction methods, especially from small and medium-sized plants.
- Developing and improving the technological paths of biodiesel production.
- Developing studies on the catalysts and reagents used in industrial processes.
- Improving the efficiency of the biodiesel production processes.
- Developing processes that use floaters from the animal product processing industry.
- Developing processes to transform organic residues that pose health risks into energy sources.
- Improving processes that use suet from the animal product processing industry.

- Improving the biodiesel quality and diminishing biodiesel shelf time.
- Evaluating the impact of biodiesel on motors and associated systems.
- Improving motors and associated systems for use with biodiesel.
- Carrying out studies on the emissions of biodiesel motors.
- Developing technologies for the use of cakes in human and animal nutrition.
- Developing new glycerol-derived products.
- Making available processes that use biomass from oleaginous plants to the fine chemistry and pharmaceutical industries.
- Developing new products based on oil chemistry.
- Integrating the agroenergy chains, such as ethanol/biodiesel, forests/biodiesel, and biogas/biodiesel, using residues/biodiesel.

Energy forests

Forestry technology

- Establishing the dynamics of the energy-biomass production systems.
- Establishing forestry parameters (spacing, fertilization, rotation, etc.) that maximize sustainable forest biomass production.
- Defining multiple-use systems adapted to small-scale tree farmers.
- Developing technologies that will enable the establishment and management of energy forests in areas unsuitable for agriculture and in areas degraded due to improper agricultural management.
- Developing new management practices and specific harvesting schemes for the generation of biomass for energy purposes.
- Identifying and selecting tree species with appropriate calorific power to be used as alternatives to eucalyptus in the production of forest biomass in different regions of the country, including bamboo species.
- Developing agro-forestry arrangements appropriate for small farms.
- Identifying alternatives for the production of forest biomass from non-timber activities.
- Improving biomass harvesting, transportation and storage techniques.
- Developing integrated planning models, including the various sources of energy, efficient-use technologies, environment, etc.

• Developing models and tools for the analysis of the technical-economic viability and market potential of alternative sources of energy.

• Encouraging the use of geographic information system technology in planning the use of energy from forest biomass.

Industrial technology

• Developing studies on biomass gasification.

• Developing more efficient process to use wood as an energy source in the residential sector.

• Generating technologies for the recovery of condensable gaseous products during the wood carbonization process.

• Enabling the use of complementary fuels in existing commercial technologies (cogeneration, direct burning in the paper and cellulose industry).

• Developing technologies to solve the low efficiency problems in the generation of energy from forest biomass.

• Setting up protocols, certification and technical standards for the technologies associated with the supply and use of energy from forest biomass.

• Improving the efficiency of the energy generation processes from forest biomass (firewood, charcoal, forestry residues and residues from the wood transformation industry) for small- and medium-sized energy generation projects for industrial purposes.

• Developing studies on the quality of charcoal to be used in blast furnaces, with emphasis on carbon fines studies.

• Generating technologies for the recovery and preprocessing of residues from forestry based activities and palm oil industrialization.

• Developing technologies associated with biomass gasification and lignocellulose conversion into ethanol.

• Developing biomass pyrolysis processes for the production of bio-oils.

• Developing clean and efficient charcoal combustion technologies, such as fluidized bed, pressurized fluidized bed and gasification.

• Generating advanced and mixed combustion technologies.

Biogas

• Developing and evaluating the kinetics of anaerobic digestion in the different biodigester models available.

• Supplying new biodigester models with biomass heating, stirring and thermal insulation, for the purpose of increasing biogas production and improving the efficiency of organic matter removal.

• Evaluating the use of biodigesters in the treatment of wastes from swine and poultry production and consequent elimination of health risks.

• Developing and evaluating complementary systems for the final treatment of liquid biodigester wastes.

• Evaluating the quantitative and qualitative characteristics of biogas as a function of climatic seasonality and type of animal production system.

• Evaluating and developing mathematical models for estimating biogas generation and evaluating the qualitative and quantitative characteristics of biogas as a function of the effect of climatic seasonality.

• Evaluating the use of bio-fertilizers, such as organic manure, to replace chemical fertilizers in grain and pasture planting systems.

• Evaluating the environmental the risks that the intensive use of organic bio-fertilizers in grain and pasture planting systems would pose to superficial and underground waters.

• Developing equipment for the use of biogas, instead of PLG and firewood, as heat source in swine and poultry production facilities.

• Developing equipment for the use of biogas, instead of PLG and firewood, as heat source in grain drying.

• Developing equipment to compress and transport biogas under low pressure.

• Developing biogas-fueled machines and equipment for the transportation and distribution of bio-fertilizers.

• Developing and adapting motors and generators fueled by biogas to produce electric power in animal production systems.

• Developing ion exchange membrane, fuel cell, electric power generators that use biogas.

• Developing low-pressure biogas storage systems for use in swine and poultry production farms.

• Generating new biogas treatment and purification systems to reduce corrosion, diminish humidity and increase the methane ratio, with a view to increasing the caloric capacity.

Use of residues and wastes

• Generating technologies that use agricultural residues to produce energy.

• Developing technologies that use farming, livestock, forestry, and agro-industrial wastes to produce energy.

• Developing technologies that use forestry residues to produce energy.

• Supplying technologies that use agro-industrial residues to produce energy.

• Developing technologies to eliminate health-hazard organic compounds resulting from agricultural production by using them to produce agroenergy.

• Developing technologies for energy densification and other ways of using sawdust, shavings and other residues from the wood transformation industry.

• Developing technologies that use residues from energy production for other purposes, such as correcting soil acidity or increasing soil fertility.

• Promoting the integration of the concepts of agroenergy and carbon market.

• Interacting with the research networks working on the use of urban wastes for energy purposes.

Institutional Partnerships in Agroenergy

In Brazil, there are institutions and companies in each of the major areas of agroenergy that either supply or demand new technologies, whether in raw material production or industrial transformation processes, or linked to commerce, distribution or supply of final products to the domestic and foreign markets.

The success of the National Research, Development and Innovation Program in Agroenergy depends on the articulation of the organizations and companies that make up the supply and demand sides, whose activities are currently dispersed. It is also contingent upon the organization of a joint technical program, of multidisciplinary and multi-institutional nature, that points to and fills gaps in the program in order to ensure the viability and maintain the competitiveness of biomass energy sources.

The Ministry of Agriculture, Livestock and Supply (MAPA) intends to gather and articulate these companies and institutions as a consortium, whose central objective will be to design and execute the National RD&I Program in Agroenergy taking into account regional specificities. Other commercial and investment aspects could also be part of the consortium's program.

Institutional partnerships are major agreements between founding entities, for either operational or sponsorship purposes.

The articulation between the parts and the relationship of the consortium with the set of institutions, including potential participants, will be carried out through a formal structure that concretizes and institutionalizes the institutional arrangement itself, a fact that will be contemplated in the document creating the consortium, to be signed by the leading entities.

Institutionally, this structure will fulfill the objectives and execute the operations envisioned for the consortium, which could be later joined by other organizations and will be supervised by an Administrative Council made up of representatives of the participants.

The formal institutional partnership or consortium will be directed by technical personnel hired or seconded by the participating entities, albeit administrative and financial independent from them. The consortium will act through operational centers in various regions of the country, in partnership with the participating entities or with domestic or foreign third parties, and with Embrapa Agroenergy, to be incorporated.

Objectives of the Institutional Partnerships

a. To assemble governmental agencies, private institutions, companies, banks, cooperation organizations, universities, and R&D institutions involved with agroenergy.

b. To become an institutional reference and the operational core of an information and experience exchange network in the fields of commerce, investments and R&D of agroenergy in Brazil and abroad.

c. To implement the National Agroenergy Plan and carry out related research activities together with participating or retained, domestic and foreign entities.

d. To fund studies and research of a productive, commercial, or logistics nature oriented to the production, agro-industrialization and commercialization of agroenergy products and processes in Brazil.

Public and private research institutions, universities, entities and trade associations from the energy and agroenergy sector, private companies linked to the sector, and financial institutions that promote the development of agroenergy, among others, are eligible to participate in the consortium.

The Ministry of Agriculture, Livestock and Supply, through Embrapa, will be responsible for the operationalization of the Consortium and will negotiate the participation of a broad range of organizations. Embrapa will also be responsible for the management of the Consortium through the early stages of its incorporation.

Creation of Embrapa Agroenergy

The purpose of the Brazilian Agroenergy Plan is to organize and develop a technology research, development, innovation, and transfer program that guarantees agroenergy chains sustainability and competitiveness. The Brazilian Agroenergy Plan also provides for institutional arrangements to structure research, such as the creation of a new Embrapa unit, Embrapa Agroenergy.

The execution of the National Agroenergy Plan requires multidisciplinary technical teams organized into scientific networks, organizational and strategic partnerships, together with the mobilization of skills, entrepreneurship, training, and guaranteed funding.

From the temporal standpoint, the PD&I and TT program must encompass short-, medium- and long-term goals. Geographically, the program must take into account the various ecosystems and environments in the country. The environmental interface of the technologies to be development must comply with the principles of environmental protection and lessened environmental damage. From the social point of view, the program must consider the need to increase job and income opportunities and to improve their distribution. In the disciplinary dimension, the program will deal with the entire production chain and focus on the development of agronomic technology, transformation and commercialization processes, as well as agricultural and agro-industrial coproducts, byproducts, wastes, and residues, while complying rigorously with all standards and regulations.

Considering the current conditions of the economy, state-of-the-art knowledge of the Brazilian agribusiness and possibility of producing energy from renewable sources of biomass, it is absolutely necessary to strengthen and consolidate the research, development and innovation components of the National Agroenergy Plan in order to examine and enable the alternatives opening before the country with the implementation of the Plan.

The National Agroenergy Plan must necessarily encompass the entire country since much progress has already been made in some regions (Center-South) and with some products (sugarcane and soybean, for example) of the Brazilian agribusiness. Among the challenges to be faced is the need for more knowledge and innovations to technically and economically enable the sustainable use of other sources and forms of energy.

Since agroenergy is a field that demands a cross sectional approach to policies, actions and resources, it is necessary that the Ministry of Agriculture, Livestock and Supply have a trained, legally constituted, technical arm to network and interact with other ministries and correlated entities, as well as municipal, state and international institutions.

The characteristics of the National Agroenergy Plan assign Embrapa a leading role because of its comprehensive research network extending over the entire country and its facilities abroad, namely, the Overseas Laboratories (Labex), as well as cooperation programs with several developed and developing countries.

Thus, Embrapa will create a decentralized research unit focusing on agroenergy topics and issues to act as the central link of the country's Agroenergy Research System and the core component of the Brazilian Agroenergy Plan. In executing the Plan, Embrapa will join multi-institutional and multidisciplinary RD&I networks, as well as carry out its own research, development and innovation activities in the field of agroenergy.

The central role to be played by the new unit should include:

a) Coordinating agroenergy research actions.

b) Bringing together the knowledge and specific skills currently disseminated throughout the various Embrapa research units.

c) Attracting specialists whose skills have not yet been incorporated or internalized into the technical-scientific profile of the Company, but are necessary to support the National Agroenergy Plan.

d) Acting as a reference center for Embrapa, through which the Company will join the multi-institutional networks and consortia to be form for the agroenergy RD&I activities.

International Biofuel Market

Ethanol is consolidated in the Brazilian biofuel market, wherein gasoline contains 25% anhydrous alcohol. Hydrated alcohol is consumed pure or mixed with any percentage of gasoline in bi-fuel or dual fuel automobiles. The demand varies depending on the gasoline prices. The biodiesel market is still incipient.

The size of the Brazilian market guarantees the success of biomass energy initiatives, and a foreign market is beginning to emerge. Several countries have their own domestic biofuel production and consumption programs, particularly biofuel mixed with fossil fuels. Nevertheless, Brazilian alcohol exports demonstrate that the international biofuel market is barely getting started: practically all our production is not used as fuel.

It is important for Brazil to organize, drive and lead the external biofuel market, as set forth in the federal government's Agroenergy Policy Guidelines:

"Leadership in the international biofuel commerce.

A series of comparative advantages should enable Brazil to lead the international biofuel market and promote energy products derived from agroenergy.

Expanding exports would not only generate hard currency, but also consolidate the sector and drive the development of the country."

The successful implementation of any ambitious program of foreign alliances requires that both government and private sector join efforts and diligently strive to achieve the same objectives.

It is possible to assert that the circumstances are favorable for the creation of an international biofuel market, beginning with an expansion of alcohol trade and encouraging its use as a fuel. The reasons for success in such an endeavor are the following.

a) Petroleum prices are rising and the petroleum market is prone to uncertainties.

b) The world has become increasingly concerned with the environment, particularly after the Kyoto Protocol went into effect.

c) In view of the increased petroleum prices and the systematic depletion of petroleum reserves, the countries are emphasizing the need to diminish dependency on petroleum in their energy matrixes.

The Brazilian government has propounded in international negotiations that the countries broaden their energy matrixes to include the new renewable sources of energy in order to lessen future environmental impacts.

At the World Summit on Sustainable Development held in South Africa in 2002, the Brazilian delegation proposed that "the share of the renewable sources of energy in the countries' energy matrix increase to 10% by 2010".

As several international events on the environment held in the last few years indicate, the renewable sources of energy could solve the problem of dependence on fossil fuels of the countries' energy matrix.

At the present time, Brazil is promoting international events in partnership with international organizations and other interested countries. These events will offer ample opportunity of discussing solutions to environmental problems and to the current dependence on fossil fuels, in cooperation and even with the participation of other countries.

Achieving a leadership position in the international market necessarily involves undertaking important negotiations, particularly with large consumer countries – which are frequently producers as well – with potential producers and with some potential producers that only need technical, economic and financial advice to launch their own programs. In such a scenario and with a growing interest in biofuels, as shown by the International Energy Agency's recently published book, the OECD and the Paris seminar[1], the following actions should be undertaken in a concerted manner within the government and with the private sector:

a) Organizing a schedule of visits to biofuel projects in Brazil for government and private sector representatives of countries with biofuel production or consumption potential.

b) Organizing and promoting meetings of biofuel producing countries.

c) Organizing and providing technical, economic and financial advice to developing countries that produce alcohol for the purpose of assessing the feasibility of joint ventures and capital good exports.

d) Organizing and promoting, in partnership with IEA/OECD and the World Bank, meetings similar to the Paris seminar in selected countries, such as USA, Belgium-EU and Japan.

e) Maintaining the world informed about the progress achieved by the biodiesel program.

f) Initiating negotiations for the creation of an International Organization of Producers and Consumers of Biofuel (IOPCBio).

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[1] Seminar on Biofuels, organized in partnership with OECD, held in June 2005.

The purpose of these actions is to help consolidate the path of the international biofuel market, eliminating potential tariff and non-tariff barriers ahead of time, creating arenas for the solution of eventual problems arising in the transactions between the countries and, at the same time, providing Brazil conditions to lead the evolution of the international biofuel market.

Other Government Actions

Under the coordination of the Ministry of Agriculture, Livestock and Supply (MAPA), several governmental actions will be executed as set forth in the recommendations of the National Agroenergy Plan. The MAPA will also participate in activities that fall within the sphere of action of other ministries.

As a result of its greater interaction with one of the basic links in the sugarcane and oleaginous plants production chains – primary production – MAPA could and should act as catalyst in these efforts to solve problems and overcome crucial bottlenecks.

Government policies and investments that affect or drive biofuels – with special emphasis on the expansion of the domestic ethanol and biodiesel productions for the purpose of achieving large-scale exports – should be appropriately assessed and conducted by the various governmental institutions and agencies.

Since new businesses and technologies with high implementation costs and long maturity periods are involved, it is essential to minimize risks for private investors and, at the same time, maximize the efficiency of the investment projects.

Market mechanisms, particularly in a new free-price system, could induce some short-term decisions that will not necessarily lead to the best strategic alternatives for the country.

Investments in infrastructure and transportation and storage logistics are fundamental to increase investors' interest in projects located outside the traditional areas. Among such projects, mention must be made of the conclusion of the North-South Corridor, which will help consolidate the sugar-alcohol agro-industry in the states of Maranhão, Piauí and Tocantins, as well as projects involving the production of biodiesel from oleaginous species in the Northeast and Center-West regions.

Because of the strategic nature of the products – as substitutes or complements of fossil products, with a positive environmental effect instead – and the international commercial prospects, it should be possible to seek and reckon on funds from international financial institutions. Furthermore, government and private sector actions should be decisive in attracting foreign investments, including investments in infrastructure.

Supplying lines of credit adequate to the profile of the investment and working capital needs should also stimulate additional private investments and even of direct foreign investments to the various links of the ethanol production and commercial chains.

During the initial implementation phase, regional inducements and incentives from directly interested state governments, working in accordance with the guidelines of the federal government, are also very important.

One of the first government steps will be an integrated effort by Embrapa, Inmet and other partners to draw up a strategic plan for the expansion of sugarcane plantations and oleaginous species cropping areas that include the agronomic and agro-climatic aspects, as well as the socio-environmental components and logistics.

One of the guidelines of the Plan is to promote regional de-concentration of production and stop the verticalization process, as seen with sugarcane in the State of São Paulo, where more than 70% of the raw material for the industrial mills come from their own plantations and consequently exclude small- and medium-size sugarcane producers from the production chain.

It is also necessary to establish international negotiation channels for the purpose of opening the way to promising markets and increasing the alcohol market liquidity, thus strengthening, for example, the alcohol futures market. These problems will only be solved when new actors come into play, supply is dispersed and the systemic risks of future importers are reduced.

The Ministry of Foreign Relations (MRE) and the Ministry of Development, Industry and Commerce (MDIC), with the participation of the Ministries of Mines and Energy (MME), Science and Technology (CT), and Agriculture, Livestock and Supply (MAPA), will head the efforts to guarantee Brazil's leadership in international biofuel commerce.

The private sector is a consequential partner in the discussion of the strategies to be adopted and in their execution.

In terms of social inclusion, MAPA – in partnership with the Ministry of Agrarian Development – shall undertake actions to develop appropriate technology for agroenergy production, as well as for its application, focusing on remote communities without access to electric power.

Figure 3 synthesizes the links involved in the successful implementation of the National Agroenergy Plan.

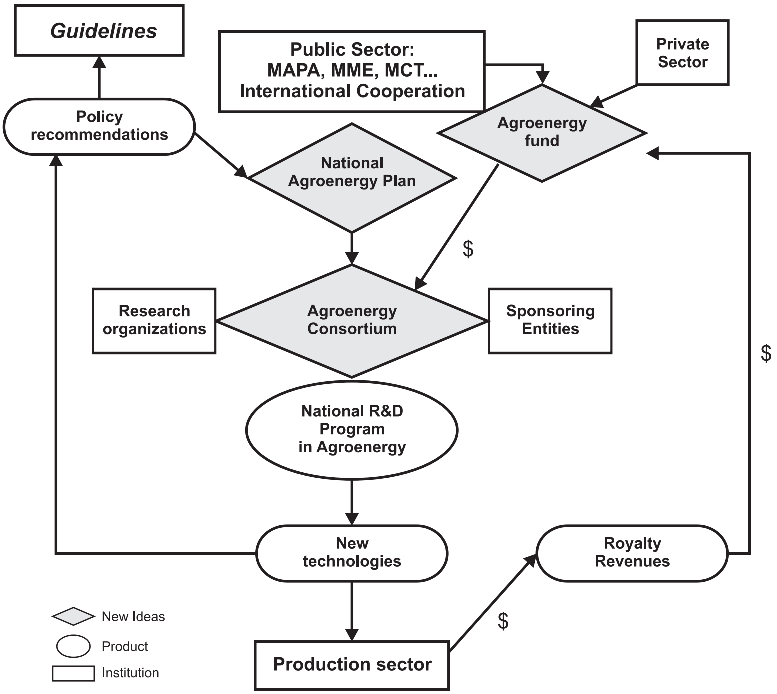

Figure 3. Actions and actors in the Brazilian Agroenergy Plan.

