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CHALLENGES IN RESEARCH, DEVELOPMENT, AND INNOVATION IN BIOFUELS IN BRAZIL

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Three quarters of the world's energy consumption is represented by fossil fuels. They are responsible for a great deal of local pollution, and for most of the emission of greenhouse gases (GHG) on the planet. The scale in which they have been used will quickly, lead to their rarefaction; considering that global energy consumption should grow, as result of progress in various areas undergoing development. Industrialized countries were not successful in reducing energy consumption without compromising quality of life, in spite of knowing that this can and should be done. The present challenge is to promote the use of renewable energy sources, and to increase the efficiency in energy generation and usage in an unprecedented scale. Sugarcane bioethanol, and other biofuels that may be developed in a sustainable way, could contribute significantly to this end. . However, this will require an unprecedented global research effort.

In Brazil, the sugarcane agro-industry has been transforming itself into an energy agro-industry, replacing fossil fuels and opening the possibility to be, in the near future, an important source of renewable materials (plastics and chemical products). Its participation in the national energy matrix has been growing, currently representing about 15% of the total energy consumed in the country, comprising both bioethanol for transportation, and bagasse for electric, thermal, and mechanical power generation. Better use of sugarcane waste and efficient co-generation may significantly increase electricity power generation. And the development of new processes for obtaining bioethanol from bagasse and trash, can increase power generation by up to 40%, using the same quantity of sugarcane.

The Brazilian experience demonstrates that sugarcane bioethanol represents an actual possibility for reliably supplying part of the world's fuel market. Significant progresses in domestic and international research, development, and innovation capabilities will determine the success of such endeavor.

However, it is necessary to consider that innovation is a complex process, not exclusively limited to the research and development dimension. This point is very relevant to discussions in terms of domestic and global outlook regarding biofuels expansion, as innovation processes assume interaction among the various players and segments of the society that make up what is usually called the "innovation environment". This encompasses universities and research centers, and definitely industriey; however, it also covers other aspects such as regulatory benchmarks and domestic and international rules. It is a socio-technical process by nature, which must be considered in all its various dimensions to develop with the required vigor.

Historically, Brazilian breakthroughs in biofuels research are obvious: productivity gains in all production steps, either agricultural or industrial, or even environmental controls, are evident. Bioethanol and bioelectricity production and distribution costs were reduced by advances in technology and management, in addition to investments in infrastructure. Nowadays, producing bioethanol

and bioelectricity in the most efficient plants is competitive with all other sources of fuel production and electric power generation.

At the same time, Brazil is still a very uneven country, though all of the recent indexes show improvement, and this unbalance is also reflected on employment quality and production capacity, which require special attention to reach levels capable of ensuring competitiveness and sustainability of biofuels in the domestic and international energy commodity markets.

The widespread adoption of the most efficient and available technologies may further reduce costs, and this holds considerable potential using technologies that are still being developed, including precision agriculture, new transportation systems, genetic improvement, and improved industrial processes.

Therefore, it is necessary to face the challenge of improving the whole production chain as well as the value chain associated to biofuels production. The research and development theme is challenging, pervades all links in the chain, and should consider not only the amassed knowledge and previously incorporated, visible innovations; it also has to consider the potential of new transforming technologies that may have impact on various links in the chain, such as biotechnology, new materials transformation technologies, and nanotechnology. Such technologies create opportunities at every step of bioenergy generation, and must be exploited.

Brazil stands out from other sugarcane producing countries for the progress it has achieved in sugarcane biotechnology, having non-commercial transgenic varieties since the 1990s. In 2003, Brazilian laboratories completed theidentification of 40,000 sugarcane genes, and dozens of research teams are working on the functional genoma; their data being used in genetic improvement experimental programs, which should bring commercial results in the next few years. Furthermore, a growing number of sugarcane varieties are used in Brazil, providing considerable assurance regarding the resistance to exogen diseases and predators. Over 500 sugarcane varieties have been mapped, and 50 of them are currently in commercial use. The 20 leading varieties make up 80% of the harvested area; however, no single variety covers more than 13% of the area.

Water catchment for use in the industrial process has decreased substantially, as well as the quantity of fertilizer used is reduced in comparison to other countries and cultures. Nutrient recycling has been improved by ferti-irrigation, and by the use of production process waste, which has increased considerably.

