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INNOVATION FOR AGROENERGY USE IN BRAZIL: CHALLENGES AND PERSPECTIVES

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Abstract — The worldwide demand for renewable energy creates a great opportunity for Brazil's development. The country has unmatched natural comparative advantages (soil, climate, available area), technology and expertise to partially supply that demand. Exploitation of feedstock suitable for biomass production and its conversion to energy, requires a model considering the aptitude and potential of each terrestrial biome (Amazônia, Cerrado, Caatinga, Mata Atlântica, Pantanal and Pampa) addressing: regional production and use of renewable energy with adequate balance; job and income generation in rural and urban areas; socio-economic insertion and reduction of regional differences; reduction of greenhouse gas emission and attention to environmental services. To face that challenge Embrapa has recently constituted the Embrapa Agroenergy to coordinate and develop research and innovation, focusing sustainable biomass production and its conversion to energy, the economical use and recycling of residues and co-products.

Index Terms — Agroenergy, biomass to energy, energy balance, renewable energy

INTRODUCTION

The modern World demands energy, in increasing quantities, for the dynamic evolution of society. To date, much of this energy is supplied by fossil, non-renewable sources (oil, natural gas, coal, shale and peat) in the process of exhaustion. This scenario brings attention to changes in the world energy matrix, with a focus on the opportunity to other renewable energy sources, such as hydraulic, eolic and biomass.

For the moment, in which becomes evident the impacts of climate change on agriculture, biodiversity, patterns of social and political behavior, the balance between the fossil

and renewable energy matrices requires strategy, knowledge, action for change and straight communication.

The territorial location, land ownership and usage, logistics and technical as well as managerial capacity for prospection, processing, distribution and use of these sources of energy pose countries and groups competing with unequal political and economic comparative advantages. These basic elements guide current and future opportunities of each of these interest groups, but, also, develop new and differential conditions for geographic areas in tropical regions.

In this context, Brazil appears in the worldwide scenario with unparalleled natural comparative advantages (soil, climate, land availability) and built advantages (technology, expertise) that places it on high competitiveness conditions for biomass energy production. In addition, strategic planning and territorial management in the compatibilization of interests and goals, allow food and biomass energy production, without competition, attending the criteria of socioeconomic and environmental sustainability.

Undoubtedly, Brazil seeks, through technology improvement, higher productivity yields to reach greater volume of food and biomass energy production. Productivity increase due to technological innovation means gains in energy efficiency and reduction of the environmental impacts, because smaller area is used for food and energy. In turn, gains in efficiency contribute to planning, given an agenda which compatibilizes production of food and biomass energy.

In Brazil, traditional production factors (land, capital and labor) do not create obstacles to the expansion of agroenergy on a sustainable basis. The competitive demand for modern inputs, like fertilizers, becomes a real issue for the development, because efficiency in agricultural and industrial processes is necessary for jumps in competitiveness.

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PRIMARY AND SECONDARY ENERGY SOURCES: BIOMASS PRODUCTION AND BIOMASS ENERGY

Solar energy is the primary source of energy, therefore, all forms of life on Earth, as we know them, are dependent on solar radiation. The primary energy is transformed into chemical energy, which is transferred to the biomass formed in the photosynthesis process which occurs in chlorophyll bearing organisms. The biomass (agricultural residues, wood and plants such as sugar cane), the product of photosynthesis, is a secondary form of energy that can be processed into fuel, heat and electricity.

The exploitation of energy aimed at primary and secondary uses by society is dependent upon knowledge of natural resources and ways to scaling up its use. Instability in oil prices, climate change and greenhouse gases emissions, signal significant changes in the energy matrix with global use of renewable energy alternatives, which become strategic for mankind, placing each territory in a different condition for this application. In this scenario, countries in the tropical region show up in conditions for rational exploitation of their natural resources, with new knowledge, to contribute to the transition energy matrix.

Biomass - composed of about 220 billion tons of dry matter - seems to be the largest and most sustainable source of renewable energy ready for use. Estimates indicate that biomass can produce between 3,000 to 4,500 EJ2 of energy.

