SUSTAINABLE
DEVELOPMENT
GOAL
7

AFFORDABLE AND CLEAN ENERGY

CONTRIBUTIONS OF EMBRAPA

Airton Kunz
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Technical Editors

Embrapa

Brazilian Agricultural Research Corporation
Ministry of Agriculture, Livestock and Food Supply

Sustainable Development Goal 7

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Foreword

Launched by the United Nations in 2015, 2030 Agenda for Sustainable Development is powerful and mobilizing. Its 17 goals and 169 targets seek to identify problems and overcome challenges that affect every country in the world. The Sustainable Development Goals (SDG), for their interdependent and indivisible character, clearly reflect the steps towards sustainability.

Reflecting and acting on this agenda is an obligation and an opportunity for the Brazilian Agricultural Research Corporation (Embrapa). The incessant search for sustainable agriculture is at the core of this institution dedicated to agricultural research and innovation. Moreover, sustainable agriculture is one of the most cross-cutting themes for the 17 goals. This collection of books, one for each SDG, helps society realize the importance of agriculture and food in five priority dimensions – people, planet, prosperity, peace and partnerships –, the so-called 5 Ps of 2030 Agenda.

The collection is part of the effort to disseminate 2030 Agenda at Embrapa while presenting to the global society some contributions of Embrapa and partners with potential to affect the realities expressed in the SDG. Knowledge, practices, technologies, models, processes and services that are already available can be used and replicated in other contexts to support the achievement of goals and the advancement of 2030 Agenda indicators.

The content presented is a sample of the solutions generated by agricultural research at Embrapa, although nothing that has been compiled in these books is the result of the work of a single institution. Many other partners joined in – universities, research institutes, state agricultural research organizations, rural technical and extension agencies, the Legislative Power, the agricultural and industrial productive sector, research promotion agencies, in the federal, state and municipal ranges.

This collection of books is the result of a collaborative work within SDG Embrapa Network, which comprised, for 6 months, around 400 people, among editors, authors, reviewers and support group. The objective of this initial work was to demonstrate, according to Embrapa, how agricultural research could contribute to achieve SDGs.

It is an example of collective production and a manner of acting that should become increasingly present in the life of organizations, in the relations between public, private and civil society. As such, this collection brings diverse views on the potential contributions to different objectives and their interfaces. The vision is not homogeneous; sometimes it can be conflicting, as is society's vision about its problems and respective solutions, a wealth captured and reflected in the construction of 2030 Agenda.

These are only the first steps in the resolute trajectory that Embrapa and partner institutions draw towards the future we want.

Maurício Antônio Lopes
President of Embrapa

Preface

The 17 Sustainable Development Goals (SDG) define a set of actions focused on reducing poverty and promoting people's prosperity and well-being while protecting the environment and fighting global warming. They are an evolution of the eight Millennium Development Goals proposed in 2000 and of Rio+20 in 2012.

This publication deals specifically with SDG 7: Affordable and clean energy – Ensure access to affordable, reliable, sustainable and modern energy for all. Among the targets proposed for this SDG, Embrapa has important actions in three of them: target 7.1 – By 2030, ensure universal access to affordable, reliable and modern energy services; target 7.2 – By 2030, increase substantially the share of renewable energy in the global energy mix; and target 7.3 – By 2030, double the global rate of improvement in energy efficiency.

Target 7.1 was addressed by Embrapa in proposing industrial processes that allow the development of agribusiness production chains linked to the production of energy, either in the form of electric energy or of biofuels.

Target 7.2 was associated with investigations carried out by Embrapa on new cultivars and on improvements of cultivars so that they can be used as energy crops. In addition, this target also includes the identification of waste with potential for use in energy and biofuels production.

Embrapa has been working with tools to evaluate the impact of technologies on the environment, as well as process technologies that use less energy than that commonly used in Brazil. These tools and technologies were associated with target 7.3.