Annex 1
Current Energy Scenario and Prospects

Current Energy Scenario and Prospects

Projections of the world energy demand estimate increases of 1.7% p.a. from 2000 to 2030, when it will have reached 15.3 billion petroleum ton equivalent (tep) p.a., according to the base-line scenario drawn by the Institute for International Economics (MUSSA, 2003). Fossil fuels will account for 90% of the projected world demand increase by 2030 unless changes are made to the world energy matrix.

The progressive depletion of world petroleum reserves is readily demonstrated by the fact that they grow at a lower rate than consumption. In a study called Statistical Review of World Energy 2004, British Petroleum asserts that world petroleum reserves should last about 41 years; natural gas, 67 years; and Brazilian petroleum reserves, 18 years.

Fossil carbon sources weigh heavily in the world energy matrix, with an overall share of 80%, of which 36% are petroleum; 23%, carbon; and 21%, natural gas (Table 1). Brazil stands out among industrialized economies because of the high share of renewable sources in its energy matrix. This is easily explained: nature has endowed Brazil with extensive river basins and several plateau rivers, which are fundamental for the generation of hydroelectric power (14%), and Brazil is the largest tropical country in the world, an advantageous differential in the production of biomass energy (23%).

The 100-year period of cheap petroleum (10-20 dollars per barrel), which ended in 1970, is definitely over and done with (Figure 1).

Circumstances may influence the petroleum spot market so that prices may oscillate below US$ 60.00/barrel, but the medium-term trend calls for

Table 1. Composition of the energy matrix.

Source	World (%)	Brazil (%)
Petroleum	35.3	43.1
Coal	23.2	6.0
Natural Gas	21.1	7.5
Traditional Biomass	9.5	8.5
Nuclear	6.5	1.8
Hydroelectric	2.2	14.0
Modern Biomass	1.7	23.0
Other renewable sources	0.5	0.1

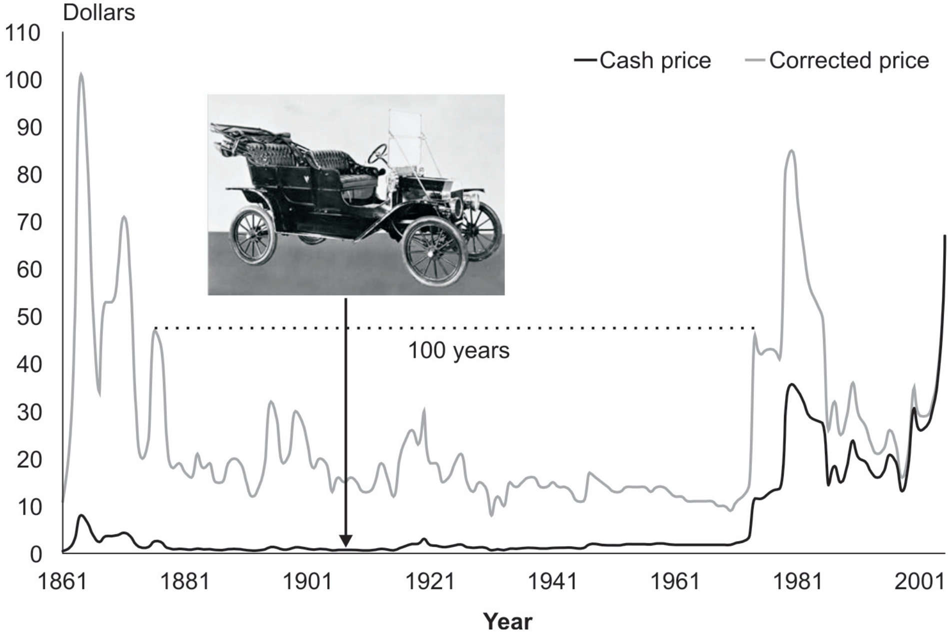

Figure1. International price of the petroleum barrel.
Source: Drawn by D. Gazzoni with primary data from DEA/USA.

increasing prices. It is perfectly logical, at the present time, to draw scenarios with bottom-line quotes of US$ 100.00/barrel beginning in the next decade.

Under the present technology and price conditions parity between the tax-free prices of alcohol and gasoline varies from US$ 30.00 to US$ 35.00. Since bioenergy technology has yet to attain maturity, it is estimated that parity will only be achieved when the petroleum barrel price is US$ 60.00 in the case of biofuels derived from vegetable oil (Figure 2). Nevertheless, like fuel ethanol, whose production cost has dropped by more than 60% along the last 30 years, biodiesel production costs should decrease as technological breakthroughs are implemented, gains in scale are achieved, production factor management is mastered, and the market matures.

Since most international petroleum price scenarios foresee a continuous price escalation, the prospects of the fuel ethanol program are strengthened not only at the domestic level, but also internationally, creating the necessary leverage for the biodiesel program.

The world is growing increasingly afraid of the negative impact of fossil fuels on the climate, particularly because of the recent phenomena in Europe, the USA and Asia, which have experience much more rigorous weather conditions, draughts, floods, hurricanes, and tsunamis, and the perception of governments and scientists that these extreme weather conditions are becoming increasingly frequent and severe. Those changes intensify the incidence of agricultural pests, have serious economic, social and environmental consequences and alter the plant health scenario, highlighting the vulnerability of agriculture to climatic changes and the need to develop long term strategies.

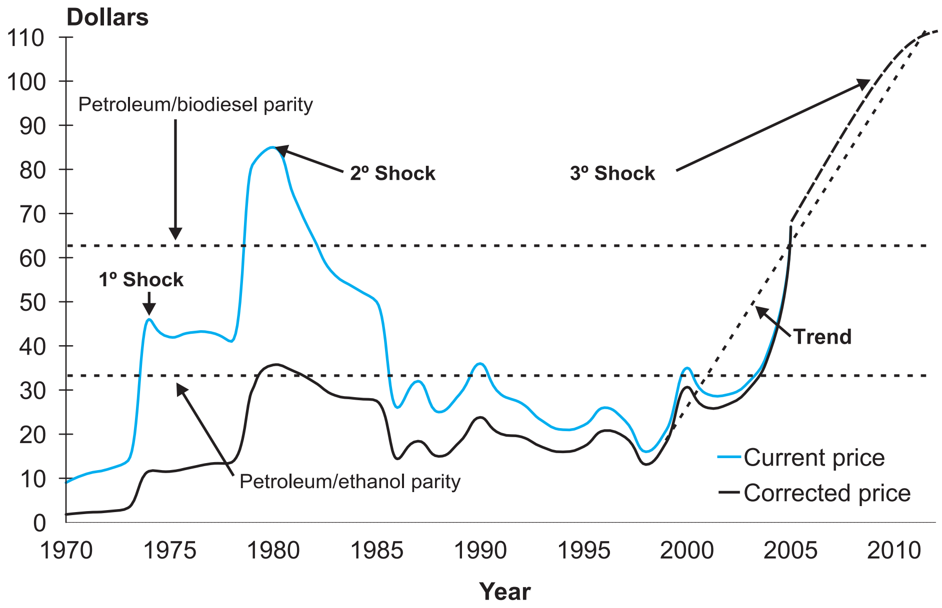

Figure. 2. International petroleum barrel price – events.
Source: Drawn by D. Gazzoni with primary data from DEA/USA.

The Brazilian experience also indicates that it is possible to generate 10 to 20 times more jobs in energy agriculture that in the fossil-based industry, with the added advantage that those jobs would be created in Brazil. The incentive to energy farming enables the country to face the challenges of producing sustainable energy, protecting the environment and generating jobs and income.

In addition to the environmental themes, health issues are closely connected with agroenergy themes. The development of technologies to treat and use residues and wastes is a major challenge for regions with large numbers of swine and poultry farms, which struggle to find a balance between the pressures to increase productivity and the pressures of public opinion against environmental destruction and in favor of the rules of the Clean Development Mechanism (CDM).

Furthermore, the actual possibilities of each source of energy having a share in the evolution of the energy matrix should take into account the medium-term projections and their more marked positive and negative aspects (Table 2).

Table 2. Analysis of the main energy sources in the energy matrix.

Fuel	Advantages	Disadvantages
Coal	• Abundant, economically accessible, safe use • Easy transportation and storage • Widely distributed	• High greenhouse gas emissions • Huge investments needed to develop technologies that reduce greenhouse gas emissions to acceptable levels • Dangerous extraction
Petróleo	• Convenient • High energy density· Easy transportation and storage • Co-evolution of the energy source with the equipment required for its use	• Very high level of atmospheric pollution • Volatile prices • Geographic concentration of natural deposits • Product monopoly and maneuverable market • Vulnerability to supply interruption and geopolitical instability • Transportation and storage hazards • Waning reserves
Gas	• Efficient and convenient • Multi-use fuel • High energy density	• Produces greenhouse gas emissions • Hazardous and expensive transportation and storage • Requires expensive, exclusive and inflexible infrastructure • Volatile prices • Geographically concentrated natural deposits • Product monopoly and maneuverable market

To be continued...

Table 2. Continuation.

Fuel	Advantages	Disadvantages
Nuclear	• No greenhouse gas emissions • No major resource limitations • High energy density	• Low acceptance by society • No waste disposal solution • Risky and dangerous operation • Very capital intensive
Renewable	• Low greenhouse gas emissions • Sustainability	• High costs • Intermittent sources • Unequal distribution • Lower technological stage than that of other sources being used

On the one hand, there are appropriate technical and economic conditions to enable agroenergy exploitation. On the other, social (employment, income, migration flows) and environmental (climatic changes, pollution) pressures strengthen and consolidate this position and bring the timetable forward.

Petroleum demand

Scientists had estimated the world petroleum reserves at slightly more than 2.2 trillion barrels at the end of the 19th century, before exploitation began. Today, total world reserves are only 1.137 trillion barrels, of which 78% in OPEC countries (ORGANIZATION OF THE PETROLEUM EXPORTING COUNTRIES, 2005), which should be sufficient to cover world demand for another 40 years at the present rate of consumption.

It is clear that both reserves and consumption will increase during that period. Projecting the numbers of the last 50 years, however, it is estimated that demand will grow 1.5-1.9% p.a., or roughly 120 million barrels per day in 2025, while the rate of growth of the reserves would be more restrained. It should also be noted that net incorporation of proven reserves was only 13% in the last 15 years, i.e., an average .8% increase per annum. In the absence of any drastic changes in the world energy matrix, the decline of the petroleum era is foreseen for the mid 21st century.

This scenario of increasing scarcity is rendered worse by the strong world dependence on petroleum and gas from a specific region – the Middle East – controlled by the cartel of petroleum producing countries (OPEC), which holds 78% of world reserves. Such facts, together with the finitude of the reserves and the heavy concentration of petroleum, coal and gas in the world energy matrix, demand that alternatives be found for a secure transition to an environment of sustainable energy supply.

While during the first and second petroleum shocks in the 1970s the prevailing structural reason for price increases was a voluntary decrease of supply (as a means of increasing prices), the price leap in this century is linked to an expansion of the demand. From the strategic viewpoint, an expansion of the demand is much more disquieting than a contraction of the supply, because while the latter may be negotiated, the former is a proven fact and much more difficult to work out. It points to the need of a radical change in energy consumption habits or a drastic alteration of the world energy matrix.

From 2002 to 2004 the world petroleum consumption rose from 78 to 82 million barrels/day. China accounted for 36% of the increase and the United States, for 24%. China's high economic growth rates transformed the country from petroleum exporter to importer and added uncertainty to the market, similarly to the phenomenon that occurred in Great Britain (MUSSA, 2003). India is a vulnerable country from the energy standpoint as its growth is predicated on greater pressure on the current fossil fuel demand. The same is true for Japan, South Korea and other Southeast Asia countries with high economic growth potential and dependent on petroleum imports.

In 2004 the energy consumption of rich countries rose to 4.5 tons equivalent petroleum (tep) per person per day for approximately one billion citizens. In emerging countries, on the other hand, consumption is .75 tep/person/day, but for a universe of five billion people (WORLD BANK, 2004). The cultural and commercial globalization and the assimilation of the customs of rich countries by emerging countries has resulted in a considerable energy consumption pressure that is felt more intensely in the emerging countries. The latter will experience greater population growth during the 21st century, with the accompanying pressure on the energy demand.

While the consumption of the rich countries has increased by less 100% in the last 20 years, South Korea, India and China increased their consumption during the same period by 306%; 240%; and 192%, respectively, and Brazil by 88% (INTERNATIONAL ENERGY AGENCY, 2004). Any social inclusion effort, therefore, will give bring about additional pressure on energy consumption.

Renewable energy

In addition to agroenergy – bioenergy produced from agricultural and forestry products – the renewable sources include hydroelectric, wind, solar, and geothermal power, as well as the energy of the oceans (Figure 3).

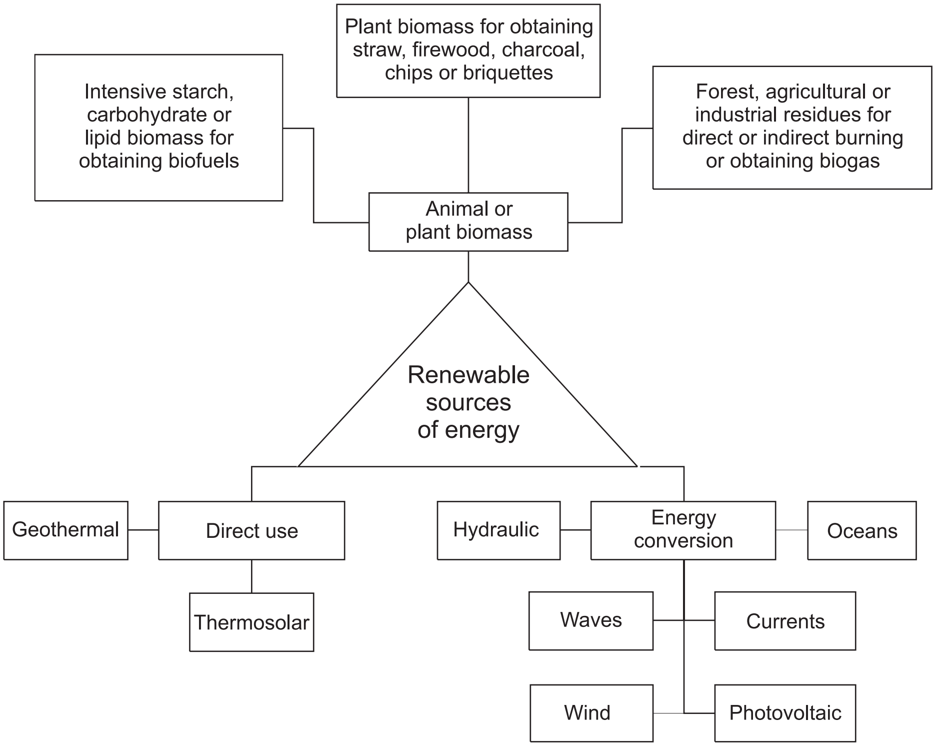

Figure 3. Renewable energy sources.
Source: Drawn by D. L. Gazzoni

World Energy Outlook's reference scenario (WEO 2000) estimates that the demand for renewable energy will grow 2.3% p.a. along the next two decades, thus topping the average growth rate of the overall energy demand. The demand for renewable energies, with the exception of hydroelectric power, will grow about 2.8% p.a. This projection, however, allows for neither market externalities nor interventions resulting from public policies or social pressures.

Biomass – composed of almost 220 billion tons of dry matter p.a. – seems to be a larger and more sustainable and readily obtainable source of renewable energy. Some scientists, such as Hall e Rao (1999), estimate that biomass could produce approximately 4,500 EJ[2] of energy, while other authors point to a sustainable energy capability of about 3,000 EJ. In developing countries, agroenergy will continue to be an important source in the energy matrix.

From the technical standpoint, renewable sources can meet a good part of the increase in world energy demand, regardless of its final purpose (electric power, heating, or transportation). Nevertheless, the economic feasibility, sustainability of each source and availability of renewable resources to generate that kind of energy vary depending on the region. Tropical regions receive strong solar radiation, while plains, particularly costal plains, have greater wind energy potential. Geothermal sources are more abundant in regions with intense volcanic activity. Wastes are available everywhere, and both its volume and concentration increase with urbanization. The main discrepancy, therefore, occurs with biomass, since few countries, among which Brazil, can increase the energy-agriculture area without competing with other land uses, such as food growing, leisure, housing, transportation, environmental protection reserves, etc.

Renewable energy in the energy matrix

The Brazilian energy matrix stands among the cleanest in the world. International Energy Agency (IEA) estimates indicate that 35.9% of the energy supply in Brazil comes from renewable sources, as compared with only 13.5% in the world at large. In the United States and United Kingdom, the share of renewable energy sources is 4.3% and 1.1%, respectively (Table 3).

Table 3. World energy supply.

Country	Primary energy supply (tep)	Renewable energy (tep)	Renewable energy (%)
Argentina	57.6	6.2	10.8
Australia	115.6	6.6	5.7
Brazil	185.1	66.4	35.9
France	265.6	18.6	7.0
Germany	351.1	9.2	2.6
United Kingdom	235.2	2.5	1.1
United States	2.281.4	99.1	4.3
World	10,038.3	1,351.9	13.5

[2] (E = 10^{18}) and J is Joule, unit of energy.

Despite its considerable technical potential, the economic potential of renewable energy sources is not high at the current price regime. It is predictable, however, that the cost of the energy obtained from renewable sources should become more competitive in the next 20 years as a result of investments in technology and gains in scale. Furthermore, market externalities, source diversification, hazardous supply, and the need to reduce greenhouse gas emissions should have a positive impact on the issue.

The dispute for farming area will check any reduction in renewable energy prices. Transportation costs and energy source portability will also weigh against bioenergy sources, and it is foreseen that large logistics and infrastructure investments will be necessary. The WEO 2000 reference scenario foresees investments in renewable energy of around US$ 90 billion in the OECD countries only, or 10% of the overall investment in energy in those countries. Nevertheless, in WEO's alternative energy scenario, investments escalate to US$ 228 billion, or 23% of the overall investment in the energy supply expansion capacity of the Organization for Economic Cooperation and Development (OECD).

Energy agriculture in Brazil

Agricultural energy comes from four biomass sources: carbohydrate- or starch-rich crops, which generate alcohol; plant or animal lipids, which generate biodiesel; wood, which produces methanol, briquettes, or charcoal; and agricultural or agro-industrial residues and wastes, which can generate heat and electric power. Brazil has comparative advantages in the production of all biomass sources and can create competitive advantages to lead the world biomarket and the international renewable energy market.

The first comparative advantage ensues from the possibility of opening up new land for energy biomass agriculture without competing with food production and with environmental impacts limited to what is socially acceptable (Figure 4). To that end the Cerrado expansion area, multi-cropping systems involving cattle ranching and biomass crops, degraded pastures, reforestation areas, and currently marginal land – such as the semi-arid areas in the Northeast Region – total almost 200 million hectares.

The extension to which these areas will be incorporated to produce energy biomass will depend on the final demand and on investments in research, infrastructure, etc.