Renewable sources have the potential to meet much of the increase in demand for energy in the world, whatever their purpose may be (biofuel or co-generation of electricity and heat). The economic feasibility, sustainability and availability of each source of renewable resources for power generation define the type of application in each region. Brazilian land biomes (Amazônia, Cerrado, Caatinga, Mata Atlântica, Pantanal and Pampa) and aquatic biomes have high potential for biomass production and biomass energy, putting on RD&I (research, development and innovation) actions a strong component of raw materials, processes and products.

Undoubtedly, innovation is the key to increase sustainable production and food security. First generation technologies (biofuels such as ethanol and biodiesel), second generation (lignocelulosic ethanol), and third generation (hydrogen cells) are examples of scientific-technical development and integration of logistics and commercial production in progress in many institutions.

The significant increase in fossil fuel prices have enabled the technology to use some alternative energy sources that were not previously economically competitive,

including the agroenergy. Studies show that alcohol fuel is economically competitive when compared to petrol (tax excluded) for oil prices over \$ 35.00 to 40.00 per barrel. The same limit is estimated to be between \$ 60.00 to 80.00 for biodiesel as a still immature technology. Based on these relations and in the current and projected prices of oil, it appears that the use of biomass for biofuel energy production shall grow. This strategy must also consider the possibilities of biomass use for co-generation of energy (heat and bioelectricity), and also its incorporation as organic-matter in the soil (tropical soils conditioner, as an example, non tillage systems).

The Brazilian competence in agroenergy is mainly based on sugar cane to produce ethanol, in soybean, castor bean, sunflower and palm for the production of biodiesel, and in forest products, especially the eucalyptus. It is also a fact that the analysis and management of territories may provide significant elements for the equation of national sustainable development, including energy from biomass. The Brazilian territory has 851 million hectares. Of these, about 400 million hectares are anthropic areas. And, it is in these areas that Brazil has set its agriculture (about 60 million hectares and 140 million tonnes / season of grains), livestock (220 million hectares with over 200 million heads of cattle). Areas of sugar cane or energetic forests are equivalent, individually, to just over 2% of the total area used for agricultural production.

Over the past 30 years, the reduction of pasture area and increase in the number of cattle have been observed in some competitive regions, as a result of increased management efficiency. Meanwhile, in other regions, there was degradation of pasture areas, because of inadequate management. Conservative estimates suggest that if the average capacity of animals in Brazil reaches 1.4 head per hectare, it will be possible to have around 100 million additional hectares for agriculture, including for the expansion of sugar cane cultivation.

AGROENERGY PLATFORMS

Brazil has set objective guidelines for the agroenergy business, established in the National Agroenergy Plan (2006-2011), focusing on four platforms geared towards the production of biomass energy: (1) Ethanol, (2) Biodiesel, (3) Energy Forests and (4) Use of co-products and residues. The regional diversification of raw materials suitable for each product, allows the application of production models that are best suited to regional conditions.



These platforms cover studies aiming at: (a) the increase of agro-economic technical coefficients (with the exception of the palm, the usual raw materials - soybeans, castor bean, sunflower, cotton, peanuts, etc.. - for biodiesel production yield approximately 500 liters of vegetable oil per hectare and for a sustainable program such yield shall reach at least 1000 liters per hectare; in the case of ethanol, there is still room for obtaining sugar cane varieties with yields above 80 tonnes per hectare in a rainfed crop system); (b) definition of sustainable production systems, more efficient and with less environmental impact in the areas of expansion, through zoning, new cultivars, use of technologies that demand less fertilizers (biological nitrogen fixation, etc.); (c) innovation in agro-industrial processes (obtaining the cellulosic ethanol through enzymatic hydrolysis and gasification; study routes of transesterification for biodiesel production using ethanol and without the co-production of glycerine); (d) improvement of the energy balance of the system, a key factor to determine the feasibility of the project; (e) transversal studies evaluating markets, socioeconomic and environmental impacts, among other aspects.

EMBRAPA: AGROENERGY AND BIOFUELS RESEARCH

The growing global concerns with the environment and social inequalities associated with the current development model, based on the large scale use of fossil fuels, mainly oil, have led to the proposal of a development concept with socio-economic and environmental sustainability.

Energy production through biofuels aiming at reducing, at least partially, the environmental degradation process in the Planet, emerges as a current feasible alternative, in which agriculture is a vector of the process as well as a promoter of recent positive changes in various countries.