This book is divided into six chapters, with the first and second chapters presenting theme contextualization and problematization. The next three chapters present the contributions of Embrapa to SDG 7. The final chapter presents SDG 7 as a tool for addressing the challenges of improving energy services so that they are accessible to the population.

Technical Editors

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Chapter 1

National commitments and participation of Embrapa

Rossano Gambetta
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Introduction

Brazil is a country of strong contrasts in the income distribution and in the life quality of its population. On the other hand, it is a country with great potential for growth due to its natural wealth, either by industrializing it or by the service sector that supports these activities or that serves the Brazilian population.

Within this context, agriculture is prominent in Brazil and is one of the activities with income distribution potential. The various agribusiness production chains can be strengthened by the industrialization of agricultural production, which includes energy production, generating more income outside the big cities, and making the rural production even more valuable. Like all human activities, these agricultural production chains generate substrates or waste, convertible into energy and other high value-added products, contributing to environmental sustainability.

Life and energy are intimately linked, because the organization of living things depends on the constant capture of external energy, to feed the numerous chemical reactions that maintain its organization and functioning. This connection appears in the evolution of living beings and, finally, in the very history of humanity.

From humanity point of view, the search for energy has led our ancestors to assume the role of collectors, hunters and, later, farmers, with concomitant energy demand and availability. Man went through the dominion over fire, which brought light into the darkness of the night, allowing the most efficient use of food and, at the same time, producing more complex tools than would be possible by only availing himself of his physical strength.

In the Middle Ages, because of the development of mathematics and engineering, man began to dominate the transformation of energy forms, either by mechanical devices (lever) or by harnessing the wind (windmills, irrigation and navigation) or water (steam machines). The combination of these factors gave birth to the Industrial Revolution, advancing to the present stage of humanity's development (Farias; Sellitto, 2011).

The maintenance of the current technological level and of the comfort it provides demands increasing energy expenditure to meet the demands of new technologies and a growing population. Notably, developed countries provide the means for their citizens to have access to food, health, education, etc. On the other hand, developing countries are unable to achieve the same levels of distribution. It is visible that the lack or the difficulty of access to energy has been an agent that reduces economic development, although great efforts have been made by the governments.

SDG 7 in the world

Today, the world is undergoing a major transformation in its energy matrix, which is now dominated by fuels and chemicals derived from fossil sources (e.g., oil, coal, natural gas, shale), which inevitably lead to greenhouse gases in the atmosphere, among other pollutants, ultimately impacting the global climate and the quality of life (health) of urban populations. Governments in several countries, or even economic blocs, have set emission reduction targets for these gases, usually leading to a commitment that includes increasing the use of renewable sources, either by generation of electricity, heat, fuels or by chemicals (Ren21, 2017).

In addition to the effects cited to the climate and the population health, fossil sources are concentrated in certain regions of the planet, which leads to social and economic inequality, provoking tensions, or even wars, among different nations. Renewable energies, in turn, are obtained locally – whether through the sun (solar or photovoltaic energy), wind (wind energy), tidal energy, potential energy from rivers (hydroelectric energy), from thermal sources (geothermal energy), or through biomass (organic material from animal or plant sources) –, and help reduce the inequalities introduced by the economy derived from fossil sources, generating energy security and income.

Today, renewable energy accounts for 19.3% of the energy consumed in the world and generates 9.8 million jobs, mainly in the photovoltaic and biofuels sector (Ren21, 2017). Global investment in renewable energy generation is roughly twice the investment in fossil fuel power generation in the last 5 years, and, in 2016, reached 241.6 billion dollars (Ren21, 2017).

Approximately 1.2 billion people do not have access to electricity (16% of the world's population) and 2.7 billion people do not have access to clean sources for the generation of heat to cook their food (Ren21, 2017). In part, renewable energy has contributed to reducing these numbers, since their distributed nature they can be obtained independently from the distribution networks at a lower cost.