The second comparative advantage results from the possibility of harvesting several crops a year, according to the "production windows" model. These are

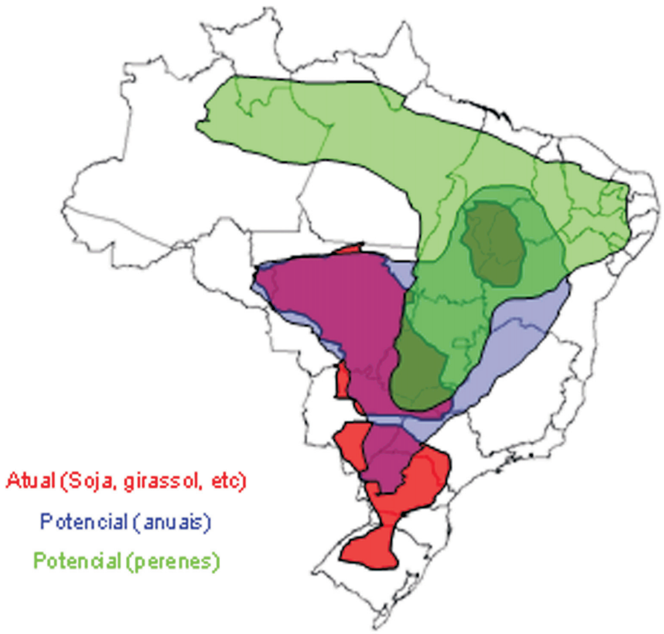

Figure. 4. Area of expansion of energy agriculture.
Source: Drawn by D. L. Gazzoni.

periods that carry certain risks for the main crop, but are perfectly acceptable for less water-demanding crops – such as castor plants and sunflower. Energy agriculture is made viable by the partially written-off fixed costs. The harvest/little harvest, winter cropping and summer double cropping systems have already been widely adopted for grain production in the country.

The third advantage is predicated on the size and geographic location of the country, extending for the most part along the tropical and subtropical zones. Consequently, the Brazilian territory receives intense solar radiation – the source of bioenergy – the year round, in addition to having a wide range of climates, which reduces the risk of agricultural shortages due to harvest losses. The country is also endowed with an exuberant biodiversity that enables a series of energy agriculture options from which to select the most convenient. The latter possibility is rather restricted in Europe, which depends on only a few species, like colza and beets, and in the United States, with corn and soybean.

Among the crops with an exploitable agroenergy potential, special mention should be made of soybean, sunflower, African palm, castor plant, and canola. Notwithstanding, the list of potential plants records more than

100 species, ten of which show good potential for domestication and future exploitation.

Lastly, one-fourth of the world's fresh surface and underground water is located in Brazil, which facilitates large-scale irrigated farming.

As for competitive advantages, Brazil leads the field of modern tropical agriculture technology generation and implementation. The country has accumulated a valuable stock of knowledge and vast experience in science and technology research, development, innovation, and management. Furthermore, we have an installed material, human and institutional capability foretelling that Brazil will continue on the leading edge of energy agriculture technology, as we already are in food agriculture.

The country has vast technical and business experience in the development of a vigorous agro-industry, whose most striking example is the ethanol production chain, known as the most efficient in the world in terms of process and management technology.

At the same time, the domestic agroenergy market is sufficiently large to permit production scale gains and technology absorption returns and, thus, ensure the country's competitiveness in international markets.

Brazil should become the main destination of resources from the carbon market, whose creation can already be envisaged and should rapidly occur once the Kyoto Protocol is fully effective.

The synergy of the natural comparative advantages (soil, water, manpower, and abundant, intense solar radiation) and the accumulated competitive advantages should bring Brazil to the privileged position of chief destination of domestic and foreign investment in the production and use of agroenergy and the implementation of appropriate facilities and logistics for the storage and transportation of the production (communications, liquid storage, railroads and water way transportation, and port facilities).

The environmental factor

The accumulation of carbon dioxide – main agent of the abnormal warming of the earth crust – has markedly increased in recent years and leads scientists to fear that the effects of global warming could become evident faster than previously expected. Carbon dioxide concentrations increased more than 2 ppm in the 2001/2002 and 2002/2003 biennia, while the rate of increase had been 1.5 ppm in previous years, the latter rate already being considered much too high.

The considerable variations in CO_2 concentration are associated with peaks of industrial activity, which intensifies the burning of petroleum and petroleum products – or with years of more intense activity of the El Niño phenomenon –, when the release of carbon from tree decomposition surpasses the withdrawal of atmospheric carbon through photosynthesis. Nevertheless, since El Niño has been inactive in recent year, this phenomenon cannot be held accountable for the increase in atmospheric CO_2 concentrations.

Various phenomena are being directly associated in the scientific literature with the fast intensification of the greenhouse effect from the burning of fossil fuels[3]. American scholars are trying to demonstrate that although forests and oceans act as sinks or deposits of carbon dioxide by withdrawing excessive carbon dioxide from the atmosphere, they are losing this capability due to system saturation, which could be another cause of the abnormal CO_2 concentrations.

There is great concern over the intensification of the greenhouse effect and consequent catastrophic changes from the global warming – rise in sea level, draughts and more increased storm frequency. It is also greatly feared that the schedule of such climate changes is being brought forward.

Few studies have been undertaken in Brazil on the possible impact of global climate changes on agriculture. This impact will probably include changes in the incidence of plant pests, with ensuing serious economic, social and environmental consequences. The current plant health scenario would be significantly altered, forcing the immediate implementation of studies and research on ways to diminish the vulnerability of agriculture to climate changes, together with a search for adaptive long-term strategies.

Since the sustainability of Brazilian agribusiness falls within its scope of action, Embrapa has encouraged networking and research on this topic. Embrapa is also seeking ways[4] to prevent the emergence or reemergence of plant diseases. Encouraging agroenergy is one of the most appropriate ways of facing the challenge.

Transition of the energy matrix

Although changes in the components of the world energy matrix are incontrovertible in the long run, there are various technological, political, cultural,

[3] American researchers have pointed out that the forest fires that have ravaged the Northern Hemisphere in the last few years may have contributed to the intensification of the greenhouse effect.

[4] See, for example, the book Mudanças climáticas globais e doenças de plantas (Global climatic changes and plant diseases) by Embrapa Environment researcher Raquel Ghini.

social, economic, and environmental conditioning factors that could speed up or delay those inexorable changes, as follows.

• Fossil fuel price increase is crucial to hasten the transition and, paradoxically, extend the duration of the petroleum reserves, making for a less turbulent transition. In a moderately priced fossil fuel scenario, few renewable sources of energy can be competitive, with the noteworthy exception of ethanol from sugarcane.

• A decline in the petroleum will affect the production chains dependent on fossil fuels and induce the replacement of fossil energy with biomass energy. The speed of substitution will depend on the volume of investments in Research, Development and Innovation (RD&I).

• The costs of obtaining energy are strongly linked to the local conditions, a phenomenon that gives rise to competitive differentials between regions, countries and continents, and only some of those competitive advantages can be overcome.

• The transition will depend on the decisive and continued support of the respective governments, particularly at the beginning. Government support could be gradually reduced as goals are met and the process becomes consolidated. The government's regulating and intervention powers can alter the picture through various policy instruments, purchasing power, standards, and regulations. The adaptation of technological resources would also be a strong incentive.

• Intense, guaranteed and continuous support to RD&I programs will act as a fulcrum in expediting the transition. As innovations increase the efficiency of the energy transformation processes environmental and economic benefits will accrue, making renewable sources of energy technically and economically viable and inducing gains in scale and costs reduction in the long term.

• International and inter-block agreements such as the Kyoto Protocol and the Directive on the promotion of electricity produced from renewable sources of energy for the internal electricity market of the European Parliament will exert strong positive influence on the transition.

• Energy cogeneration should become an important factor in the economic viability of agroenergy sources. The technique is already used in the production of ethanol and could be extended to other sources, including the generation of energy from wastes.

• If the expansion of energy agriculture occurs at the expense of food supply or the environment the strong reaction of society will compromise the changes in the energy matrix.

• The growing concern over global climate changes will give rise to global pollution reduction policies and an acknowledgement of the importance of biomass energy.

• The growing energy demand and the recent trend toward the use of energy biomass will be driven by the developing countries, whose new energy demand will attain 5 TW over the next 40 years. It is unimaginable that fossil sources could meet such demand because of the huge environmental impact, growing financial costs and depletion of petroleum reserves.

• The environmental costs will gradually be incorporated into the price of fossil fuels as a result of the punitive taxes (pollution tax) imposed, which will progressively make them more expensive; this will further worsened by the natural prices increases caused by petroleum reserves depletion.

• Public and private investments in the development of innovations that ensure the viability of renewable and sustainable sources of energy (with emphasis on the use of biomass) are growing exponentially.

• There is also a growing number of international investors interested in long-term contract for the supply of biofuels, especially alcohol and, to a lesser extent, biodiesel and other biomass products.

• Energy will become an important component of agricultural and agro-industrial production costs, making cogeneration progressively attractive.

Table 4 lists the cost of electric power generation from different sources, by country in Western Europe, and shows that bioenergy is beginning to compete with coal and gas.

Table 4. Electric power generation costs in Europe for diverse primary sources (Eurocents/kWh – 1990 prices).

Country	Coal	Combine cycle gas	Bioenergy	Wind	Solar	Nuclear
Austria	3.6	3.4	3.6	7.2	64.0	5.9
Belgium	3.2	2.8	3.7	7.2	64.0	4.0
Denmark	3.6	2.9	3.9	6.7	85.3	5.9
England	3.2	2.6	3.9	7.2	85.3	3.8
Finland	3.2	3.2	4.0	7.2	51.2	3.4
France	3.2	3.5	4.3	6.8	64.0	5.1l
Germany	3.5	3.5	4.0	7.2	51.2	4.6
Greece	3.2	3.2	4.5	7.2	85.3	4.7
Ireland	3.2	3.4	4.0	7.2	51.2	5.0
Italy	3.6	2.6	4.0	7.2	64.0	5.1
Netherlands	3.2	3.4	4.3	7.2	51.2	5.9
Portugal	3.6	3.5	4.3	7.1	51.2	4.7
Spain	3.6	3.3	3.4	7.2	85.3	4.7
Sweden	3.2	2.6	3.8	7.2	64.0	4.3

Source: AEN/NEA – IEA – Projected costs of generating electricity.

Figure 5 shows renewable energy production in 1997, in various regions and countries of the world and the estimates for 2020.

The following table (Table 5) shows the potential use of bioenergy according to a 1990 survey with projections for 2020 under two different scenarios.

Figure 6 shows an expressive growth of biodiesel production in the world with two important moments in the curve inflexion for 1994 and 2000.

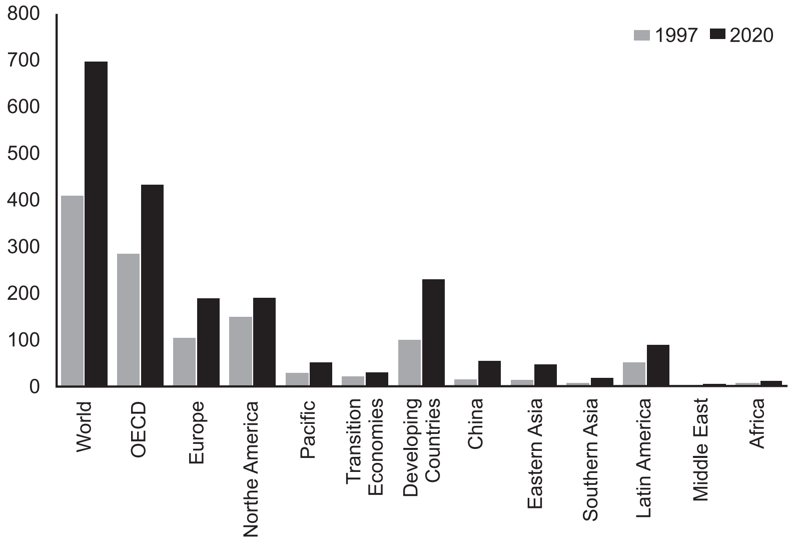

Figure 5. Renewable energy supply by region (Mtep).

Table 5. Estimated potential use of bioenergy (Mtep[1]).

Source	1990	2020	
		Reference	Alternative
Crop residues	420	482	499
Wood	1,483	1,791	2,025
Energy crops	2,689	2,971	3,535
Animal wastes	688	994	1,004
Urban wastes	112	516	516
Total	5,393	6,755	7,569

[1] M = mega (10^6); tep = tons equivalent petroleum.

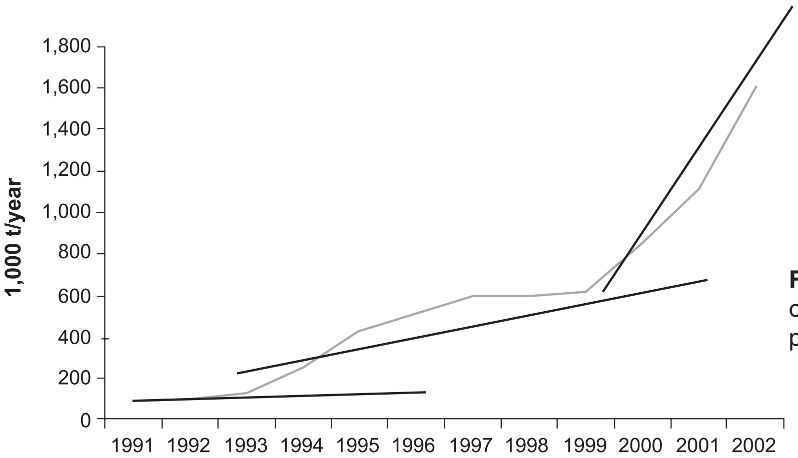

Figure 6. Evolution of world biodiesel production.

Energy supply and demand scenarios

The Special Report on Emission Scenarios of the Intergovernmental Panel on Climatic Change (IPCC) estimates that the greatest amount of renewable energy power in the medium term (2025) will derive from the development of modern biomass (70 to 140 EJ), followed by solar energy (16-22EJ) and wind energy (7-10EJ). The concept of modern biomass includes wood in the form of briquettes, carbon and black liquor. In the long term, the contribution of the renewable sources is estimated at 1,300 EJ/year, half of it obtained directly from solar energy (2,600 EJ/year).

While the main limitation to the use of solar energy is the development of a technology that makes obtaining and storing solar energy economically feasible, it is believed that in the case of agricultural energy there would be a maximum expansion limit because of the competition of food production for land. Consequently, it is important to achieve productivity gains not only in food and fiber agriculture, but also in energy agriculture, so that the dispute over land may be delayed until other renewable sources of energy have become viable.

The International Institute for Applied Systems Analysis and the World Energy Council have jointly drawn scenarios for the 21st century (Table 6). Their projections show that only scenarios that include the replacement of fossil sources of energy with renewable energy (scenarios A3, C1 and C2) could promote sustainable development with low environmental impact (local and global) and a more equitable distribution of resources and wealth. To the contrary, a projection of the current situation and trends would not to lead to sustainability even with technological advances and moderate economic growth (scenario B).

Table 6. Premises of the projection scenarios 2000-2030.

		Scenarios		
		A	B	C
		Great technological development and economic growth in the world	More technological advances and moderate economic growth in less developed countries	Ecological restrictions, efficient conservation and use of energy, and great technological and economic progress
Variants	1	Abundant petroleum and natural gas		Increased dependence on new and safer nuclear reactors
	2	With current oil and gas reserves (and increased use of coal)		Increased dependence on renewable energy
	3	With mastery of nuclear and renewable energy, eliminating fossil fuels by 2100		

According to the basic scenario of the US Department of Energy, the total energy demand during the period 1996-2020 should grow by 78% and electric power demand, 92%, which would require annual investments of US$ 400-600 billion in investments from 1990 to 2020. These investments would focus on a very diversified set of technologies that include fossil, renewable and nuclear sources of energy.

The USDE scenario considers that 80% of the current energy supply comes from fossil sources and that fossil energy will until 2020. They also conclude that only 9% of the total energy demand and 12% of the electric power demand until 2020 will occur in the USA and that most of the demand increment will come from developing countries. Petroleum production will increase from 72 to 116 million barrels per day, but drop in the USA, increasing dependency on the Gulf. The risks associated with supply and environmental impacts will increase the interest in clean fuels from various renewable sources, especially biomass, or natural gas at most.

The most promising of all fossil sources of energy is natural gas, because of the possibility of expanding its production and the fact that it is the "cleanest" energy. Nevertheless, natural gas spatial distribution is not homogeneous and demands large investments in infrastructure, complex international agreements and technological innovations in distribution. Furthermore, natural gas is particularly affected by political disputes because it depends on high fixed-cost pipelines that cannot be used for other purposes, tying clients to arbitrary political decisions and contract noncompliance on the part of government leaders and officials.

The use of nuclear energy should continue to be limited by safety issues and low acceptance by public opinion, which means that the search for safer technologies must continue.

Renewable sources of energy such as solar and wind energy should continue to meet a growing part of the demand, mostly outside the USA at the outset. Environmental and supply security considerations should strengthen the growth of renewable energy sources, including biomass, throughout the world.

As a rule, economic growth and environmental protection will drive changes and restrain the growth of the energy sector. If the world decides to maintain the atmospheric carbon concentration at the current 550 ppm level, a good part of the energy will not contain fossil carbon in the future, but fossil fuel exploitation will be much more efficient, whenever used.

In the next decades, biomass will become the basis of renewable energy and a valuable input for the chemical industry. The experts believe that energy from biomass will account for the better part of the revenues from international agricultural transactions beginning in 2050.

In certain cases, the growth of energy agriculture will also drive food production increases. For example, the expansion of crops such as soybean and sunflower for energy purposes would necessarily signify an increased supply of cakes and bran, one of the raw materials in the food and feed industries.

Portability, storage capacity and energy density are important attributes that help consolidate and broaden the share of an energy source in the energy matrix. Ethanol and biodiesel, for example, have portability, which facilitates their transportation to and storage in foreign countries, as opposed to electric power, which has transmission limitations. Biodiesel has the same characteristics of alcohol, but greater density, which reduces the relative transportation and storage costs, as measure by the potential energy per unit of volume or weight.

Projections for Brazil

The gross domestic supply (GDS) of energy in Brazil[5] in 1999 was 183 Mtep[6]. It is estimated that the domestic supply of energy should reach 617 Mtep by 2020 (Table 7), equivalent to a 4.4% p.a. growth during the period 2000-2020.

At the end of 1999 the measured petroleum reserves equaled a 20-year production, pointing to depletion by the 2020s. Eighty-eight percent of proven petroleum reserves and 65% of proven natural gas reserves are located at great ocean depths.

It is foreseen in this scenario that petroleum and the energy derived from sugarcane should become less important, while natural gas would secure a relevant share of the 2020 Brazilian energy matrix (Table 8).

Nevertheless, the predicted cost reductions in biomass energy production (Table 9) could alter this scenario, depending fundamentally on the evolution and outcomes of technological research, development and innovation along the various agroenergy lines of action.

Table 7. GDS projections in thermal equivalent values.

Year	2000	2005	2010	2020
Mtep	260	300	396	617

Source: CGEE – State-of-the-art and technology trends in energy.

Table 8. OIB Evolution by energy source.

Source	2000 (%)	2020 (%)
Petroleum	47	42
Hydroelectric	14	15
Natural gas	5	16
Sugarcane	12	8
Coal	7	8
Uranium	1	1
Other primary sources	2	3
Firewood – charcoal	11	7

Source: CGEE – State-of-the-art and technology trends in energy.