Brazil stands out for being a tropical country with high potential for production and use of biomass energy. Experiences of that retroact to the economic cycles associated with sugar, later to the energetic forests for the steel industry and to the energetic Brazilian Alcohol Programme (Proálcool) started in the 1970's. Brazil is the country that has advanced the most in technology, production and use of ethanol as fuel, followed by the U.S. and, to a lesser extent, by Argentina and other countries. Huge investments are currently being made to enable the production of cellulosic ethanol in the world, mainly in the U.S. Strategically, it will be vital to Brazil to invest resources in a dense RD&I program, especially in the hydrolysis of cellulose, thus avoiding the loss of its

competitiveness and strengthening further the leadership of the country in the production of biofuel.

National Agroenergy Plan (PNA 2006 – 2011), Agroenergy Research Program and Embrapa Agroenergy constitution

The National Agroenergy Plan (PNA) 2006-2011[1] is a landmark reference for Brazil which defines the basic national guidelines for biomass energy production. The implementation of PNA 2006-2011 is based on strengthening and consolidating the of research, development and innovation (RD&I) component, focusing on four main platforms: ethanol, biodiesel, energetic forests and residues/co-products.

By PNA 2006-2011 delegation, Embrapa has to coordinate institutional actions and a research, development and technological innovation program in agronomy and industrial areas, to increase the production and quality of ethanol, biodiesel, energetic forests and the economical use of residues and co-products. This programme includes a portfolio of projects on the agroenergy theme, involving agricultural technology, industrial technology and transversal studies (markets, socio-economic-environmental impacts, among others).

In response to one of the PNA 2006-2011 guidelines, Embrapa constituted Embrapa Agroenergy, synthesis name of the Agroenergy National Research Center (CNPAG), a decentralized and thematic R&I unit, whose mission is to enable innovative technological solutions to sustainable and equitable development of the Brazilian agroenergy business, for the benefit of society. Embrapa Agroenergy operates on a cooperative model for scientific and technological development by providing facilities and coordinating the networking with existing internal and external organizations. The structuring of Regional Units (Regional RD&I Coordinations in Agroenergy), is a strategy to implement the procedures for technology transfer in agroenergy, as well to broaden partnerships with Universities, Research Centers and other institutions for technological cooperation on agroenergy issues.

Agroenergy research at Embrapa

Embrapa currently develops a portfolio of projects in the agroenergy theme. Among them there are four major projects of transdisciplinary and multi-institutional character, with strategic approach and based on complex institutional arrangements, with intensive application of



resources. These projects address major topics of research to solve relevant national problems and are carried out by networks invariably involving hundreds of researchers from Embrapa and various partner institutions, as summarized below:

1. Technologies for biodiesel production [2]: its main goal is to improve the technology for production of some oil crops (palm, castor bean, canola, soybean and sunflower) as well as of vegetable oils for biofuels production. This project considers the incorporation of technology and territories, and is being carried out by a research network of national scope, consisting of 15 Embrapa's Research Centers, nine universities, five institutes and a private company, involving some 155 researchers.

2. Alternative agroenergy sources [3]: its objective is to explore the use of perennial species such as macaúba, inajá, jatropa and tucumã as alternative crops to enlarge and diversify the feedstock sources for biodiesel production, in order to guarantee oil supply in the production chain. This project also incorporates technology and territories with actions in some biomes (Amazônia, Cerrados, Pantanal and Mata Atlântica) and in transition areas, and it is being carried out by a research network of national scope, consisting of 20 Embrapa's Research Centers, nine universities and one State Research Company, involving some 168 researchers.

3. Sustainable production of sugar cane for energy purposes [4]: it aims at developing sustainable production systems for raw harvesting of sugar cane in the areas of traditional cultivation and expansion. Its main goal is to develop a set of technologies that shall provide a sustainable production system, and include: i) development of genetically modified sugar cane for tolerance or resistance to pests and water deficit; ii) biological nitrogen fixation, seeking to optimize the contribution of the biological fixation to crop nutrition, iii) zoning and modeling, with the purpose of identifying land potential and limitations, mainly in the areas of expansion, as well as development of harvest forecasting systems; iv) assessment of socio-economic and environmental impacts and future scenarios for the traditional and expansion areas; v) development of alternatives to overcome the limiting factors of production systems in use, with emphasis on optimization of irrigation technology, improvement of nitrogen biological fixation, development of methods for the biological control of pests and management optimization of agribusiness residues. This

project is being carried out by a research network of national scope, consisting of eight Embrapa's Research Centers, two universities, a Research Institute and six Sugar and Ethanol Plants, involving some 100 researchers.