Brazil and its commitment to SDG 7

In 2015, Brazil assumed the commitment to work towards the 17 SDG proposed by the United Nations (UN), which defined the year 2030 as the deadline to achieve the various targets that make up each SDG.

Our country has been active in SDG 7 with governmental actions, such as the recent Política Nacional de Biocombustíveis (National Biofuels Policy – RenovaBio), for the use of biofuels, such as biogas, ethanol and biodiesel from biomass as raw material. They can be produced in different regions of the country, including those farthest from oil refineries. They are also alternatives with smaller environmental impact. Some actions started decades ago, such as the 1975 Programa Nacional do Álcool (National Alcohol Program – Proálcool), which leveraged the use of ethanol and culminated with flexible-fuel technology, and the Programa Nacional de Produção e Uso do Biodiesel (National Program for the Production and Use of Biodiesel – PNPB), from 2004. Today, gasoline and diesel contain, respectively, 27% ethanol and 8% biodiesel in its composition, with the plan of increasing the former to 40% and the latter to 10% (Ren21, 2017).

Brazil is notable for the use of its hydroelectric potential (68.1%) to generate clean and renewable energy when compared to the use of coal or diesel (Balanço..., 2017). Clean energy is all energy produced without new emissions of polluting gases. In this case, wind, solar/photovoltaic, geothermal and hydraulic energies are included, as well as those resulting from the combustion of biomass and its waste, or biofuels derived from it (e.g., biogas, ethanol, biodiesel), where the emitted carbon dioxide is captured in the subsequent biomass culture.

Currently, Brazil has significantly increased its energy production from biomass, wind and photovoltaic energy, with increasing relevance in more remote regions where there is no electricity available (Balanço..., 2017; Ren21, 2017).

Brazil stands out with its agricultural production, in which the processing of sugar cane alone generates approximately 157 × 10 ^{6} t of bagasse (Leitão et al., 2017), which is used for the production of thermal energy, partly transformed into electric energy. An emerging technology is the production of second-generation ethanol from bagasse, with the potential to increase ethanol production by 30% without increasing the planted area (Embrapa Agroenergia, 2011).

Some regions of the country stand out for their use of waste from animal production through anaerobic digestion, production and use of biogas for energy purposes, and the use of digestate (sludge from anaerobic reactors) as biofertilizers (Kunz et al., 2016).

The role of Embrapa in the SDG 7 targets

In accordance with its mission in research, development and application of new agribusiness technologies, Embrapa leads several actions involving the production and efficient use of renewable energy. These actions are associated with providing energy to remote regions; crops of specific biomasses for energy production or for low productivity regions, the use of waste from agribusiness production chains, and proposing more efficient processes for energy usage.

Embrapa develops new cultivars to be used as energy biomass. The research seeks to improve its resistance to extreme climate conditions and changes (greenhouse effect, water deficit, seasonal variations, etc.) and low-quality soils, thus expanding the availability of biomass production, both for human consumption and for the production of chemical products and fuels. It is important to emphasize that even the production dedicated to human food generates waste in the countryside and in the city that can be converted into energy and high value-added chemical products, thus reducing environmental impacts.

Some technological advances produced by Embrapa include more efficient alternatives to energy production. This is achieved through so-called "energetic" varieties or even as an option for the sustained use of forests, such as firewood and charcoal. The cultivation of microalgae, by harnessing Brazilian solar potential and its potential application in the mitigation of CO_2 emissions from other production processes, has also been the object of research.

Embrapa studies several processes for the conversion of biomass into products with high added-value (chemical products, fuels, biomaterials, biofertilizers) and energy. Some conversion processes are applied to biomasses, such as oilseeds, producing oils used in the production of biodiesel. On the other hand, anaerobic biodigestion is applied, as a rule, to the agribusiness chain waste, aiming to aggregate value to these materials by means of mono- and co-digestion processes (Rede Biogásfert, 2018). Research is carried out throughout the production chain, from genetic modifications to improve yeast strains capable of fermenting the biomass for ethanol production, through new cultivars with higher sugar or oil content, or more efficient production processes, up to the use of waste as an energy source.