The use of sugarcane bioethanol as fuel for vehicles, either jointly with or replacing gasoline, contributes substantially to the improvement of air quality in urban areas, and to reduce GHG emissions; in addition sugarcane culture can also be employed for recovering degraded agricultural soils, in deforested areas, or in areas underused by extensive animal breeding.

In Brazil it was possible to responsibly expand the biofuels production area, at the same time freeing important agricultural areas which, were it not for the productivity gains attained, would have been used much more intensively in terms of requirement for such production. A considerable part of the Brazilian territory is adequate for agricultural production, preserving forests and biological diversity. Sugarcane culture expansion has occurred mostly in extensive grazing lands and degraded areas.

This issue of extension and adequacy of land, climate, and soil has been well researched, as demonstrated by the works carried out by CGEE[1], also in partnership with the Interdisciplinary Centre for Energy Planning of the Campinas State University – (Núcleo Interdisciplinar de Planejamento Energético – Nipe/Unicamp), coordinated by Professor Rogério Cerqueira Leite. It is also worth highlighting works developed by Embrapa and other public and private institutions, which examined complementarity and synergy in the production of food, energy,

[1] "Biocombustíveis" study, published in the NAE section #2 (NAE, 2005); Studies in partnership with Nipe/Unicamp between 2005 and 2008, published in "Bioetanol combustível: uma oportunidade para o Brasil" (CGEE, 2009); Study "Bioetanol de cana-de-açúcar: energia para o desenvolvimento sustentável" (BNDES, 2008).

and materials in Brazil. Contrary to the perception of many who see as a conflict in land usage, studies have confirmed the availability of this input, with soils and climate favorable for considerable growth in sugarcane production, which opens an opportunity to create a Brazilian strategic agenda, also in partnership with other countries situated in the humid tropical regions of the planet.

Doubtlessly, one extremely important aspect for Brazil is to have been able to consolidate its position as a major player based on a strongly rooted sugarcane bioethanol production. By means of knowledge accumulated over the years, as well as actual indicators of growing productivity, Brazil's privileged condition has been reaffirmed. The aforementioned studies draw attention to the Brazilian competitive advantages, such as the issue of Brazilian sugarcane bioethanol yield compared to European beets, American corn, Thai cassava, or wheat in the European Union, as well as sugarcane in India.

Indeed, the Brazilian agro-business has demonstrated an expressive productivity increase from the 1970 to the present, which has not been exhausted yet, having a significant potential for further growth. In terms of energy balance, another competitive edge, Brazilian sugarcane bioethanol has currently comparative advantage, compared to all other biofuel cultures: a ratio of almost 10 to 1 renewable energy units produced for each unit of fossil energy consumed in its production.

Thus, Brazil presently also holds a leadership position in utilization and knowledge dissemination. There is a remarkable collection of know-how in universities, companies, and qualified human resources. Additionally, there is now in Brazil an important effort towards incorporating new knowledge and enhancing innovation throughout the whole bioethanol production chain. Equally important are the available fostering instruments, adequate for supporting the various stages of innovation, from basic research and technology development to direct support devices for innovation in companies, such as economic subsidies enabled by the Law of Innovation.

This new environment has favored the development of innovation cycles in companies, also for building corporate excellence centers, either alone or in partnerships, focusing on issues that are precompetitive by nature, and that may render the breakthroughs the world needs in the sustainable production of liquid biofuels for transportation.

It is important to point out that some of the experience accumulated in Brazil could be shared with other countries. For instance, in terms of competence and qualification for the production of sugarcane varieties, programs like Ridesa's- a successful cross-institutional university network for research and development, currently organized all over Brazil, and actually a university-industry partnership- is allowing the development and utilization of new sugarcane varieties in regions where traditional production behooves gains in efficiency, or in regions deemed promising for expanding production.