4. Energetic forests [5]: This project aims at developing and optimizing the use of feasible alternatives to traditional non-renewable energy sources, through biomass of forest plantations, contributing to the sustainable expansion of national energy matrix. This project is being carried out by a research network of national scope, consisting of 17 Embrapa's Research Centers, 15 Universities, 14 Research Institutes, 11 Forestry Developing Companies, four Cooperatives, seven Industries and two Manufacturers Associations, involving around 130 researchers.

5. Use of Metagenomic, Genomic and Proteomic aiming at prospecting genes and proteins of interest to the sugar ethanol biotechnology industry [6]: its scope is the use of advanced technologies to increase the competitiveness of Brazilian sugar ethanol industry. The strategy of action includes the identification of hydrolytic enzymes of interest to the sugar and ethanol industry, the identification of genes differentially expressed during leaf senescence, stem growth and response to the application of ethanol in sugar cane, aiming at obtaining tools for genetic breeding of sugar cane, and the proteomic analysis of crop leaves for identification of proteins related to salinity stress. This project is being developed by a research network, consisting of three Embrapa's Research Centers, three universities and two Research Institutes, involving about 30 researchers.

6. Research, development and innovation in *Jatropha* (*Jatropha curcas* L.) for biodiesel production [7]: the main objective is to achieve technological domain of this species by developing studies that include genetic improvement (using biotechnological tools), development of agricultural production systems (including harvesting and post-harvest practices) and industrial processing (including use of co-products). This project is being developed by a research network of national scope, consisting of 11 Embrapa's Research Centers, eight universities, four Research Institutes, involving about 80 researchers.

7. Research, development and innovation in palm oil plants for oil production and economic exploitation of co-products and residues [8]: its main goal is to promote the technological domain / domestication of palm crops, selected by their energy density and territorial distribution



(macauba, tucumã, inaja and babassu), for use and incorporation, in the short, medium and long term, as raw materials for commercial production of oil. Also, it seeks to eliminate technological gaps that prevent the economic exploitation of co-products and residues, thus inserting the regions of palm occurrence in the geopolitics of agroenergy production. This project is being developed by a research network of national scope, made up of 13 Embrapa's Research Centers, ten universities, five Research Institutes, involving about 100 researchers.

8. Dynamization of the germplasm bank assets of oil palm (*Elaeis guineensis*) of Embrapa and support for genetic breeding [9]: it seeks the genetic breeding of palm oil for productivity and resistance to lethal yellowing, with developments in production and clonal expansion of the crop in biomes of interest. This project is being carried out by a research network of national scope, consisting of six Embrapa's Research Centers, four universities, three Research Institutes, involving about 50 researchers.

9. Characterization of alternative sources of biomass and development of technological routes for the sustainable production of ethanol from lignocellulosic materials [10]: it seeks the development of technology for production of lignocellulosic ethanol in a differential route as well as the integration and structuring of a network / multidisciplinary team composed of several Embrapa's units and partner institutions. The project and the research network of national scope (consisting of a number of Embrapa's Research Centers and Partner Institutions) responsible for carrying it out are currently being organized.

10. Conservation, characterization and documentation of native and exotic species with potential for use in agroenergy [11]: it aims at improving the overall infrastructure dedicated to conservation, characterization and documentation of genetic resources of species with potential for agroenergy production of Embrapa's units located in different Brazilian biomes and regions. This project is being carried out by a research network of national scope, consisting of 18 Embrapa's Research Centers, 16 Universities, 15 Research Institutes, involving about 150 researchers.

11. Detoxification of jatropha cake [12]: its main goal is to find an effective process to inactivate toxic and antinutritional factors present in the meal resulting from the extraction of *Jatropha* oil (for biodiesel production), in order

to allow its use for animal feeding. This project is being developed by a research network consisting of two Embrapa's Research Centers, three Universities and one private company, involving about 15 researchers.