[5] The GDS considers domestic production, imports, exports, stock variation, and unused energy.
[6] Calculating the electric power by means of its caloric equivalent: 1 kWh = 860 kcal.

Table 9. Evolution of biomass costs (in US$/GJ).

Year	2000	2005	2010	2020
Cost	2.4	1.8	1.4	1.2

Source: CGEE – State-of-the-art and technology trends in energy.

Annex 2
Agroenergy Production Chains

Agroenergy Production Chains

The agroenergy chains discussed in this annex can be divided into four main groups: a) ethanol and the cogeneration of energy from sugarcane; b) biodiesel from animal and plant lipids (); c) forest biomass and its residues; and d) agricultural and agro-industrial wastes. Energy forests produce several forms of energy, such as firewood, charcoal, briquettes, fines (small-diameter charcoal fragments), and black liquor. Biogas results from the anaerobic digestion of organic matter. Biodiesel can be obtained from plant oils, animal fats or agro-industrial residues. Although ethyl alcohol can be obtained from other sources, the competitiveness of sugarcane ethanol is unbeatable. And agricultural and agro-industrial residues, as well as the wastes from those processes, can be converted into different secondary forms of energy, such as briquettes, biogas, biodiesel, etc. (Figure 7).

The RD&I program will focus on the development of raw material technology and on process development or improvement (Figure 8). In either case, a clear vision of the final agroenergy form (heat, biofuel or electric power) is necessary to ensure raw material productivity or process competitiveness.

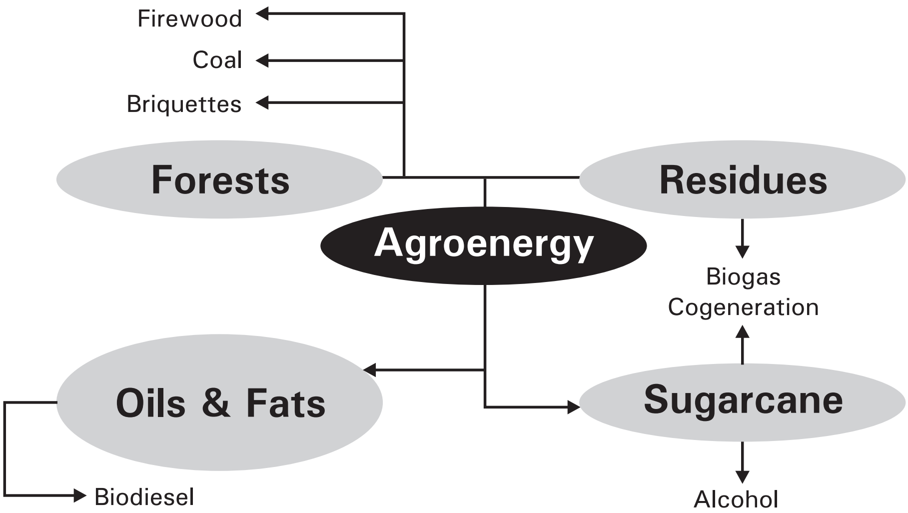

Figure 7. Agroenergy production matrix.

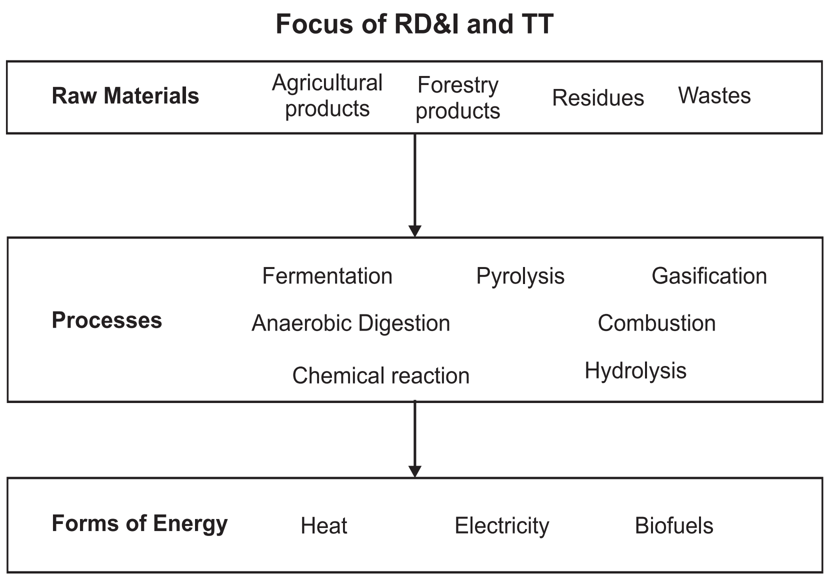

Fig. 8. Agroenergy production chain as the focus of an RD&I program.

Fuel alcohol

Brazil's ethanol production technology is the most advanced in the world; the country has also made great strides in the use of ethanol as fuel. The USA's is second most advanced, followed by that of Argentina and other countries. The world ethanol production is almost 40-billion liters, of which 25-billion liters are used for energy purposes; Brazil manufactures 15-billion liters (Figure 9), or almost 40% of the world production.

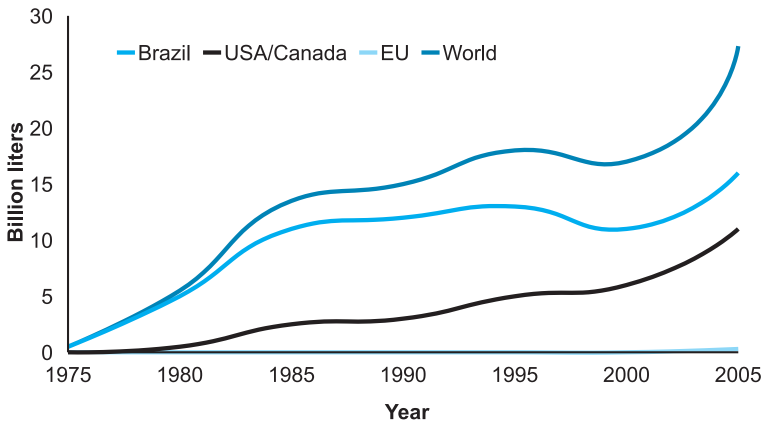

Figure 9. World fuel alcohol production.

Alcohol is used mixed with gasoline in the following countries: Brazil, the USA, the EU, Mexico, India, Argentina, Colombia, and more recently Japan. Only in Brazil is alcohol used as a fuel. In Brazil, in the 1980s and 1990s, technological innovations, modern business practices and scale gains - made possible by the Pro-alcohol Program (Proálcool) combined to draw a learning curve that resulted in reduced alcohol production costs and prices compatible with those of gasoline (Figure 10).

Alcohol can be obtained from several biomass sources. To date, however, the most viable has proven to be sugarcane. Large investments are being made to enable alcohol production from cellulose, and it is estimated that the USA could obtain close to 30-billion liters of alcohol from this source by 2020. It will be necessary to invest heavily in RD&I, especially in the hydrolysis of cellulose. To avoid a competitiveness shock, Brazil must invest in the same line of research, whose potential is extremely promising.

Enormous environmental benefits are associated with the use of alcohol: CO_2 emissions would be reduced by almost 2.3 tons per ton of fuel alcohol used instead of fossil fuels, not counting other emissions, such as SO_2.

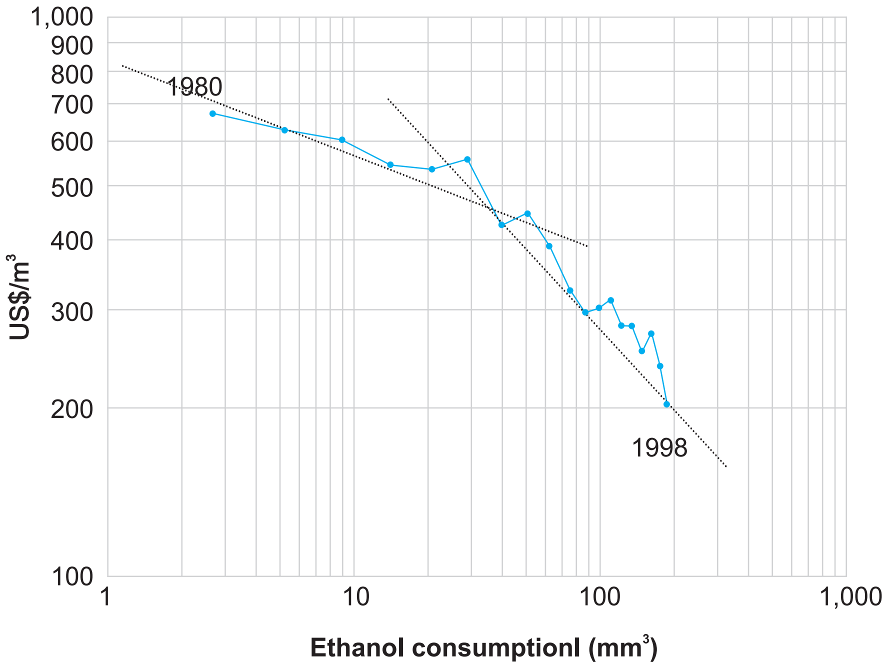

Figure 10. Learning curve of the sugarcane ethanol price.
Source: Goldemberg, J. Seminário BNDES sobre Competitividade do etanol brasileiro, 2003.

Adding fuel alcohol to the cogeneration of electric power from bagasse, sugarcane is today the largest renewable source of energy in Brazil. According to the National Energy Balance, the biomass share in the Brazilian energy matrix in 2003 was 27%; of which sugarcane bagasse accounted for 12.6%; firewood and charcoal, for 11.9%; and other sources, for 2.5%.

Sugarcane plantations in Brazil spread over almost 6-million hectares, of which 85% are located in the Center-South, particularly in the State of São Paulo (60%), and the remaining 15%, in the North and Northeast Regions.

Approximately 380-million tons were milled in the 2004 harvest, and about 48% of them were used for alcohol production. The bagasse from the crushing operation was burned in the mills' boilers, which made the mills self-sufficient in energy. In many cases the mills have energy surpluses, which can be sold. Total alcohol production was 15.2-billion liters and the total power generated was more than 4GWh during the harvest, or approximately 3% of the country's annual power generation capability.

Despite the huge cogeneration potential resulting from the increased energy efficiency of the sugar mills, the generation of electric power is only one of the uses of bagasse. There is ongoing research focusing on the transformation of bagasse into alcohol using lignocellulose hydrolysis, as well as into biodiesel; or even making better use of bagasse in the furniture industry and in the production of feeds.

Brazilian experience with fuel alcohol

At the end of 1979 only anhydrous alcohol was being used as fuel[7].

In addition to being extremely dependent on imported petroleum, most Brazilian exports were agricultural commodities at the time, which would prevent the country from achieving equilibrium in the balance of trade if the growth trend of petroleum imports were maintained. The second petroleum shock led the government and the automobile industry to establish a partnership to push the technological development of vehicles fueled exclusively with alcohol. In 1980 the federal government determined that alcohol would be sold to consumers for 60% the price of gasoline, which established an advantageous parity in the price to caloric power ratio.

[7] The first experiences with ethanol in Otto Cycle engines date back to the beginning of the 20th century. In 1912 some vehicles were fuel driven in an experiment. In 1931 the Brazilian government authorized the use of 2-5% alcohol mixed in gasoline. The alcohol content was increased to 5-10% in 1961.

Consequently, alcohol fueled more than 90% of new vehicles sold from 1983 to 1988.

At the same time the government created the National Alcohol Program (Proálcool), the world's largest renewable energy program, which included major incentives for increasing the installed capacity: sugar plantations, sugar mills, distilleries, and storage infrastructure. The new policy brought about a rapid increase in the sugarcane farming area and vertiginous growth of alcohol production, but without disturbing the sugar market supply.

During the 1980-1985 period, the learning process and technological development received an added thrust. Productivity gains in agriculture and raw material processing enabled a noteworthy reduction of the alcohol processing costs. There was also remarkable improvement in the efficiency of alcohol engines, which increased the population's reliance on these vehicles.

As petroleum prices began falling abruptly from an average value of over US$ 27.00/barrel in 1985 to less than US$ 14.00/barrel in 1986, the government was unable to maintain the alcohol price incentives[8].

Hydrated alcohol consumption continued to rise, but the 1989-1990 supply crisis shook the population's trust in this fuel and, consequently, in alcohol-driven automobiles, whose sales fell from 52.5% in 1989 to 11.55% in 1990.

After the crisis, when sales were beginning to recover (in 1992 and 1993 alcohol fueled vehicles accounted for over 25% of the fleet, on average), new technological standards definitely placed alcohol cars at a disadvantage: the concept of 'world car' and the new engines of up to 1,000cc piston displacement. Since the price ratio did not favor alcohol, the automobile industry concentrated its research on producing more economic gasoline vehicles, which accounted for 75% of sales in 1996, while alcohol automobile sales went down to less than 1%.

In order to prevent a collapse of the entire alcohol production structure in the country, the government determined in 1993 that the gasoline-alcohol mixture should contain 22% of anhydrous alcohol. Alcohol sales still continued to rise until 1997 and by 2000 the decrease in hydrated alcohol consumption was greater than the increase in anhydrous alcohol consumption. Total alcohol use grew again beginning in mid 2001, when the use of anhydrous alcohol was greater than the absolute drop in hydrated alcohol consumption.

[8] A new decree increased the alcohol to gasoline price ratio to 75% in 1986. This percentage is the closest possible to the vehicular power ratio between the two fuels.

At the same time, while the productivity of the sugar & alcohol sector was increasing, petroleum quotes rose again, fluctuating around US$ 25.00/ barrel from 2000 to 2002. With higher prices and an higher tax load on fossil fuels, alcohol was once again attractive and, consequently, the automobile industry began investing in a new technological standard: the bi-fuel or dual fuel, alcohol-gasoline car, also called by the North American expression, flex fuel.

The refueling flexibility of these vehicles, which have practically eliminated the risk of running out of fuel, combined with attractive alcohol prices has redirected the market: first released in March 2003, approximately 850,000 dual fuel vehicles were circulating in Brazil by late 2005. Six automobile manufacturers installed in the country offer 52 different models[9]. These numbers predict the dawn of a new era in which multi-fuel vehicles will dominate the market almost absolutely, and this should favor enormously the consumption of biofuels.

Consequently, domestic hydrated alcohol sales will once again rise. Consumption is estimated at more than 6-billion liters in 2006. Added to another 6.7-billion liters of anhydrous alcohol mixed with gasoline, alcohol will once again hold more than 40% of the fuel market addressing Otto Cycle vehicles.

Cogeneration

The residues from sugar and alcohol production that can be used to produce electric power through cogeneration are sugarcane bagasse, straw and styles, as well as the vinasse from the alcohol distilleries. Alcohol accounts for one-third of the overall energy contents of sugarcane, the remainder being distributed among bagasse, styles and straw.

Cogeneration is the process of transforming a given form of energy into more than one form of useful energy. The more common types of cogeneration are: mechanical (to drive machinery, equipment and electric power generation turbines) and thermal (for the generation of steam, cold, or heat). According to Oddone (2001), cogeneration is very efficient from the energy standpoint because no thermal energy is wasted (as is the case with purely thermoelectric plants), since it is used in industrial processes such as drying, evaporation, heating, cooking, distillation, etc.

Authors like Wylen and Sonntag (1976), Oddone (2001), Coelho (1999), and Walter (1994) have studied the thermodynamic aspects of cogeneration

[9] In August 2005, the number of new dual fuel vehicles totaled 90,000, or 60% of the fleet.

in the sugar & alcohol production chain, especially in the Rankine and combined cycles[10].

Projections of the International Energy Agency indicate that the participation of biomass in electric power generation throughout the world will rise from 10TWh in 1995 to 27TWh by 2020.

According to FAO approximately 1,333 Mt of sugarcane were produced in 1997, or 335 Mt (25%) of bagasse. One ton of bagasse with 50% humidity holds 2.85 GJ of energy.

According to the National Energy Balance, the share of biomass in the Brazilian energy matrix was 27% in 2003. Energy from sugarcane bagasse was 12.6%; from firewood and charcoal, 11.9%; and from other sources, 2.5%. During the 1985-1992 period cogeneration already accounted for 3.6% of the electric power produced in Brazil (WALTER, 1994).

Processing sugarcane requires huge amounts of thermal, mechanical and electrical energy. Nevertheless, after the juice is extracted, it is possible to burn the sugarcane bagasse[11] in boilers to produce steam, which is used to obtain three sources of energy.

In addition to the bagasse, sugarcane furnishes straw and styles, which account for 55% of the energy accumulated in the sugar plantation. Although most of this energy remains in the fields, it can represent up to 30% of the total sugarcane biomass. Its maximum caloric power exceeds 15 GJ/t and its minimum caloric power is approximately 13 GJ/t. Although it could double the amount of energy obtained from sugarcane, all this potential is seldom used and, in most cases, is burned in the fields.

The bagasse – 25% to 30% the weigh of the sugarcane processed – was initially, used in the sugar mills instead of firewood to generate heat. More recently, however, it has been used to generate steam, with the additional possibility of being transformed into other forms of energy, such as heat, electric power, or mechanical traction. The increased costs of electric power and petroleum have made the use of bagasse in cogeneration very attractive.

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[10] In the Rankine cycle, a boiler is used in which a source of energy (sugarcane bagasse or straw) generates steam under high pressure at a temperature above 100ºC. The steam is released by means of mechanical systems that move machinery and transfer heat to the industrial processes or move turbines to generate electric power. The cycle is completed when the steam returns to the boiler to be heated again. In the combined cycle, a high-temperature gas turbine drives a generator and the heat of the gas is transferred to the water, generating steam. The steam moves a second generator, and both generators produce electric power.

[11] Understood as the macerated sugarcane stalk with 50% humidity, a residue from the crushing operation in the sugar mill.

Since we are barely beginning to use this process there is much room for technological improvement before maximizing its efficiency.

Brazilian policy makers have identified enormous cogeneration possibilities. The Electric Energy Regulating Agency (Aneel) set up a Convention for the Commercialization of Electric Power (Normative Resolution n° 109, of 26 October 2004), which recognizes self-producers, namely, the holders of a concession, permission or authorization to produce electric power for his/her exclusive use; free consumers, who have chosen to buy electric power; and independent producers, corporations or consortia of companies that hold a concession, permission or authorization to produce electric power and are entitled to sell all or part of the energy produced at their own risk.

In addition, the Program of Incentives to Alternative Sources of Electric Power (Proinfa) was created in 2002 and regulated in 2005. Proinfa contemplates the purchase by the National Interlinked System (SIN) of 3,300 MW of energy produced from wind and biomass sources, as well as small hydroelectric power plants (PCH), whereby 1,100 MW come from each source. The Ministry of Mines and Energy (MME) coordinates the new program.

Aneel has authorized cogeneration undertakings of up to 1,376.5 MW, considering only generating plants that use sugarcane bagasse (1,198.2 MW), wood residues (41.2 MW), biogas or landfill gas (20 MW), and black liquor (117.1 MW). Three new power plants have gone into commercial operation this year, all of which use sugarcane bagasse. They have added 59.44 MW to the national electric power matrix.

As an alternative to cogeneration, bagasse has other applications in addition to the mills and distilleries. It is used to add volume to animal feeds, to manufacture paper and structural building elements and even in the production of additional fuel alcohol through hydrolysis. In fact, technologies to produce ethanol from bagasse hydrolysis are being developed and could be commercially available in 10 to 15 years. Therefore, the opportunity cost of bagasse use has become important because of the many alternatives available.