Embrapa, together with Ridesa, plays an important role, with chances of obtaining short-term results in expanding overseas a sugarcane variety research and development agenda, in the same way as done in Brazil for regions with lower productivity with traditional varieties. This type of experience can easily be shared with other countries by integrating programs of the National Scientific and Technological Development Council of the Ministry of Science and Technology (CNPq/MCT), such as ProSul and ProAfrica, and of the Ministry of Foreign Affairs (Ministério das Relações Exteriores) – ProRenova; as well as through partnerships with multilateral organizations, such as ECLAC (Economic Commission for Latin America and the Caribbean), IADB (Inter-American Development Bank), CAF (Corporación Andina de Fomento), relative to Latin American and Caribbean countries, and UN-ECA (United Nations Economic Commission for Africa) as well as regional UN offices for food and agriculture – FAO.

Regarding countries that, unlike Brazil, do not have yet explicit and policies for biofuels, especially those having both a natural inclination and a competitive advantage in terms of sugarcane (cultivated in over 130 countries) production and use, joint efforts should be made to promote greater cooperation around relevant knowledge. The reason is that though bioenergetic routes

may be envisioned (and they are extremely important), as well as the implementation of advanced technology in each step of the production chain, there are some issues that are not being treated with the required priority. This includes the strong dependence on technology that even Brazil has to face e.g. fertilizer options, extremely important to render bioethanol more renewable than it is currently the case. Credit should be given here to the endeavors by Embrapa and other research institutions in developing alternatives for these inputs, which are at one end of the chain, and should be strengthened.

Many Latin American and Caribbean countries, like Brazil, may obviously exceed by far their own needs in bioethanol from sugarcane production, and may become important players in the global biofuels market. Surplus production can certainly be exported to Europe, North America, and other countries, as it has been done in Brazil, whose bioethanol exports surpassed five billion liters in 2008 over 40% increase in relation to the previous year. This is a global scenario that creates opportunities for countries located on the humid tropics, particularly Brazil and its neighbors in Latin America and the Caribbean.

However, Brazil a relevant player in the international biofuels arena, must pay attention to the next steps to be taken, considering the world scenario. If other countries actually adopt diversification strategies in the use of liquid fuels, with environmental concerns related to GHG emissions and air quality in urban centers, Brazil will be the leading player in terms of sugarcane bioethanol production capacity, as its global demand has been growing.

Yet another segment to be considered, in terms of international cooperation, concerns experiments at the development stage, by companies that are introducing more radical technological innovations in new processes and products. Such companies may find qualified partners in Brazil, in universities, research centers, and other companies, so that they may complete the development of such products and processes, reaching new levels much sooner, towards the next-generation bioethanol. Indeed, Brazil now has outstanding capabilities to attract international research centers and foreign companies for them to carry out, with Brazilian partners, all the development steps, in an environment where basic inputs production is complete; there is also qualified personnel available to develop new technologies.

In terms of an international cooperation agenda, different guidelines may be foreseen regarding the developing and industrialized countries, however they cannot clearly preclude, in both cases, some kind of cooperation that Brazil already keeps, but which needs to be strengthened in qualifying human resources. This should take place by means of existing – or to be created – graduate programs, on subjects related to the borderline between knowledge on biofuels and all the knowledge chain around them.

In this context, the public-private partnership is fundamental for the innovation process to take place with overflowing intensity, necessary for the development process. This comprises setting up networks with institutions and researchers, the development of cooperative projects, implementation of strategic alliances, and assembling strategic R&D agendas. It is a challenging process, with many difficulties to be overcome, but certainly very important to be implemented in Brazil.

The challenge in research nowadays is huge, and organizing a research agenda is much more complex than it was a few decades ago. The current scenario is different, not only in Brazil, but worldwide. The generation of knowledge, and the speed this knowledge is taken in by society and industry, the dimensions society today demands that be built in a decision-making process relative to strategies to be adopted, or, meaningfully, the investments to be made, put into the building of research, development, and innovation agendas, variables not yet properly perceived or embedded in corporate and public policy decision-making processes.

Thinking and planning a research agenda assumes a wider and more diversified view of the dimensions associated to it. Furthermore, the way in which this research effort will be organized must be responsive to the identified challenges. This response is no longer provided by scattered

action of people or restricted research groups, but by sharing knowledge through collaboration networks in a competitive environment.

In Brazil, the concept of a research agenda must consider the t extent to which it really creates opportunities, causes problems, and how it intends to solve them. Considering the country's vast territory and soil and climate diversity, specific research agendas are needed for each one of these areas. Research agendas for different kinds of institutions in bioethanol production are also required. Most likely production plants in São Paulo and Minas Gerais have their relationships with sugarcane suppliers structured in a different way than their counterparts in the more traditional regions in the Northeast, and in the northern part of the Rio de Janeiro state.