PRODUCTIVE ARRANGEMENTS FOR FEEDSTOCK PRODUCTION AROUND INDUSTRIAL PLANTS

The National Program for Biodiesel Production and Use (PNBP) has as guidelines: (a) the establishment of a sustainable program, promoting social inclusion; (b) to ensure competitive prices, quality and supply; (c) the production of biodiesel from different sources oil and in various regions. To meet these guidelines and to attend the legal framework (Laws 11.097/2005 and 11.116/2005), the organization of the raw material production system around the biodiesel plants is of fundamental importance for the success of the Brazilian biofuel production program.

The fulfillment of the principle of regionally produce and use the biodiesel depends upon the availability of raw materials, which must meet four criteria for the feasibility and sustainability of the program with competitive biofuel prices: 1) defined and efficient agronomic technology; 2) well established industrial technology; 3) logistics and infrastructure for production and 4) scale of production to guarantee supply for present and prospective demands. Currently, among all oil crops, soybean is the only one that meets the four criteria, however, the PNPB guidelines determine that it can not be a desirable option, indefinitely. Meanwhile, the other conventional oil crops (such as: castor bean, sunflower, cotton and palm oil) partially meet the four criteria. Thus, it is necessary to develop solutions to critical issues such as planning and territorial management, logistics and industrial agriculture, production infrastructure / storage / distribution of raw materials, financing, and local / regional productive arrangements.

Embrapa supports PNPB, contributing on three levels: 1) mapping biofuel technologies for immediate release; 2) identifying and generating new knowledge and technology in the short, medium and long term, and 3) identifying and articulating local / regional productive arrangements around biodiesel plants. In that matter, Embrapa engages in public-private partnerships, focusing technical and management arrangements for the achievement of developments in areas such as: agroclimatic zoning, crop breeding to obtain seeds with high agricultural and industrial quality and yield, sustainable production systems, technology transfer, human resources training (managers and support personnel in the production of energy crops), organization of production and



producers, availability of raw materials, and integration of family farming in the agroenergy business, taking into consideration the economic, social, environmental, regional differences and social inclusion aspects of PNPB.

Embrapa's Strategy

Under public-public and public-private contracts, Embrapa can participate in arrangements for the definition of agroecologic zoning, research for solving local problems, training of managers and support staff in agricultural activities, supply of basic seed for multiplication by certified companies, as well as in the optimization of industrial processes for biomass conversion into energy. Actions of this magnitude, established as projects, require the establishment of networks connecting the system of agricultural research to Technical Assistance and Rural Extension - ATER (public and private) agents and producers, having as final goals: the continuous technical and management training of technicians in energy crops; establishment of a permanent forum for discussion of the knowledge and technology transferable to the producers in the area of agroenergy, and continuous monitoring of results achieved at the level of rural properties. The specific project, financed with resources from public and private agents, managed by a foundation, will speed the execution of planned activities, including recruitment of technical staff and support people.

FINAL REMARKS

The prospects of using the agroenergy worldwide and in Brazil are very promising, as trends have strongly signaled for a change in fossil energy matrix towards a renewable energy matrix. Recent and historic facts have demonstrated that there is an opportunity for tropical countries in biomass energy production, with the implementation of first generation technologies and input of new knowledge for development of lignocelulosic ethanol, alcoholchemistry, lipochemistry and related processes.

The production and use of biomass energy shows complementarity in the platforms of ethanol, biodiesel, energetic forests and residues. The coordinated implementation and operation of the entire Agroenergy Platform is strategic and important for a country of continental dimensions such as Brazil, with large regional differences and extensive demand for renewable energy production, with specific economic, social, environmental and regional characteristics. There is, therefore, a need for

integration of efforts on a national level, for the development of RD&I, production and use segments, as well as market adjustments. Each of these platforms "per se" presents technology and management gaps, which deserve a cohesive action to consolidate a national agroenergy program for Brazil.

Being strategic for the expansion of Brazilian agriculture and to transform Brazil into a larger food producer, the Brazilian Agricultural Research Corporation - Embrapa also works to consolidate the position of Brazil as the world's largest producer of renewable biomass energy. To overcome this challenge, the company, with other national (public and private) research institutions, is substantially expanding its efforts, investments and human resources for the development of agronomic technology (more efficient production systems with positive energetic balances), industrial technology (increasing efficiency in conversion processes) and transversal studies (about environmental, sociological, economic as well as market, management and public policy issues, among others).

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