As regards vinasse, the residue from alcohol production in distilleries, it can be used as energy source after anaerobic biodigestion and biogas production. At present the vinasse goes back to sugarcane plantations as liquid fertilizer. The caloric power of this biogas is estimated at 21.32 J/m^3.

For many years gas production from vinasse biodigestion has been the object of numerous studies and efforts to make it commercially viable. Only recently has interest in using biogas to generate electric power been awakened. The technology has become sufficiently mature in demonstration scale, but some uncertainties still remain: the corrosive effects of biogas on auxiliary equipment and motogenerators and the stability of biodigestion vis-à-vis the fluctuations in the quantity and quality of the vinasse to be processed. These potential problems could have negative impacts on the future commercialization of the technology, and the problems can only be evaluated and solved after some units start operations.

There are numerous electric power plants in developed countries that run on biogas produced through the bio-anaerobic digestion of other substrates, such as industrial effluents and animal wastes. The operational experience of those power plants should be used to improve the technical and economic reliability of future power plants fueled by biogas from vinasse.

It would be convenient, therefore, to set up some pilot units before going into industrial scale production and provide R&D adequate funds to analyze said units from the technical and economic viewpoints. Because of the potential to generate surplus power, estimated at 3.6 TWh/year[12] in that stage, it would be advisable to introduce the vinasse biodigestion technology and the use of biogas in electric power generators at the commercial level, albeit cautiously.

If the sugar & alcohol activities grow markedly in the next few years as predicted, the electric power generation potential could attain average values of 16 – 21GW by 2025.

Nevertheless, this effective economically viable power, which already falls below 65% of the theoretical power, is produced by only a few power plants. In the other units being set up or enlarged, ongoing investments contemplate the adoption of less efficient technological solutions, which will limit the effective additional power to 0.5 – 2 GW in the next five years, even after expanding the sugarcane production. More advanced technology configurations could increase the effective surplus power to 3 – 6.4GW by 2010, of which 1.7 GW to 3.8 GW would be economically viable.

In order to make full use of the cogeneration opportunities it would be necessary to replace the main existing power equipment, install it in new plants and enlarge others. Yet this would mean even larger investments than those being made by most companies and businessmen in the energy sector. For the picture to evolve favorably it is essential to define immediately the strategy required to make this power generation effectively viable.

[12] Considering an energy yield of 20 kWh/ton of sugarcane and a volume of 180-million tons of sugarcane earmarked for alcohol production.

Institutional model

Until 1990 the sugar & alcohol industry evolved owing to heavy governmental intervention, which has been defended since colonial times by the strategic role played by sugar exports, an argument later strengthened by the introduction of alcohol in the Brazilian energy matrix.

After the Sugar and Alcohol Institute (IAA) was terminated in 1990, the sugar & alcohol economy was gradually deregulated until almost total liberalization. In 1999 the responsibility for coffee, sugarcane, sugar and to a certain extent alcohol was finally transferred to the Ministry of Agriculture, Livestock and Supply (Mapa). The ministry's structure was modified to include a Production and Commercialization Secretariat and a specific department for sugar and alcohol[13].

Despite the liberalization, the government must have market regulation mechanisms for the alcohol sector because of the some characteristics of the fuel alcohol market, as shown below.

Seasonal production. Like other agricultural products, alcohol is produced during the sugarcane harvest months, although consumed year round. This requires building up stocks in order to minimize price fluctuations and the risk of fuel scarcity between harvests.

Strategic product. Because of its strategic nature, the widespread use of fuel alcohol and the fact that no adequate substitute is available, an insufficient or excessive alcohol supply could generate fuel market crises and undermine consumer trust, as was the case in the late 1980s.

No international market. Since there is no significant international market for the product, it would not be possible to buy or sell large volumes of fuel alcohol in times of scarce or excessive supply in the domestic market.

Underdeveloped intermediation sector. Until recently more than 90% of the fuel alcohol production was purchased by fuel distributors, which were never interested in building up fuel reserves and left that task and resultant investments to producers. When alcohol becomes a commodity foreign buyers will probably impose a change of strategy by encouraging, for example, a futures market. In this case the new strategy could contemplate reducing the producers' risks and costs associated with keeping fuel alcohol reserves.

Because of its technical and economic characteristics the sugarcane economy tends to verticalization, which progressively excludes small- and

[13] Since February 2005 the ministry's structure has included the Secretariat for Production and Agroenergy (SPAE) and the Sugarcane and Agroenergy Department.

medium-size farmers by favoring sugarcane production in the sugar mills' lands. This trend encourages increased concentration of land ownership and the prevalence of monocultures, which have ruinous socio-economic and environmental effects. A reversion of this process tends to create market structures with a small number of buyers, who can only be somewhat neutralized by some degree of government intervention or supervision to increase the bargaining power of sugarcane suppliers.

Law nº 9.478 of 6 August 1997[14] and Constitutional Amendment n° 33 of 11 December 2001[15], later complemented by laws n° 10.336 of 19 December 2001[16] and n° 10.453 of 13 May 2002[17], were the mainstays of the sugar & alcohol regulatory framework that governs the establishment of a free market environment (end of the State's monopoly of the petroleum industry) and defines the tax model to be used for fuels.

The government has two other mechanisms to intervene in the fuel alcohol market. The first mechanism is fixing the anhydrous alcohol contents of gasoline, which can vary between 20% and 25% depending on the availability of the product. The other mechanism is a more structural intervention into the tax load on automobiles, whereby lower rates of the Tax on Industrialized Products are set for alcohol fueled vehicles, with the exception of those with piston displacement of up to 1000cc.

Another institutional aspect relevant to the agroenergy sector is the National Program of Incentives for Alternative Electric Power Sources (Proinfa), whose purpose is to increase the share of alternative sources of energy in the energy matrix. These sources include wind energy and cogeneration from biomass residues in small hydroelectric power plants. Nevertheless, despite the remunerative prices, the sugar & alcohol sector has not shown much interest in the program, particularly because they are focusing their investments on increasing sugar and alcohol production while waiting for the outcome of the research on the utilization of sugarcane bagasse. Since they would have to accept long-term contracts with large fixed-capital investments most units have preferred to act cautiously.

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[14] Law nº 9.478 establishes provisions for the national energy policy and activities pertaining to the petroleum monopoly and institutes the National Council for Energy Policy and the National Petroleum Agency.

[15] Constitutional Amendment n° 33 amends articles 149, 155 and 177 of the Federal Constitution and defines the basis for the creation of a Contribution on Intervention in the Economic Domain (Cide).

[16] Law n° 10.336 establishes the Contribution on Intervention into the Economic Domain (Cide) on imports and commercialization of petroleum and its byproducts, natural gas and its byproducts, and fuel ethyl alcohol.

[17] Law n° 10.336 defines the set of economic policy instruments through which the government can intervene in the production and commercialization of fuel alcohol.

Current scenario and prospects

The sugar & alcohol industry currently capitalizes on a set of favorable factors both domestically and internationally.

In the domestic front the economy's recovery and the new jobs being generated have resulted in sugar consumption increasing in excess of the natural growth rate of the population, although Brazil has one of the highest sugar consumption rates in the world (close to 54 kg/inhabitant/year).

As regards alcohol, consumers are again interested in alcohol-fueled cars because of the increased domestic gasoline prices, the prospects of more increases in the international petroleum prices and the new dual fuel vehicles. Barely two years after their coming into the market dual fuel vehicles account for 70% of new vehicle sales in the country. Consequently, hydrated alcohol is once again very good business, especially in the cities located in the sugar & alcohol regions. Nevertheless, if the sugar & alcohol industry raise fuel alcohol prices, it would have a deleterious effect on dual fuel vehicle sales, as befell alcohol-fueled cars in the past, which became practically unviable. The government, therefore, should watch the market carefully.

It is estimated that the market will absorb at least one million dual fuel vehicles per year during the next few years, which would represent a hydrated alcohol[18] demand increase in excess of 1.5-billion liters p.a. and an estimated demand of 25-billion liters by 2013. After adding the predicted alcohol sales in international markets, it is possible to imagine an overall ethanol demand of close to 30-billion liters by 2015, which could be easily met by the Brazilian sugar & alcohol industry.

These projections lead to an estimated domestic sugarcane demand leap from 240-million tons (70-million tons of sugarcane for sugar production and 170-million for alcohol) to about 334-million tons (84-million tons of sugarcane for sugar production and 250-million tons for alcohol) in the next five years, a production increase of practically 100-million tons for the domestic market.

In the international markets the situation is also heartening for sugar, which in Brazil competes with ethanol for the same raw material. A world consumption increase of about 2% p.a. would help the growth of Brazilian exports. Moreover, the expected reduction in sugar production that should take place in several countries investing in fuel alcohol production without the

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[18] Assuming that the vehicles' average annual consumption is 2,000 liters and subtracting 500,000 liters/year on account of the alcohol cars in the fleet growing old.

possibility of increasing their overall agricultural production must also be taken into account[19].

In the European Union changes in the sugar policy resulting from a recent decision of the World Trade Organization, together with internal budget pressures, have reduced expectations about future total sugar production. Even if the picture is modified after the incorporation of the Eastern European countries into the EU-25, sugar production is expected to decrease throughout Europe for two basic reasons: the high financial cost of sugar and alcohol production from beets and the low energy consumption to energy production ratio for that crop.

The international market is also adjusting to India's reduction of sugar sales, which was motivated by a forceful revision of its sugar policy and by sharp drops in sugar production in that country and in Thailand. Furthermore, both countries have ample possibilities of producing and using fuel alcohol, with the resultant decrease in sugar sales.

These reductions of the sugar sales on the part of some of our main competitors occur when the Asian market is becoming increasingly dependent on foreign countries for the most part on account of increased per capita consumption and the urbanization phenomenon, particularly in China. According to specialists this additional demand on the world supply could cause an increase of up to 10-million tons in additional sugar exports in the next 6-8 years.

Thus, it is estimated that Brazil will be exporting 25-million tons p.a. in eight years, which added to a domestic consumption of approximately 11.5-million tons, total 36.5-million tons of sugar. These numbers are very important because of the interrelation between alcohol and sugar; they also ascribe additional competitiveness to fuel ethanol.

Although international alcohol sales are still small, they are growing rapidly. The strategic nature of the product, however, should bring about some degree of protectionism, which would make access to Brazilian alcohol sales more difficult and delay purchases from important countries or groups of countries, such as the United States and the European Union, which will turn to domestic production before importing[20].

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[19] In the European Union, the possibility of producing alcohol from beets, the need to change its sugar policy to comply with the OMS decision, and internal budget pressures concur to reduce estimated total sugar production in the future. Even if this picture were modified due to the incorporation of Eastern Europe countries into EU-25, the expected reduction would still be maintained for the whole Europe.

[2`0] Although the USA is the second largest alcohol producer in the world, its alcohol production is equivalent to only 3% of its gasoline consumption. Even so the expensive production of ethanol from corn is sufficiently protected to prevent imports from Brazil, although the Brazilian product is much more competitive. Something similar will probably occur in the European Union, as they cannot increase their agricultural production. The EU will have to make changes in some traditional production chains, such as those of beets and wheat, in order to meet their commitments under the Kyoto Protocol.

Petrobras' contracts with Venezuelan and Nigerian oil companies, along with the expectations about the Japanese market and the investments being reprocessed in the Caribbean with a view to the American market[21], could represent an increase in alcohol exports of 4 to 5-billion liters.

It can be properly inferred, therefore, that external demand will probably press for an increment of more than 120-million tons of sugarcane, most of which for sugar production.

If these expectations are confirmed, the additional demand would total almost 220-million tons of sugarcane in the next eight years, or more than 50% of the current annual production, to be met by enlarging some units and setting up at least 60 new medium-size plants.

There were 320 sugar & alcohol mills in Brazil in 2005, with a total installed processing capacity in excess of 430-million tons of sugarcane. Together they could produce up to 20-million tons of sugar and 18-billion liters of alcohol. The 390-million tons of sugarcane to be processed this year will yield 27.5-million tons of sugar and 16.7-billion liters of alcohol.

In addition, close to 3 GWh will be generated during the average yearly operation period of 4,000 hours, almost 90% of which for the mills' own consumption.

Electric power cogeneration from sugarcane bagasse, straw and styles is only one of the new development possibilities open to the sugar & alcohol industry. Like gasification, which substantially raises the efficiency of bagasse burning, studies are underway to produce alcohol, and even biodiesel, through the lignocellulose hydrolysis of bagasse. In the opinion of some experts, the market remuneration for liquid fuels can grow sufficiently to encourage some sugar mills to produce either alcohol or biodiesel from bagasse using natural gas as energy source.

Challenges to the Brazilian sugar & alcohol industry

Renewable energy should become really big business in the 21st century, with biomass playing a special role in this context, particularly sugarcane biomass. The revitalization of the domestic fuel alcohol market coincides with an increase

[21] This strategy takes advantage of the American market quotas for the countries in that region under the protection of the Caribbean Basin Initiative (CBI).

in Brazil's share of the international sugar market, while the world moves towards using ethanol as fuel oxygenant, as we do.

It is estimated that a sugarcane supply of 220-million tons would require increasing the sugarcane-farmed area by almost 3-million hectares in the next 6 to 8 years.

The goal of planting three million hectares could be substantially reduced by means of continuous, substantial productivity gains and by increasing sucrose contents. Either way sugarcane plantations occupy only 10% of the total planted area and much farmable land is still available in the country, particularly in the Cerrado[22].

Brazil faces other more worrisome internal and external challenges that involve government policies and the large public and private investments required to meet the growing domestic and foreign demands. Despite the pioneering spirit and technical qualifications of our industry, as well as the lower costs and considerable potential to increase production, such challenges require concerted planning and action by both government and private sector.

The first and perhaps greatest challenge relates to the size of the world fuel-alcohol market. Half of Brazil's sugarcane production suffices to replace 40% of the gasoline consumed in the country, while world ethanol production and demand are still insignificant, although quickly growing.

It is absolutely essential to seek partnerships, particularly with other sugarcane producer countries. They could follow in the steps of the Brazilian agro-industry, invest in improving the use of their raw material by diversifying production and improving sugarcane quality, which would give them access to two different markets: the food market and the energy market. Alcohol production can be an alternative for countries benefiting from special USA and EU quota regimes, such as the Caribbean and Pacific countries (ACP). In turn, this would bring Brazil closer to them and dispel any dissatisfaction caused by the WTO panel brought by Brazil, Australia and Thailand against the European sugar regime from which they benefit.

In addition, alcohol production in the ACP countries would mean more demand for Brazilian services and industrial equipment, as well as new investment opportunities abroad focusing on new markets.

Contacts with countries that have a large demand, particularly the United States, for the purpose of working together to define international technical

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[22] The pasture area with some degree of degradation is estimated at 50-million hectares, most of it in the Cerrado.

specifications for fuel alcohol are equally important. The objective is to prevent national incentive programs for the domestic industry from imposing non-tariff barriers to restrict their imports and hinder our sales abroad.

Another consideration in our external agenda is to work diligently to increase business liquidity and fluidity in the biofuel market, which would require some adaptation of the legislation and much networking with and among the private production sector and the trade sector in Brazil and abroad.

Internally, an important challenge is developing a master plan for the expansion of the sugar & alcohol industry. This plan should begin with the agro-climatic zoning of sugarcane, which will serve both to plan and restrict the settlement of new areas and to manage public policies focusing on traditional sugarcane areas.

Other domestic challenges to the sugar & alcohol industry include the spatial concentration of production and the lack of interest in achieving greater energy efficiency on the part of producing units.

As regards spatial concentration, the State of São Paulo not only already has approximately half its farmable lands dedicated to sugarcane, but also holds the sugarcane expansion record in the country. Twenty-five of the 40 projects currently being established are located in São Paulo, particularly in traditional cattle raising areas in the western part of the state. Likewise in the State of Minas Gerais, which has the highest sugarcane growth rates and where new projects are being set up in the Triângulo Mineiro, practically as an extension of the standards that prevail in the São Paulo production. Although it seems irreversible in Minas Gerais, this concentration should be avoided in other new areas because, along with verticalization, it tends to create serious socio-economic and environmental problems, as well as to increase the sugarcane plantations' vulnerability to pests.

The alternative to concentration is directly related to another challenge: the need for investments in transportation infrastructure in the country's hinterlands. Despite its expressive growth, the sugar & alcohol production is still incipient in the Center-West Region considering the prevalent regional topography, climatic regularity, land cost and availability, and the example of the soybean performance at present. In addition to the Center-West Region, the so-called Mid-North (which includes the State of Tocantins, eastern Pará, and eastern and southern Maranhão and Piauí), where the conditions are similar to those prevailing in the Center-West's Cerrado, could also become a new production belt. This, however, would depend on investments in infrastructure, which would be vital to transport the sugar and alcohol productions to the ports of São Luís, MA and Fortaleza, CE.

Another important challenge is the industry's capacity to meet the growth needs of the sugar & alcohol sector. Considering the demand growth estimates it would be necessary to set up at least 15 new processing units every year for the next five years, and another ten units per year during the three following years.

On the basis of a standard profile of two million tons/year for each plant, these 100 new undertakings and the remodeling of other projects would be sufficient to meet the predicted growth of the domestic and foreign sugar and alcohol markets. Nevertheless, it is necessary to consider both the internal and external demand for equipment and services from the sugar & alcohol sector, whose expansion needs have been fulfilled by our base industry. Brazilian suppliers are now responsible for the equipment of practically 80% of the installed sugarcane alcohol capacity in the world. They operate to capacity and have difficulties in accepting new orders, particularly for delivery periods of less than three years. The insufficient capacity of our base industry could become an obstacle to the consolidation of the international fuel alcohol market.

The very favorable scenario for sugar and alcohol has led sector businessmen to invest more in the expansion of the processing capacity than in achieving increased energy efficiency, not only in the units already installed but also in those being built. The greater profitability of the traditional products, together with the heavy costs of investing in more efficient technology for the cogeneration of electric power, has put cogeneration in the back burner.

If the processing goal were met – 610-million tons of sugarcane by the 2012/2013 harvest, in addition to supplying 36.5-million tons of sugar and 27.4-billion liters of alcohol – more than 160-million tons of bagasse would be available. If all the bagasse were burned in high-pressure boilers, the equivalent of 66 GW of electric power, i.e., 16.5 GW/h could be generated during the average yearly 4,000-hour harvest period by using the sugarcane straw and styles, which are usually burned in the field.

Two factors help explain the lack of interest in electric power cogeneration investments. Firstly, the scarce experience in this new business, which can even hinder client relations. A second and equally important factor is associated with the higher costs of the more efficient technologies. These costs have led investors to choose intermediary technologies, with boilers of 40-60kg of steam, which usually bring higher rates of return in the short term and require less capital investments. Since this type of equipment has a relatively long working life, the units could work for decades while underusing the bagasse potential. Also to be considered are the uncertainties of the wholesale energy market and the lack of experience of sugar mill operators with that type of negotiation.

Biodiesel

The use of oleaginous plants for energy purposes was first proposed in Brazil in 1975. The proposal resulted in the Plan for the Production of Vegetable Oils for Energy Purposes (Pró-Óleo). Its objective was to generate vegetable oil surpluses in order to make its production costs competitive vis-à-vis petroleum's. The Plan contemplated mixing 30% of vegetable oil to diesel oil, with the possibility of completely replacing diesel with vegetable oil.