The sugar and alcohol production from biomass, extraction under pressure, fermentation, distillation, and production are issues well settled in Brazil for many years, which were doubtlessly reinvigorated by Proalcool, leading to the learning and knowledge available as of today. The new technological routes, the agendas that are being developed today for the future production of next-generation biofuels and new production processes, show the dimension that this issue will present, considering production from cellulosic biomass.

Cellulosic biomass utilization is an intense worldwide race, enlarged by mastery of this specific niche. So this niche, where the enzymatic hydrolysis issues and other variations are found, is driving a worldwide research agenda. Brazil has competence in several of the dimensions involved, but not in all of them as yet, nor does the country has the strong investment in research required to take the lead in this game. The existence of some qualified excellence research groups providing important results is great news as well as a necessary condition; however it does not suffice to advance on this level at the required speed to ensure that Brazil finds, in time and at an affordable cost, an exclusively Brazilian solution for this issue.

The technology route, from the primary input production stage y through the final step of the energy vector, the dimension of technologies offered, the technology intake, the efficient water usage, are all issues to be dealt with in a research and innovation agenda for bioethanol. What are the implications and relationships between the different uses of land for producing food, materials, and energy? What answers are being given to this question? What are the needs in studying the water usage issue? And the issues related to plant nutrients? What are the issues with fertilizer availability? If, for instance, there are fertilizers available only for producing food nowadays, what are the options? What if we are overly dependent on imported fertilizers? Finally, what is the Brazilian capacity to overcome some of, or all, these challenges? All these elements must be considered. Yet there is the dimension regarding new knowledge areas, which bring information specific to bioethanol, such as biotechnology, and even the development of social and economic policies, upon encompassing these dimensions.

In the conversion phase, that involves electricity or multiple generation, there are several research and development items that behoove some attention. In the first generation, as it is usually named, there are, for example, combustion processes, most of them are already well understood. In the next biofuels generation, including enzymes, catalysis, gasification, pyrolysis and other technologies, it is obvious that the required infrastructures are differentiated, complex, requiring immediate technological servicing capacity.

There is also a false dilemma between the first and the next biofuels generations.

There is room for improvement in every step, and challenges ranking from incorporating some technologies to the capital goods industry itself (e.g. intelligent machines, machines embodying new production methods) to environmental issues and rules established in a global scenario..

Finally, regarding the final use of energy vectors, it is necessary to examine not only the research issue, but also production scale and its possible integration with others.

This big and complex picture helps to illustrate the dimension of the problem in defining a research, development, and innovation agenda for bioethanol. Various groups have been studying and working with the CGEE to define and

select an initial agenda that could be shown as the priority for research on bioethanol, covering from conventional genetics improvement issue to genetic engineering; production models and infrastructure, technological routes, biotechnology, precision agriculture; mechanized harvesting, and all their subdivisions, among others.

As we saw, the points to be considered are many: fermentation, distillation,management; the water and energy issue, how surplus energy generation capacity can be increased, how to integrate electricity distribution networks, and how to optimize this system in order that ethanol production can be part of an energy vector, that can be used as a fuel or diverted to feed the electric power distribution network. All this is possible, the technology is already available, but still requires further research to become a commercial reality.

The issue of mechanized harvesting without damaging the soil or the plant, for instance, is a challenge requiring the use of knowledge in robotics, sophisticated instrumentation, and thinking of a new mechanization concept and its relationship with the soil and the plant.

As mentioned before, there is also the bagasse hydrolysis and gasification issue, and high bagasse content sugarcane, known as energy cane. The integration of such innovation leads to the idea that when Brazil fully masters the know how for the full utilization of sugarcane, it will be primarily about chemical sugarcane, rather than bioethanol-bioethanol will become just another product.

Therefore, innovation cycles must be observed, and the chemical and thermochemical routes that may be taken varied. On the other hand, all this process also assumes the rapid evolution in cultural, political, and social discussions on the use of bioenergy and its implications.