The greatest challenge at present is to meet the goals established in the National Program for Biodiesel Production and Use, as set forth in Law n° 11.097 of 13 January 2005, which introduces biodiesel into the Brazilian Energy Matrix and determines that the diesel oil sold to final consumers throughout the national territory must be at least 2% (B2) biodiesel by 2008[23] and 5% (B5) by 2013.

The current national biodiesel production structure is still incipient and mainly based on experience with pilot plants, which means rather small final volumes. The ANP calculates that Brazil produced approximately 736,100 liters of biodiesel from March to December 2005. Nevertheless, the first auction for the delivery of 70-million liters beginning in January 2006 altered the development pattern of the market. Table 10 shows the estimated national biodiesel production for 2006 and 2007.

It will be necessary to produce approximately 800-million liters of biodiesel in 2008, during the initial phase of the program, in order to meet the legal requirements.

The National Petroleum, Natural Gas and Biofuels Agency (ANP) is currently analyzing several authorization requests and after the operation of

Table 10. Brazilian biodiesel production.

Type of undertaking	Production capacity estimated	
	2006	2007
Units installed and operational (5)	48.10	48.10
Units installed not yet authorized (14)	125.60	125.60
Extension of installed units (5)	146.80	146.80
Projects in the design stage (16)	380.00	811.00
Total (million liters)	700.50	1,131.50

Source: ANP and MME.

[23] The deadline for adding 2% biodiesel to diesel oil from petroleum and the compulsory purchase of biodiesel with a social stamp have in fact been brought forward to January 2006.

those biodiesel plants has been approved the country's production capacity will be sufficient to meet the 2008 goals, but would have to be significantly increased in order to meet the legal requirement of adding 5% biodiesel to petrodiesel by 2013.

Production and technology

Biodiesel research has made considerable progress in the last 20 years. In addition to testing different types of motors several pilot plants were built in various cities. After a purely experimental phase biodiesel is finally being sold. The technological processes developed enable the production of biodiesel from new and residual vegetable oils, animal fats and fatty acids obtained during the vegetable oil refining process.

Esterification is the name of the chemical reaction through which esters (biodiesel) are obtained from alcohols and free fatty acids or their byproducts. Transesterification consists of a chemical reaction of triglycerides (vegetable oils or animal fats in which the fatty acids form esters with glycerol) with alcohols (methanol or ethanol) in the presence of a catalyst (acid, base or enzyme) that results in the substitution of the ester group in the glycerol with an ethanol or methanol group (Figure 11). The glycerin obtained after purification is a valuable byproduct of the reaction and its sale increases the total economic yield of the process. An alternative to transesterification is catalytic or thermal cracking, whereby the molecules are broken down at very high temperatures to form a mixture of chemicals whose properties are very similar to those of petrodiesel.

A tropical country of continental dimension, Brazil can produce vegetable oils from a variety of raw materials. Consequently, it can also structure its biodiesel production and use program in several ways. The challenge is to take advantage of the potential of the different regions of the country and derive the greatest possible social benefit from biodiesel production by applying advanced technology not only to traditional crops, such as soybean, peanuts, sunflower, castor beans, and African palm fruits, but also to new cultures, such as physic nut (*Jatropha curcas*), radish (*Raphanus sativus* L. var. oleiferus Metzg), pequi or Souari nut (*Caryocar brasiliense*), buriti or aguaje palm (*Mauritia flexuosa* L.), macaúba or grugru palm (*Acronomia aculeate*) and a large variety of oleaginous plants still to be explored.

Although some native plants have shown good results in the laboratory their production is purely extractivist, and there are no commercial plantations

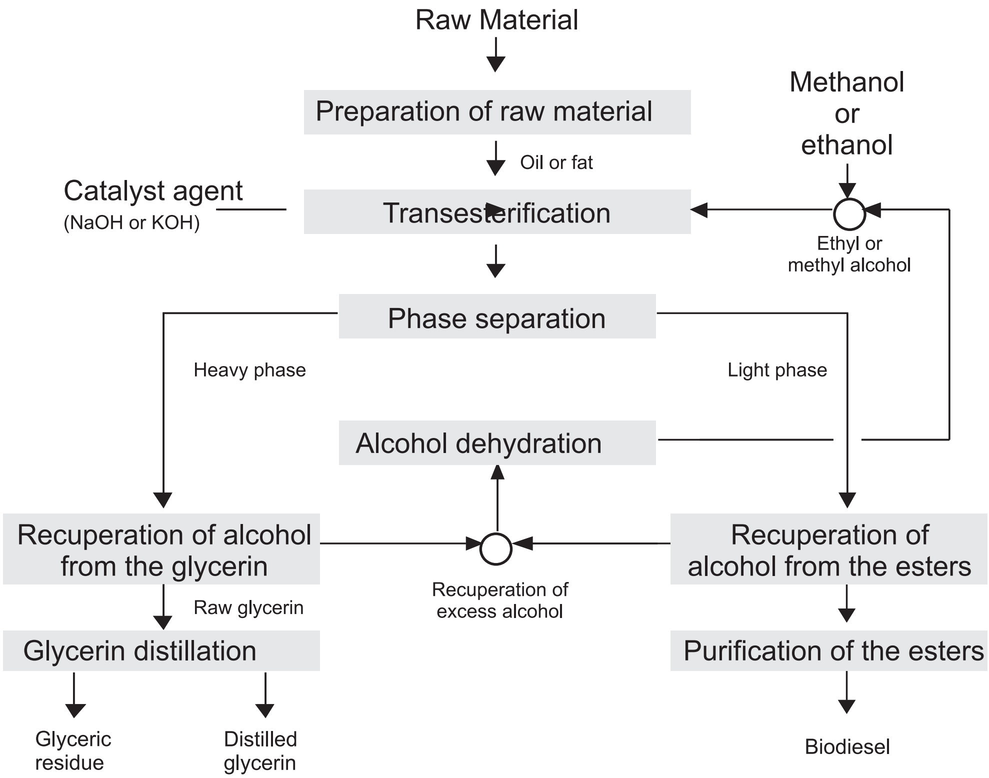

Figure 11. Biodiesel production by transesterification.

that would enable a precise determination of their potential. This will take some time since agricultural research in Brazil, which focuses primarily on the botanical and agronomic cycles, has not yet made much progress.

Among the crops available for biodiesel production (Table 11) special mention should be made of soybean, whose oil accounts for 90% of the Brazilian vegetable oil production; African palm, coconut and sunflower, because of their productivity; and castor plants, because of their resistance to draught.

The alcohol source for the transesterification process can be methanol (well known and widely used in industry in several countries) or ethanol. In strategic terms, the more advantageous choice for Brazil would be ethanol, which the country produces in large amounts and at a very competitive cost. Methanol, on the other hand, is toxic and has to be imported or produced from natural gas (fossil carbon).

Table 11. Characteristics of oleaginous crops in Brazil.

Species	Oil origin	Oil contents (%)	Harvest (months/year)	Yield (tons of oil/hectare
African palm	Nut	22.0	12	3.0 – 6.0
Coconut	Fruit	55.0 – 60.0	12	1.3 – 1.9
Babassu	Nut	66.0	12	0.1 – 0.3
Sunflower	Grain	38.0 – 48.0	3	0.5 – 1.9
Colza/canola	Grain	40.0 – 48.0	3	0.5 – 0.9
Castor beans	Grain	45.0 – 50.0	3	0.5 – 0.9
Peanut	Grain	40.0 – 43.0	3	0.6 – 0.8
Soybean	Grain	18.0	3	0.2 – 0.4
Cotton	Grain	15.0	3	0.1 – 0.2

Source: NOGEUIRA, L. A. H. et al. Agência Nacional de Energia Elétrica. Adapted by DPA/Mapa.

Studies carried out by four ministries – Agrarian Development; Agriculture, Livestock and Supply; National Integration; and Cities - show that for each 1% share of the biodiesel market derived from family agriculture it would be possible to generate approximately 45,000 jobs in the hinterlands, at an approximate cost of R$ 4.900,00 each (HOLANDA, 2004). Approximately 180,000 new jobs would be created assuming that each job in the rural areas generates three jobs in the urban areas. Finally, it should also be emphasized that industrial agriculture employs, on average, one worker for every 100 hectares farmed. In family agriculture each worker farms 10 hectares.

Almost 220-million reais (R$) per year are necessary for every 1% share in the biodiesel market, with yearly gross revenues of approximately R$ 470 millions. Every real invested in family agriculture yields R$ 2,13 more in the annual gross income. So that the family income would double if family agriculture participated in the biodiesel market.

As regards the paths used to produce biodiesel in the Northeast Region and in the State of Minas Gerais, the products of choice would be methyl alcohol and castor oil. In the Center-South, the preferred product would be ethyl alcohol, mainly because its ready availability.

In Brazil most of the biodiesel will be produced by transesterification (80%) for a large wholesale market addressing the mixture of biodiesel into petrodiesel, large fleet consumption and consumers interested in increasing the proportion of biodiesel mixed to petrodiesel. The remainder would be obtained by cracking in small remote communities.

Large investments in RD&I would be necessary over a long period of time in order to produce the most adequate raw material for each region and a sufficient amount of each raw material to supply the biodiesel industry in an economically viable manner. Research should focus on increasing the energy density of the oleaginous species, going from the current oil yield[24] of 600 kg/ha to approximately 5,000 kg/ha. Initially this could be achieved by improving production with a view to increasing the physical productivity of the raw material.

At the same time, medium- and long-term research should try to increase the contents of the energy components (cellulose, sugar, starch, oils, etc.) of the oleaginous plant currently being used and incorporate new plants, particularly tropical plants, with high oil producing capacity per unit area.

Biotechnology and traditional plant breeding should play a relevant role in achieving those objectives either through research in new varieties and development of genetically modified organisms, or by adapting the energy crops to the various agro-ecological conditions.

Lastly, the expansion of biofuels in the country will also depend on technological innovations, improvement of industrial processes and increasing the efficiency of the energy sources.

Regional prospects

North Region

The North Region holds the largest part of the national territory covered by native forests – the Amazonian biome – in addition to Cerrado areas in the states of Tocantins, Rondônia, Pará, and Roraima. The Amazon forest harbors a great variety of native species, including palms, which could contribute to reducing our dependency on petrodiesel. To that end local communities should be organized around simple extractivist activities or agro-forestry exploitation. There are more than 5-million hectares already deforested and appropriate for cultivating African palm.

Pará is the largest African palm oil producer in the country: close to 100,000 tons p.a. from a 50,000-ha cultivated area, a good part of which has not yet reached maturity. African palms start producing fruits four years after planting, attain maturity on the 7th year, and maintain high productivity levels

[24] An energy-density increase would help reduce the pressure due to the incorporation of new areas and the inducements to destroy the environment, as well as the unplanned settlement of the agricultural frontier.

until the 17th year, in a productive life of approximately 25 years. Productivity is still on the rise in those plantations and the agronomic potential is up to 40 tons of fruit clusters per hectare with a 22% oil yield.

The region depends heavily on diesel oil for stationary power generators and river craft. The sole company registered to produce biodiesel is called Agropalma, a large palm oil producer that has installed an esterification unit and uses fatty acids obtained in the oil refining process. The unit's production capacity is 8,100 tons of biodiesel per year, with ethanol as reagent. Another plant will be built in the State of Tocantins with a production capacity of 40-million liters/year.

The region's current consumption is more than 3-million tons of diesel p.a. and, since the current installed capacity meets slightly more than 10% of the biodiesel volume currently required, it is very unlikely that the region will achieve self-sufficiency by 2008. Another challenge is decentralizing biodiesel production using the cracking process to supply remote communities directly; these communities would produce the raw material and transform it into biodiesel.

The long-term prospects of using African palm oil as raw material to meet the regional and even national demand for biodiesel are very good. Nevertheless, there are technological problems to be solved as regards the use of palm oils as raw material. Furthermore, the agronomic cycle of palms is rather long and both the economic results and the research need more time to achieve maturity.

Northeast Region

The Northeast Region accounts for 15% of the diesel oil consumed in Brazil. The first biodiesel plants installed in the country are located in the Northeast Region, namely, Nutec in Fortaleza and Brasil Biodiesel in Teresina, both experimental units with daily biodiesel production capacity of 800 and 2,000 liters, respectively. Brasil Biodiesel has another commercial plant in Floriano, in the State of Piauí.

Because of the social slant given to the National Program for the Production and Use of Biodiesel from the very beginning, the Program's main focus in the Northeast Region has been on biodiesel from castor beans. The crop is fully adaptable to semi-arid areas and is an excellent alternative for family farming. Because of its social importance and agronomic adaptability it has been appointed as the crop of choice for the initial phase of the program.

Biodiesel should be an important instrument of income generation in the hinterlands. In the semi-arid zones, for example, the annual net family income from five hectares of castor plants, with an average production between 700 and 1,200 kg per hectare, can vary from R$ 2,500 to R$ 3,500. And beans and corn can be intercropped with the castor plants. In the 2004/2005 harvest, almost 33,000 family farmers planted 84,000 hectares of oleaginous plants for the production of biodiesel. When broken down by region 29,000 family farmers cultivated oleaginous plants over 59,000 hectares in the Northeast Region that year.

The processing capacity of the Brasil Biodiesel plant will be 90,000 liters per day. It is a very daring project because no raw material is produced in its vicinity. The company built a model settlement in the Canto do Buriti municipality, which is located approximately 225 km from its industrial unit. The idea is to harvest up to 14,000 tons of castor beans per year, the equivalent of 25% of the industrial unit's demand. The remainder would be purchased from family farmers in the region.

The international price of castor oil oscillates around US$ 1,000.00/ton, because of the many uses of castor oil in the chemical industry. To make castor-oil price compatible with biodiesel production it would be necessary to achieve substantial increases in the crop's productivity and yield in order to reduce the price to the same level of the other oils'.

In 2005 Petrobras began setting up a plant in the Municipality of Guamaré, in the State of Rio Grande do Norte, with technology developed at the Petrobras research center. The first commercial-scale experience in biodiesel production from castor oil using ethanol as reagent will take place in Petrobras' Guamaré plant, whose daily processing capacity is estimated at 2,000 liters. The plant's output should cover the '2%' biodiesel needed to mix with petrodiesel in that state and in several municipalities in neighboring states, all of which are served by the same Petrobras distribution base.

In addition to the biodiesel processing plants already installed several expansion and construction projects are underway, which together will increase the production capacity of the region to approximately 248.3-million liters by the end of 2007 according to the Ministry of Mines and Energy's estimates. The production will amply meet the regional B2 demand.

Castor has become an important alternative in the central region of the State of Bahia, where more than 150,000 hectares are being farmed. Production will exceed 100,000 tons of castor beans, or more than 90% of the national production. The plantations using the technology recommended by Embrapa produce up to 3 tons per hectare.

Using agricultural zoning Embrapa has already mapped more than 600,000 hectares of farmable lands suitable for castor bean cultivation, which could be an alternative crop for more than 100,000 rural families. Following the recommended management practices can be as important as the agronomic suitability of the land. This is particularly true when polycropping is used to reduce risks, diversify the opportunities and obtain the maximum number of food sources from a single area.

Despite reports of a large expansion of castor plantations – estimated at 600,000 hectares by 2007 – the research on new castor bean varieties and crop management technologies is still incipient, particularly the research on harvesters[25]. Although castor oil could be a vector for social inclusion in the semi-arid zones, farmers should be prepared to face competition from new areas with capital-intensive production.

The State of Maranhão is located in the transition region between the semi-arid, the Cerrado and Amazonia. The state has great potential for perennial crops, particularly babassu, which is native to the region and is believed to cover more than 18-million hectares. Although babassu oil is excellent there are some restrictions, among which the extraction costs: not only the oil represents barely 4% to 5% of the fruit (whose protective shell is very hard to crack open), but babassu coconuts are gathered in the traditional way, that is, with very little formal organization.

Center-South

Soybean can supply the oil necessary to mix 5% biodiesel in fossil diesel. There are still some economic restrictions to this crop, however, because of the relative cost of the raw material for manufacturing biodiesel. The producers are concerned with the competitiveness of biodiesel from soybean oil since fiscal benefits would be rather small or even nonexistent in the Center-South. Consequently, some companies[26] are still hesitant or even afraid to think about producing biodiesel for the domestic market. It should be emphasized, however, that the government has reconsidered the tax issue with a view to granting incentives to any biodiesel, regardless of region, type of company and raw material used. Special treatment would only be accorded to family agriculture the North and Northeast regions and the Semi-Arid.

[25] As a rule, farmers still use corn harvesters with some adaptations.

[26] For example, Ecomat in the State of Mato Grosso is a pioneer in the production of esters from soybean oil for the purpose of mixing the alcohol to diesel. The company's installed capacity is 26,666 liters/day.

The biodiesel production capacity in the Center-South is estimated at 835.2-million liters p.a. by the end of 2007. At the present time there is only one plant in operation in the region, in the State of Minas Gerais, with capacity to produce 12-million liters per year. Nevertheless, the biodiesel production should grow rapidly to approximately 125-million liters p.a., since another 13 units have already been built, albeit not yet commissioned. There are also several other new plants or plant expansion projects underway, whose production will total 698.2-million liters by the end of 2007 according to the Ministry of Mines and Energy.

The region has very good potential to produce biodiesel from other crops, such as peanuts, sunflower and castor beans. The experiments with castor plants in the State of Mato Grosso and the research on the crop at the Instituto Agronômico de Campinas have had very satisfactory outcomes, especially with the so-called dwarf varieties, which not only are very productive in the field (up to 4 tons of castor beans per hectare), but also enable the use of mechanical harvesters.

In the Center-South as a whole and particularly in the states located in the Center-West Region, large extensions of farmable land with appropriate topography and optimum climatic regularity are still available. This means that if biodiesel becomes the new business opportunity in Brazilian agriculture, the Center-South, which already accounts for almost 80% of the national fuel consumption, would have perfect conditions to expand its production base very rapidly, as in the case of fuel alcohol.

Competitiveness of soybean for biodiesel

A comparative study of petroleum and soybean oil prices shows that the average price of refined soybean oil has been US$ 69.00/barrel during the last 15 years (Figure 12), which includes refining, domestic freights and other commercialization costs.

A US$ 10.00 discount is considered reasonable to account for the various elements that make up the price of eatable soybean oil, as opposed to soybean oil for energy purposes, in addition to the cost of obtaining biodiesel. Thus, biodiesel becomes competitive when the cost of petroleum is US$ 60.00 per barrel, given the current conditions of technological development, managerial capacity, production scale, market size, industrial plants, capital costs, taxes, and fixed costs, among others. A consideration of the ethanol learning curve for the last 30 years leads us to conclude that this cost could be substantially reduced in the medium term.

A useful reference is an Abiove study that points to an internalized value for soybean biodiesel (before taxes) of US$ 1.00/liter as compared to US$ 0.97 for petrodiesel. The competitive break-even price for soybean biodiesel is attained when the international market quote for soybean oil is less than US$ 480.00/ton, as in the 2005 harvest, or R$ 1.20/liter at the rate of exchange on 21 July 2005.

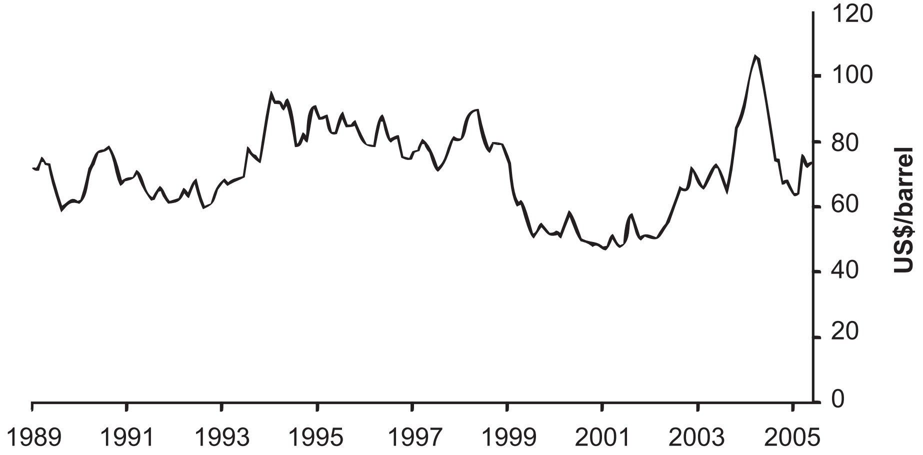

Figure. 12. Market quotes for soybean oil.
Source: Abiove.

Cultivated energy forests

Energy can be directly obtained from wood, charcoal or black liquor[27].

Approximately 5% of the world energy demand is met through direct wood burning (Table 12). It is estimated that black liquor produced approximately 75 Mtep of energy in 1999, which would increase the share of wood in the world energy supply to 550 Mtep, lower than nuclear energy's share (650 Mtep), but higher than that of hydroelectric power and other biomass energy sources.

Although regional variations make for rather unreliable data, the world's yearly per capita wood consumption is estimated at .3 to .4 m^3 of wood, or .1 tep.

[27] Black liquor is a mixture of chemicals and dissolved wood remnants after sulfate pulp cooking. Black liquor is recovered during the wood pulp washing process in paper manufacturing, then concentrated by evaporation and burned to regenerate the cooking chemicals and generate energy.

Table 12. Energy produced exclusively from wood in 1999.

Region	Mtep	%
Africa	141.1	29.9
Asia	38.5	8.1
Europe	37.7	8.0
Middle East	216.1	45.8
North America	34.9	7.4
Oceania	0.2	0.0
South America	3.8	0.8
World[(1)]	472.3	100.0

[(1)] Does not include black liquor.
Source: IEA Statistics.

The largest biomass energy consumer is the rural sector. The rural per capital consumption is estimated at 1 t/year (15GJ), while consumption falls by 50% in urban areas.

The variations in energy consumption from plain firewood and its residues are strongly associated with the degree of development of the country. Firewood is commonly used in the rural areas of developing countries and accounts for almost all the energy used in the homes. Practically all consumption usually takes place where the firewood is produced.

Charcoal consumption, on the other hand, is more common in urban and peri-urban areas. Close to 6 m^3 of wood are required for the production of one ton of charcoal. Thus, the price of charcoal includes the costs of the raw material, transportation, processing, and stocking.

The production of energy from wood has fallen consistently in Brazil in the last few years. It is estimated that wood extraction decreased by 35% in the 1990s: from 106-million tons to 69.5-million tons/year. The main reason for the reduction was diminishing charcoal consumption in the homes (47%), industry (39%), agriculture (13%), and commerce (1%).

In 1999, while 25-million tons of wood were transformed into charcoal, only .5-million tons of wood were used to generate electric power. In Brazil the main industrial consumers are the food and drink sector and ceramics and paper manufacturers.

Eucalyptus plantations for charcoal production are estimated at 3-million hectares. If the forest biomass market improves, there will be a wood deficit in the next ten years due to the long maturity period required by reforestation projects.

Production and productivity indicators

World wood consumption increased to 3.3-billion m^3/year in the mid 1990s. The area of the world covered with forests was 3.41-billion hectares in 1995, or 27% of the Earth surface, excluding Greenland and Alaska. At the time Brazil accounted for 16% of forests. The area doubled from 40.2-million to 81.2-million hectares during the 1980-1995 period, from 40.2-million to 81.2-million hectares.

Industrial consumption of firewood for energy purposes is concentrated in the agro-industries located in rural areas, where firewood is used mainly in drying grain, tea or tobacco; producing bricks; and the ceramics industry. These uses account for 10%-20% of the wood energy obtained in Asia and 9.5%, in Africa. Charcoal is used in larger industries. The Brazilian annual charcoal consumption is estimated at 6-million tons, especially in the steel and other metal alloy industries.

Charcoal and other types of wood energy are used so widely because of the low cost and availability of wood, particularly in rural areas. As a rule it is an extractive process in which production and processing costs are negligible. Preference is explained by charcoal's ease of transportation and combustion.

According to FAO, Brazil's forests cover 5.3-million km^2 or two-thirds of the total area of the country and are the second largest in the world, after the Russian Federation's.

Brazil consumes 300-million m^3/year of wood, of which 100-million m^3/year come from forests planted for industrial purposes. Industrial consumption in 2001 was estimated at 166-million m^3/year, including 32-million m^3 for paper and cellulose; 45-million m^3 for charcoal; 29-million m^3 for industrial firewood; and 60-million m^3 for solid products (saw logs, boards, plywood, panels, etc.).

The role played by planted forests has grown substantially in Brazil in the last few years. In the paper and cellulose industry 100% of the wood used comes from reforestation projects. In the charcoal industry the share of planted forests grew from 34% to 44% and in solid product industry, from 28% to 44% from 1999 to 2000. The area covered with planted forest is estimated that 6.4-million hectares in Brazil, of which 4.8-million hectares are planted with eucalyptus and pinus and almost 2.6-million hectares more with interspersed native forests.

The average eucalyptus yield was 36 m^3/ha/year in São Paulo in 2000. When three 6-year cycles were considered, productivity increased to 44.8 m^3/ha/year. Estimates indicate 50-60 m^3/ha/year averages in the near future.

Current forest energy costs in São Paulo are US$ 1.16/GJ (44.8 m^3/ha/year, for an average transportation distance of 21.4 km), future costs being estimated at US$ 1.03 (56 m^3/ha/year, for the same distance). These numbers provide an idea of Brazil's comparative advantages, since our rural-area parameters for 2000 are equivalent to projections for the Northern Hemisphere in 2020.

The excellent performance of the Brazilian paper and cellulose sector suggests that the country enjoys exceptionally advantageous conditions to explore the energy from forests also. In 2000 the energetic use was 21.4 Mtep of firewood (approximately 140-million m^3), distributed as follows: charcoal, 36%; electric power, 0.5%; domestic consumption, 31%; industry, 25%; and agriculture, 7.5%.

Brazil' comparative advantages in the use of wood for energy purposes lie on the size of its territory, adequate climatic conditions, plentiful manpower, and experience in the energy area. It should be realized that investments in technological development must be made in order to meet the environmental, economic, business, and logistics requirements. It is estimated that 3.2-billion m^3 of wood were produced throughout the world in 1998, more than 50% of which were used to obtain energy. Gradually, wood extraction activities have forsaken native forests and are moving towards reforested areas, like in some Asian countries that earned fame as forest fellers. There are large reforestation areas throughout the world, in China for example, where reforestation projects for energy purposes have been encouraged and total 13.5-million hectares, with exploitation scheduled for 2010.

Charcoal

Nine percent of Brazilian charcoal was used in the homes (to cook) in 2000 and 86%, in industry, most of which to produce pig iron. Out of 21.2 Mtep (~ 69.5 Mt) of firewood used for energy purposes, 7.8 Mtep were intended for charcoal production. The coke and coal import reduction policies encouraged increases in charcoal production in the 1980s, reaching an all-time high in 1989 (40% for pig iron production). Facilities for importing coke and a rigorous environmental policy limiting the use of native forests for charcoal production led to a reduction in the share of charcoal as energy source in pig iron production to 25% in 1998.

More recent trends indicate that charcoal production from native forests (80% in the 1980s) dropped rapidly to the 10% legal limit: it reached 13% of the charcoal for the steel industry in 1997 and 28% of all charcoal in 2002. Technology began to evolve from the traditional kilns to rectangular furnaces, and more efficient processes are gradually being adopted. The use of planted forests also reduces transportation costs.

The interest of steel mills in charcoal was renewed due to the prospects of using the CDM to reward "green steel". Cleaner and more efficient technologies are being sought, including the use of byproducts (from tar to effluent gases). It is estimated that the current pig iron production (27-million tons) would require 17.5-million tons of charcoal, with a planted area of approximately 3.3-million hectares.

Agricultural and forestry residues

The development of technologies to treat and use residues with a view to reducing production costs and environmental pollution is the greatest challenges of our time.

This challenge is very important in regions that concentrate animal production activities, particularly swine and poultry farms. On the one hand, producers are under pressure to increase productivity and the number of animals in small production areas. On the other, there are increasing pressures to ensure that said increase does not destroy the environment. Limited space and the need to meet increasing demands for energy, good quality water and food have presented some challenges to producers, most of which are related to the environmental issue and the availability of energy (OLIVEIRA, 2003; SANTOS, 2001).

The energy potential of residues is hard to estimate because of statistical unreliability and regional variations. Nevertheless, Woods and Hall (1994) point to values close to 93 EJ/year. That number is similar to Smil's (1999), who concluded that there are from 3.5 to 4-billion tons of agricultural residues, with an energy potential of 65 EJ, or 1.5 Gtep. Considering only the main crops (wheat, rice, corn, barley, and sugarcane), Hall et al. (1993) estimated that it is possible to recover 25% of the residues in the form of energy, generating 38 EJ and thus avoiding the emission of 350-460 Mt of CO_2 per year.

The use of residues for energy purposes will compete in the future with the preparation of animal bedding for livestock farms, organic fertilizers, erosion control, animal nutrition, etc. It would also be necessary to reinforce the concept of residue from the viewpoint of the sustainability of its exploitation, i.e., not removing from the site where the biomass is produced an excessive amount of organic matter to the point of depleting soil nutrients and interfering with future exploitation of the site.

The current, inappropriate use of residues causes environmental and public health problems. For example, Andreae (1991) estimated that 2 Gt of agricultural residues are burned unused every year. Smil (1999) estimates that 1-1.4 Gt of residues are burned, generating 1.1-1.7 Gt of CO_2/year. The authors state that the estimated energy potential of agricultural residues, if used to generate electric power, could produce 4.5 GW.

Animal wastes and biogas

Energy is one of the most important components of the final production cost in both swine and poultry farms, where small costs and price variations can drastically reduce competitiveness. The recent energy crisis and the rise of petroleum prices have made it mandatory to seek alternative sources of energy in the rural areas.

Woods and Hall (1994) estimate the potential of animal production residues at 20 EJ/year anywhere in the world. Nevertheless, this number should not be considered immutable because of the huge methodological variations in the calculation of the usable wastes, which vary depending on the animal species, feed, bedding, management, etc. As in the case of plant residues, there are limitations to the use of animal residues for energy purposes, such as:

- Great potential as fertilizer.
- Low energy density source, viable only in large scale projects and when other more competitive choices are not available.
- Need for bioprocessing, usually in biodigesters, which creates problems associated with logistics, discharges, gas compression and storage, and use of the final fertilizer.
- Possible impact on the environment and human health resulting from handling animal wastes (ROSILLO-CALLE, 2001).

According to Sánchez et al. (2005), the treatment of wastes by anaerobic digestion has several advantages, such as a) the capacity to destroy pathogenic organisms and parasites; b) use of methane as a source of energy; c) production of a reduced volume of wastes at a lower cost due to low biomass production; and d) capacity to stabilize large volumes of diluted organic wastes at a low cost.

The anaerobic digestion process (biomethanization) consists in metabolizing a complex of organic matter by a mixed culture of microorganisms to produce methane (CH_4) and carbon dioxide (CO_2) and cell material (LUCAS JUNIOR, 1994; SANTOS, 2001). The organic matter includes carbohydrates, lipids and proteins. Anaerobic digestion in biodigesters is the most viable process for the conversion of swine and poultry residues into thermal or electric power.

The main use of rural biodigesters in Brazil has been in rural sanitation, its byproducts being biogas and biofertilizers.

Biogas is a gaseous fuel with a high energy content, similar to natural gas, and constituted mainly of short- and linear-chain hydrocarbons. It can be used to generate electric, thermal or mechanical energy in the farms, thus helping to reduce production costs.

The biomethanization process involves the anaerobic conversion of biomass into methane. The biological decomposition of organic matter can be divided into four phases: hydrolysis, acidogenesis, acetogenesis, and methanogenesis. This conversion of an organic complex requires a mixture of bacterium species and can take place through a sequence of the aforementioned reactions.

There are three types of treatment of organic residues depending on the temperature used in the process. Biomethanization, wherein the temperature varies from 45ºC to 60ºC, is considered a thermophilic process. Treatments at temperatures varying from 20ºC to 45ºC are mesophilic. The anaerobic digestion of organic matter at low temperatures (> 20ºC) is psychrophilic.

Anaerobic conversion produces a relative small amount of energy for the microorganisms, so that their rate of growth is reduced and only a limited part of the residue is converted into new cell biomass. Figure 13 shows a simplified scheme of the metabolic phases (SANTOS, 2001):

The presence of steam, CO_2 and corrosive gases in raw biogas is the main obstacle to biogas storage and to energy production from biogas. The useful life of sophisticated equipment – such as combustion engines, generators, pumps, and compressors – is extremely shortened. Control equipment – such as thermostats, pressure gages and flow gages – is also attacked, not only reducing their useful life, but also making them unsafe and unreliable. It is essential to remove the water, CO_2, sulfur dioxide, sulfur, and other elements by means of filters and devices for cooling, condensing and washing the gas in order to ensure the reliability and use of the biogas.

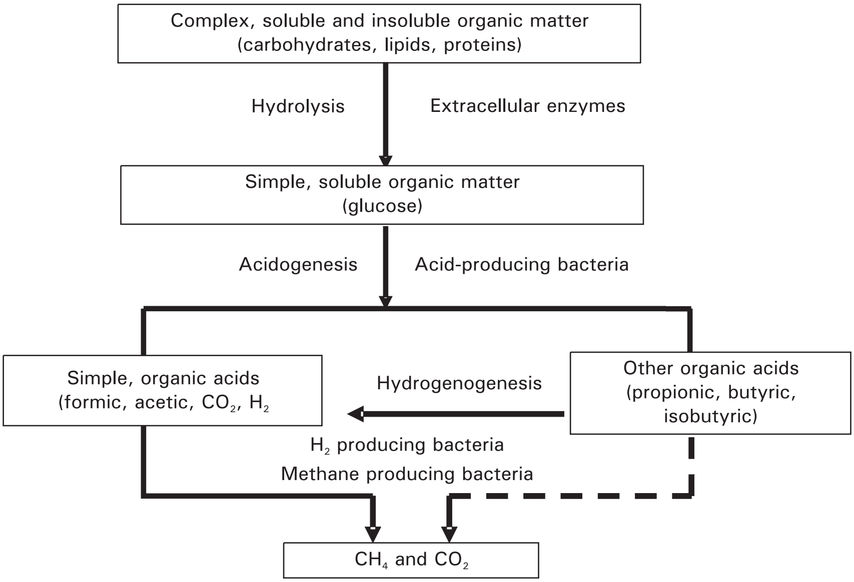

Figure 13. Metabolic phases of the anaerobic digestion process in biodigesters.

Biogas use in poultry and swine farms

Brazilian swine and poultry farms standout because of their high technological level and the special place that Brazil holds among meat exporters. Nevertheless, the climatic conditions, particularly in the South and Southeast Regions, have contributed significantly to changes in the consumption of the energy used to keep the young animals' environment warm during their first days at the farms.

Large amounts of poultry bedding are being produced because of the huge number of broiler farms coming into operation in the last few years. This growth is based on the high technical standards of the sheds, which cause increased energy and economic dependence on the systems. Biodigestion, or anaerobic digestion, is a good alternative for the treatment of the poultry bedding. Furthermore, biodigestion's byproducts – biogas and biofertilizers – are very valuable as sources de energy and plant nutrition, replacing inputs previously purchased by the poultry farmers.

These systems are composed of liquefied petroleum gas (LPG) fueled bell jars and infrared or incandescent lamps. All these heating systems use non-renewable sources of energy, with high production costs for the farmer.

The average electric power consumption in broiler farms is 2,169 kWh/farm/month according to the Cemig power company in Minas Gerais, not taking into account the electric power used to keep the poultry warm. However, when we also consider the use of electric bell jars to warm the chicks (1,000 W for every 500-chick lot) during the first 21 days of life, consumption rises to 16,128kWh.

The average LPG consumption in the bell jars to warm the chicks in farms with 16,000 birds (12 x 100 m), in the South Region's cold winter, is about 546 kg (42 13-kg containers), or R$ 1,260.00 (42 x R$ 30.00) for each chicken lot in the farm, or a total of R$ 8,820.00 (cost of the LPG container in October 2004 = R$ 30,00) for seven lots per year.

Souza (2001) observed that the percentage of energy used to warm the substrate is very high and that it would be possible to improve the efficiency of the system in a way that would enable the net biogas production to be used simultaneously for other purposes.

The expansion of swine production in some regions, especially in the South, has led to the discharge of a significant volume of residues in certain areas, causing serious concern over environmental degradation and the resulting impact on the qualify of life.

The search for technologies that help reduce environmental pollution has been in the agenda of the most varied sectors of society, particularly in the producers' agenda, with a view to improving and preserve the quality of life of the population. Because of the legislation, there are growing demands regarding the criteria used for the management of wastes. The criteria have become increasingly more rigorous and impose a heavy economic burden on producers. It is essential that the processes used for treating wastes evolve and that their cost decrease, so as to make them available to swine farmers.

By combining environmental action – aiming at reducing effluent and gas emissions – and the creation of a viable and attractive alternative for swine farmers, well-known innovative companies are building and facilitating the installation of biodigesters in the swine farms in their network. In exchange, these companies benefit by collecting carbon credits in the market as a function of the biodigesters they have had installed. It is estimated that more than 70 biodigesters have been built recently under such schemes, in addition to the 320 biodigesters currently being built in the states of Minas Gerais, Mato Grosso, Mato Grosso do Sul, Santa Catarina, and Goiás.

When submitted to anaerobic digestion in biodigesters, swine wastes only release carbon as CH^4 and CO_2 (diminishing the C/N ratio in the organic matter). Thus, the final residue is more appropriate for use as organic fertilizer because the nitrogen is mineralized and some nutrients are partially solubilized (SCHERER et al., 1996).

Agroforestry residues

A sizable proportion of the electric power produced from biomass in Brazil comes from agricultural, forestry and agro-industrial residues. According to the 2004 National Energy Balance, 2.86% of the electric power in the national energy matrix comes from biomass: 1.69% from sugarcane bagasse and 1.17% from wood and various agricultural and forestry residues.

The maximum generation potential of the wood and rice sectors is much smaller and has been estimated at 594 MW for wood and 200 MW for rice, on average. If only 50% of this potential were used due to economic reasons or transportation difficulties, about 300 MW and 100 MW would be generated, respectively. After subtracting the installed capacity – 142 MW for wood residues and 9 MW for rice hulls – the remaining wood and rice biomass would produce approximately 160 MW and 90 MW, respectively, in the short term.

Although the identified power generation potential in the wood and rice industries is rather unimportant in national terms, it is relevant from the regional standpoint. The wood production and processing centers are located in the states of Pará, Mato Grosso and Rondônia (native wood) and Santa Catarina, Paraná and São Paulo (planted forests). In the former case, the future of the forestry activities is uncertain, so that it would be important to analyze what the actual prospects are in the context of the sustainable exploitation of forestry resources.

As in all renewable sources of energy, in order to effectively exploit the electric power generation potential from residual sugarcane, wood and rice biomass it would be necessary to define and implement medium- and long-term development policies establishing clear conditions that effectively encourage businesses to use this economically viable and strategically significant potential.