It should be clear that there is still a lot of room in Brazil to reduce costs, to improve production sustainability, and to incorporate new technologies and incremental innovations in production, which may keep Brazil competitive for some time, in some market niches and under certain conditions. It is possible to establish a competitive margin with petroleum around a certain price range, or have a margin with the exchange relationships within a certain system; however, this is definitely not enough if Brazil wants to be a competitive global player.

Controlling new technology generations will require a more daunting agenda. It will be necessary to integrate synergically and intensively the domestic efforts, in the public and the private sectors. This support and involvement of both sectors will be of utmost importance to ensure that existing initiatives – and the new ones – are at the edge of scientific knowledge; like a new paradigm that guides and contributes to the production process, in terms of new technological routes such as the aforesaid biotechnology and nanotechnology. The bioethanol chain is strongly tied up to these agendas, as it is associated with biotechnology, nanotechnology, the use of advanced materials, and the intensive use of information and communication technologies. In other words, it is no longer possible to think that the bioethanol issue is restricted to the chemical or mechanical engineering departments, which know all about unit operations. Not any longer, a system vision is required.

Within this context, the Brazilian Bioethanol Science and Technology Laboratory (CTBE) was set up in Campinas, in the state of São Paulo, to carry out basic research and technological innovation, both internally and in strategic partnerships, representing a major investment by the Brazilian federal government in science and technology linked to sugarcane bioethanol. Through this center, the expected result is to aggregate the Brazilian scientific efforts to make feasible a renewable source of energy that merges high productivity with optimum raw material usage with sustainability.

A research, development, and innovation agenda for the bioethanol chain must consider the advantages and challenges for Brazil in this area. The advantages are remarkable: the availability of land, lack of competition with food production, and the considerable know-how. It is noticeable that Brazil's know-how on the whole bioethanol production chain finds no match in any other country.

On the other hand, there are threats that the nation will face, and should be alert. It begins with the technology control issue. Who will control some of the key technologies in the future? Who

will have ownership of this knowledge? Who will have resources to invest in acquiring such proprietary domain? And who will have the capacity to follow all the advances in scientific knowledge, to include them with the required intensity and speed, throughout the whole production chain?

Another important threat is to acknowledge the degree of competition in this trade. The energy industry, be it biofuels or any other source of energy, is a big business, which requires working with different parameters. If Brazil acts as an international player, the competition business game includes variables like industrial property and marketing devices about which academic sector still has the greatest learning needs. It is still necessary to learn how to deal with this business dimension in the academic environment, which is a considerable challenge.

Obviously, the possible repercussions of the current financial crises should not be disregarded, as it may reduce investments, redirect strategies, diverting not only public investments, but private ones as well. Thus, another challenge for Brazil is to monitor the global landscape, in a difficult credit scenario, or financing difficulties, or problems in obtaining resources for investment.

Finally, it is not a market reserved for Brazil only; this is a world game where Brazil has some advantages. In order to preserve and expand these advantages, it is necessary to add knowledge to the whole chain, to mobilize and identify areas of competence in all technologies and synergies, and, above all, to have a clear vision of the future. To accomplish this, it is necessary to consider together all issues covered here. It is also necessary to realize that this challenge is not to be faced by the government alone, but by the whole society, a partnership between public and private endeavors becomes significantly relevant. Summing up, Brazil must explore the advantages it holds and to benefit from upcoming innovations as o a window of opportunity for the nation to act as a global player.

REFERENCES

BNDES – Banco Nacional de Desenvolvimento Econômico e Social. **Bioetanol de cana-de-açúcar:** energia para o desenvolvimento sustentável. CGEE, em colaboração com BNDES, Cepal e FAO, Rio de Janeiro, 2008, 326 pp. Available at: <http://www.bioethanoldecanne.org>.

CENTRO DE GESTÃO E ESTUDOS ESTRATÉGICOS – CGEE. **Bioetanol combustível:** uma oportunidade para o Brasil. Nipe/Unicamp e CGEE, Brasília, 2009, 536 pp. Available at: <http://www.cgee.org.br>.

NÚCLEO E ASSUNTOS ESTRATÉGICOS DA PRESIDÊNCIA DA REPÚBLICA – NAE. **Biocombustíveis**. CGEE. Caderno NAE n. 2, Brasília, 2005.

POPPE, M.; MACEDO, I. Sugar solution. In: **Our Planet**. Unep, 2006, pp. 24-25.