Forestry residues

Forestry residues obtained through appropriate management of reforestation projects can increase the energy yield of forests. Here, again, few statistics are available due to factors associated with regional diversity, such as faunas, technologies, soils, and climates. Nevertheless, Woods and Hall (1994) estimated the energy potential of forestry residues in the world at 35 EJ/year (10GW). A sizable proportion of the residue is obtained at wood processing mills and paper and cellulose plants.

Considering the energy density of native and planted woods, studies indicate that the lower caloric power is 11.3 MJ/kg and 8.8 MJ/kg, respectively. In the Brazilian case, it is estimated that the paper and cellulose industry generates approximately 5 Mtep of residues without energy generation. There are no feasibility studies regarding the generation of energy from the greater part of the residues (twigs, branches and trunk parts), which remain in the field after the trees are felled.

The forestry-based sector is divided into two main areas: paper and cellulose and solid wood products. In Brazil companies work in one or the other, never in both areas. In countries where the forestry sector is more developed (Finland, the United States and Canada), large companies operate in both areas, increasing their competitiveness in international markets. (ASSOCIAÇÃO BRASILEIRA DE INDÚSTRIA DE MADEIRA PROCESSADA MECANICAMENTE, 2003).

In order to assess the electric power generation potential of the wood industry, the industries that process logs to produce plywood and composite boards, where most wood residues originate, were studied.

Most of the bark and chips are produced during the initial stages of production – log peeling or debarking, sawing and laminating. Those residues can be used to generate electric power on site or sold, since they can be transported relatively easily because of their size, which facilitates storage and manipulation.

The companies that process sawn wood to manufacture various added value products[28] tend to produce fewer and smaller residues, such as shavings and sawdust, which can be better used on site, because of the transportation difficulties. According to the IBGE (2003) the states of São Paulo, Paraná, Santa Catarina, and Rio Grande do Sul have larger planted-forest areas. In Pará and Mato Grosso, native forests prevail.

Rice residues

There are hundreds of rice mills in Brazil, of which 300 are located in Rio Grande do Sul. Rice milling does not necessarily take place near the rice fields since the transportation of rough rice – or unhulled rice – to be milled in the nearest consumer market is economically justifiable. São Paulo is not a large rice producer yet has a rather reasonable milling capacity.

Rice mills are divided into three groups, depending on whether they mill only white rice, only parboiled rice, or both. White rice is the most popular and its

[28] Such as blocks and blanks, frames, panels glued to the sides (EGP), doors, floors, furniture, and wood products.

production is concentrated in the State of Rio Grande do Sul. Santa Catarina, the second largest rice producer in the country, is the largest parboiled rice producer. According to the IBGE (2003), Rio Grande do Sul and Santa Catarina produce 700,000 tons/year of unhulled rice.

The moisture content of the paddy leaving the field varies from 25% to 30% depending on the farming conditions and time of year. The moisture content must be reduced to 12-15% before milling and to no more than 13% for storage. The combustion gases from burning the hulls are used as heat source for drying the grains. Mills that produce only white rice do not require steam. The higher caloric power of dry-base rice hulls is 15.84 GJ/t. The lower caloric power of rice with 11% moisture is 12.96 GJ/t, much higher than sugarcane bagasse.

The following parboiled rice milling operations require steam: (i) soaking; (ii) autoclaving; (iii) parboiling, and (iv) drying, in some industries.

Rice mills receive the harvested rice, which is taken to the mill as paddy. Approximately 15% of the hulls produced per year are burned to dry the rice; this operation usually takes place as the harvest proceeds (January through April) and consumes 60% of the hulls collected. It is estimated that only 50% of the total hull volume is used to produce electric power, since in addition to the 15% used in the drying operation, approximately 35% are produced in small, dispersed mills. The energy density of hulls is very low, so that transportation is only economically feasible with return freight.

Carbon credit market and agroenergy

Background

Atmospheric CO_2 concentrations have increased by 31% in the last 250 years (Figure 14), and have probably reached an all-time high. CO_2 concentrations tend to increase significantly if greenhouse gas (GG) emissions are not kept under control. Fossil fuel burning and cement production account for almost 75% of GG emissions. Changes in land use that demand deforestation have also contributed significantly: 25%.

Global warming from anthropic sources – resulting from greenhouse gas emissions (GGE) – has been a source of concern to modern societies. These emissions occur associated with the growing demands for energy (from non-renewable sources mostly) resulting from population growth. Climate changes can have negative consequences for future generations.

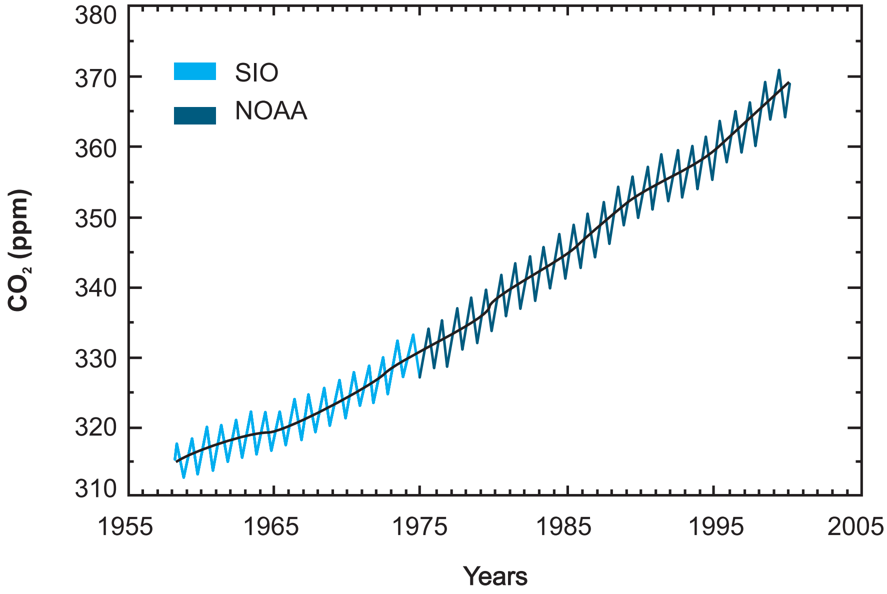

Figure 14. Atmospheric carbon dioxide concentration in Mauna Loa (Hawaii).
Source: www.mlo.noaa.gov/projects/GASES/co2graph.htm (cdkeeling@ucsd.edu).

Figure 15 shows the region from 30º to 60º north latitude parallels, where the First World countries are located. These countries account for most of greenhouse gas emissions.

Concern over global warming led the United Nations member countries to sign an agreement establishing control over human interventions in the world climate. The Kyoto Protocol stipulates that the signatory states, developed countries (also called countries in Annex I), shall reduce greenhouse effect gas emissions by an average 5.2% during the 2008-2012 period in comparison with the 1990 emissions. There are alternatives to help them meet their goal, the so-called flexibilization mechanisms.

The Clean Development Mechanism (CDM) was first proposed by Brazil as part of the UN Framework Convention on Climate Change (UNFCCC). The mechanism contemplates carbon credit trading on the basis of sequestration or mitigation projects, whereby developed countries would buy carbon credits, in CO_2 equivalent tons, from the developing countries responsible for such projects. A series of criteria must be met for a project to be acknowledged, among which compliance with the sustainable development premises of the host country, as defined by the Designated National Authority

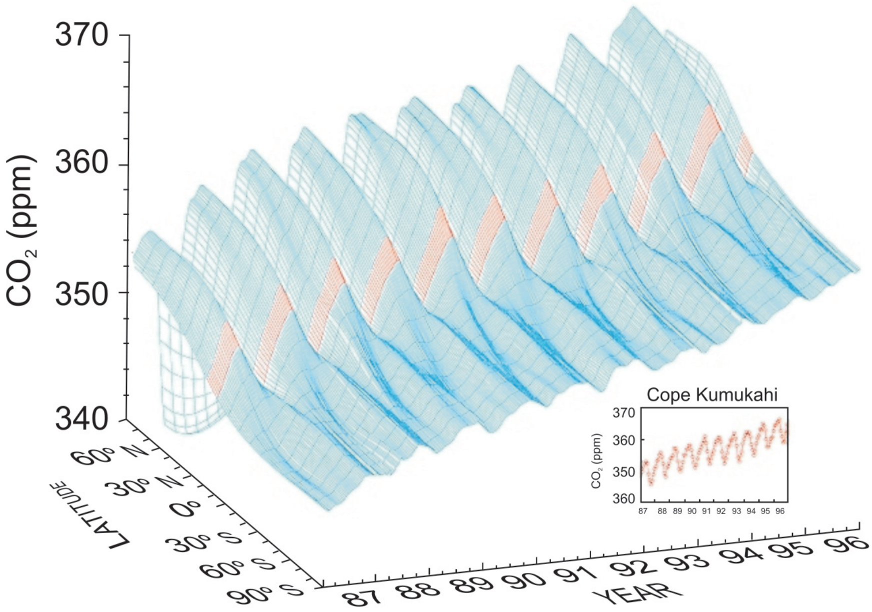

Figure 15. Distribution of the atmospheric carbon dioxide concentration according to date and latitude.
Source: www.mlo.noaa.gov/projects/GASES/co2glob.htm

(DNA). The Brazilian DNA is the Interministerial Commission on Climate Change. Only after approval from the DNA can a project be submitted to the UN for evaluation and registration.

Current CDM panorama

The CDM is the flexibilization mechanism with the highest risk to investors, because of the considerable uncertainty and red tape involved until the UN finally approves the project, in addition to its high transaction costs (from US$ 100,000 to US$ 150,000). Some countries (Annex I), such as Iceland and Australia, have not yet signed the reduction commitment (with the possibility of even increasing their emissions during the commitment period), while others, such as Russia, have substantially reduced their emissions and can profit considerably from allowance trading, since allowances are the safest and most valuable credits.

It would be extremely important to undertake economic studies to obtain long-term projections as soon as possible. At present, the price of a ton of carbon from a CDM project varies from US$ 5.00 to US$ 6.00, in the case of projects that comply with the premises of the Kyoto Protocol. Nevertheless, there are other trade options (voluntary initiatives) with more flexible rules, such as the CCX (Chicago Climate Exchange), in which the unit price is lower (around 90 cents of a dollar). After the recent ratification of the Kyoto Protocol, these values are expected to increase.

According to the World Bank, the main credit traders from January 2004 to April 2005 were Japan (21%), the Netherlands (16%), the United Kingdom (12%), and the other European Union countries (32%). In terms of credit supply (volume), considering the CDM and IC (Incremental Cost) mechanisms, India heads the list with 31%; Brazil, 13%; the remaining countries of Asia (including China), 14%; and the remaining countries in Latin America, 22%. The shares attributed to India and the other Asian countries are substantial due to their HFC_{23} destruction projects. The global warming potential of HFC_{23} is 11,700 greater than that of CO_2.

The projects that emphasize energy efficiency improvements, biomass, etc. very often have a 7-21 year timeframe, although the first commitment period in the Kyoto Protocol extends from 2008 to 2012. It is very difficult to determine the potential of carbon credit projects. Since there is much uncertainty about the negotiations for the second period, it has been decided to estimate Brazil's and Brazilian agribusiness' annual participation potential in this market for the first period only (Table 14).

Twenty-three CDM projects have been officially approved in the world within the scope of action of the Convention. Only two of them are located in Brazil; they are related to burning gas from landfills and, therefore, are not linked to agribusiness.

Table 14. Estimated annual participation potential of Brazilian agribusiness in the carbon credit market during the first commitment period of the Kyoto Protocol (2008-2012).

Emission of developed countries in 1990	13.7-billion tons of CO_2
Reduction commitment = 5.2% of total	714-million tons of CO_2/year
Price in 2005 = US$ 5.63/ton of CO_2	Total = US$ 4.0 billion/year
Estimated CDM share (40%)	US$ 1,6 billion/year
Brazil's expectations in the CDM market (25%)	US$ 400 million/year
Agroenergy potential in the Brazilian CDM (40%)	US$ 160 million/year

Source: Embrapa/Mapa.

Characteristics of the CDM

In order to be approved, a project must fulfill the additionality requisite, which assumes, among other factors, that the project has not been selected only because it was the most economically feasible alternative, but that it requires other investments, such as purchasing carbon credits, in order to be viable. Since the emphasis of the CDM is based on sustainable development premises, the more economically attractive actions, by themselves, do not require supplementary contributions (such as carbon credits) most of the time and occur naturally on account of the rules of the market or the private interests of the candidates. Very often the projects preferred showed that they would only be feasible if they received resources from the CDM.

In addition to the significant net emission avoidance there are other requirements for the project to be considered "additional", namely, a preliminary classification referring to the initial date of operations; the identification of alternatives consistent with the effective legislation and local regulations; analyses of investments, obstacles, common practices; and an analysis of the impact of registration as a CDM project.

In the case of Brazil and from the point of view of sustainable development, Resolution nº 1 of the Interministerial Commission on Climate Change determines that the projects submitted bring about substantial environmental and social benefits and generate income and jobs.

The development, monitoring and verification methodology must be have been previously evaluated, approved and registered by the CDM Executive Committee. The purpose of this prior processing is to guarantee that the projects are developed following a given methodology, which was previously recognized by the UN Methodology Panel.

On the basis of trend scenarios, the project must show that the entire reality would change if the project were not implemented, which is also called the "base line". In other words, this means that in order to evaluate the contribution that could be brought about by the implementation of a given project it is necessary to establish what would be the situation throughout the years in the absence of said project. One of the main difficulties is the lack of research to provide technical input for said base lines and to assist in obtaining approval of the methodologies required to develop the project.

Another major limitation is the transaction cost of the project, whose minimum value is approximately US$ 150,000. With a view to enabling access to low-income candidates, or even encouraging projects of lower CER (Certified

Emission Reduction), a differentiated modality with simplified requirements and methodologies was approved within the scope of action of the Convention. The purpose is to reduce transaction costs in order to encourage small businessmen to participate through association-type arrangements.

In Brazil, the Ministry of Development, Industry and Foreign Commerce (MDIC) in partnership with the Commodities & Futures Market (BM&F) and sponsored by the Fundação Getúlio Vargas, has created the Brazilian Emission Reduction Market (MBRE). Thus, a primary market would be organized by means of a bank of projects, complete with a system for registering, storing and classifying projects. The MBRE should have a favorable impact on reducing transaction costs, among other things, increasing investor visibility and even helping candidates to identify investors in the market.

Opportunities for agroenergy

A great opportunity for agroenergy is energy generation from residues and byproducts, such as the projects contemplating the cogeneration of energy from sugarcane bagasse that are being implemented to generate credits.

Since the methodology has already been approved, many projects will probably be submitted and many more initiatives will arise, such as those using rice straw and wood industry residues, among others.

Despite the limitations of the carbon sequestration market, forestry activities can receive credits for replacing fossil energy sources (coal) with renewable sources of energy (charcoal) in the steel mills. Another possibility is the use of wood mill residues to generate energy from the biomass, because of a 50% increase in wood use efficiency.

Another interesting approach is managing animal wastes and using the methane gas thus produced to generate energy, particularly since that technology has already been approved. Among the projects being implemented, special mention should be made of the Granja Becker (Minas Gerais) and Sadia projects, which are being analyzed by the Interministerial Commission, should serve as pilot projects and directly benefit rural producers.

Despite the existing technical and economic feasibility problems, the great potential of biodiesel derives from the fact that it is a governmental program that aims at replacing a source of energy. Another positive factor are the social benefits brought about by the biodiesel program.

The indirect opportunities arising from the requirements of the Kyoto Protocol should also be taken into account. Japan, in an effort to reduce its emissions, authorized mixing 3% alcohol to gasoline, which opens a huge market to ethanol exports from Brazil. An even higher percentage of alcohol could be added to the gasoline, as demonstrated by the gasoline used in Brazil, whose alcohol contents varies from 20% to 25%.

Reduction of greenhouse gas emissions (GGE)

Figure 16 shows in schematic form the natural greenhouse effect, which can be worsened by unbridled greenhouse gas emissions.

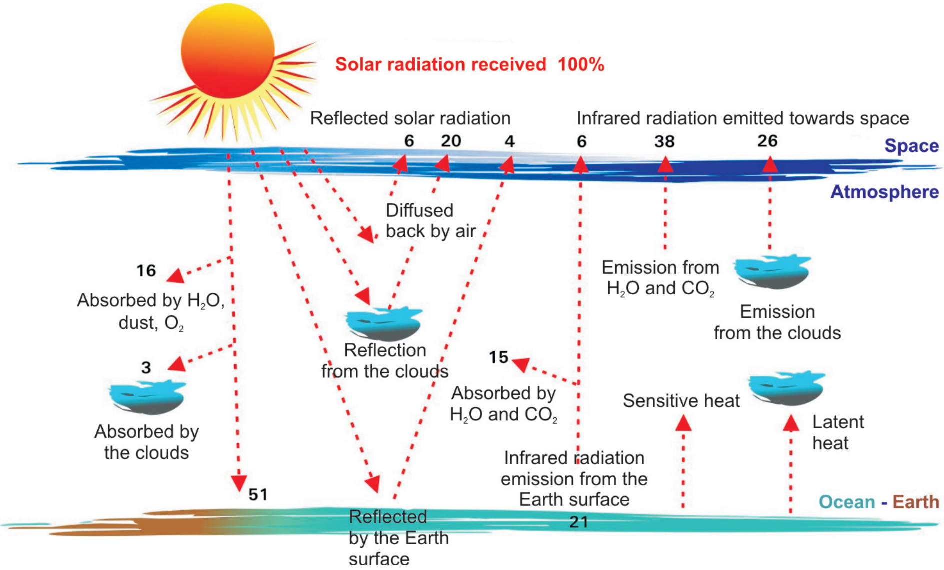

Figure 16. Schematic representation of the greenhouse effect.
Source: Drawn by D.L.Gazzoni and D. Estevão.

The use of biomass to sequester carbon is a given. The IPCC estimates that from 60 to 87-billion tons of carbon could be stocked in forests from 1990 to 2050, or 12% to 15% of fossil fuel emissions during the same period. Some requirements must be met for the biomass to mitigate effectively the impact of fossil fuels on the environment, namely:

- Sustainable production of the raw materials and use of the energy resources resulting in neutral production of CO_2.
- Carbon sequestration and fixation for long periods of time, even after the useful life of the plant (e.g., production of wood furniture).

- Direct substitution of fossil fuels – the case of ethanol and fuels derived from vegetable oils.

It is always important to consider the concept of greenhouse effect gases (GEG), of which CO_2 is only the paradigm of the emission measurement index. Other gases, like methane and sulfur dioxide, are extremely pernicious atmospheric pollutants. One of the advantages of using biomass is the low or nonexistent emission of those gases.

A comparison of the two strategies used to reduce the impact of GEG emissions shows that the use of biomass to generate energy is more advantageous than carbon sequestration and fixation, because:

- Biofuels and energy biomass can usually replace fossil fuels directly.
- Measuring the contribution of the energy biomass to carbon sequestration is less uncertain.
- Investment costs are lower because carbon sequestration means that the energy for society's consumption will have to be supplied somehow.
- Reduction of emissions through the use of biomass for energy purposes is a definitive phenomenon, while sequestering forests return CO_2 to the atmosphere when used for non-permanent purposes.
- Studies show that, in the long term, the energetic use of biomass is a more efficient use of the land than using forests for carbon sequestration (LARSON; KARTHA, 2000).

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