The research carried out by Embrapa involves the use of environmental assessment tools, such as the Life Cycle Assessment (LCA), which aims to increase the environmental efficiency of innovative products and processes. Thus, the development of new production processes to process agricultural raw materials always focuses on sustainability and leads to economic gains, generally to mitigate the use of electricity and inputs, and lower waste production.

Final considerations

The SDGs indicate the directions that must be taken to reduce inequality within each country. In this context, SDG 7 plays a key role in discussing alternatives so that energy is available to all, by encouraging the development and sustainable growth of humankind.

Brazil has abundant natural resources and a strong agricultural production, allowing the country to provide an energy matrix composed mainly of clean and renewable energy, either in the form of hydroelectric energy and energy derived from biomass or in the form of biofuels, biogas, ethanol and biodiesel.

Energy sources derived from biomass allow us to generate more income and jobs in the field and serve as an alternative to producers. In addition, the distributed nature of these energy sources makes quality energy available farther away from major centers or large production sites.

Thus, within the context of SDG 7, Embrapa has been seeking solutions to Brazilian agribusiness, with the objective of adding value to waste, developing and transforming biomass so that it can be used as an alternative energy source in our country.

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Chapter 2

What are the obstacles to universal access to energy sources in Brazil?

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Marcelo Henrique Otenio
Airton Kunz

Introduction

The availability of energy is linked to the development of several societies, since they depend on the implementation of infrastructure necessary to achieve good quality of life indicators, such as: public health; quality education; potable water supply services; waste collection and treatment; and food preparation and preservation; among others.

The main dimensions that affect access to energy when it comes to distributed systems are: difference between the cost of *off-grid* and distributor energy; fuel availability (including price stability/predictability); modularity, flexibility and solution placement time; the technology's learning curve is higher than that of fossil fuels; solution reliability and robustness; improved health by reducing pollution indoors; contribution to climate change mitigation; reduction in deforestation and environmental degradation; positive effect on women's empowerment; and poverty reduction for vulnerable groups (Ren21, 2017).

Next, some obstacles to universal access to energy in Brazil will be discussed.

Access to energy sources

Modern society lives a digital revolution; information travels the world at a speed and ease never before imagined. However, access to energy is necessary. Its lack means that a significant part of the population does not have access to much-needed information for its development, which increases social differences.

The use of wood (firewood) by the populations that have no adequate access to energy (either due to location or cost) is still a reality mainly in the preparation of food, and is often a type of income generation, in the form of charcoal for sale in urban centers. This activity is generally associated with the deforestation of native vegetation in the various regions of the country. At the same time, this practice is associated with health problems in the population exposed to the smoke produced inside the homes. Firewood and charcoal represent 8% of Brazilian domestic energy supply, including production for industries in various sectors (Balanço..., 2017).

Per capita energy consumption in terms of Tonnes of Oil Equivalent (TOE) in developing countries correlates strongly with quality of life indicators, such as life expectancy, infant mortality, illiteracy, and birth rate (Goldemberg, 1998). The same author points out that it is essential that per capita TOE per year exceeds the barrier of 1 for the development of society, since, as it reaches 2, a considerable increase in the quality of life occurs. The author also considers that, in 1998, Brazil had a per capita TOE per year of 1.3, with an expected growth in energy consumption of 4.6% per year, while population growth was at 1.3 % per year. Thus, it was estimated that, in 20 years, per capita TOE per year should reach values between 2.5 and 3, approaching the European Union average.

In 2016, the Brazilian population was estimated in 206,081,432 inhabitants and with an internal energy supply of 288,319,000 TOE, which leads to a per capita TOE per year of 1.40, well below expectations (Balanço..., 2017). This difference between the current value and the one projected by Goldemberg (1998) is due to the recent economic crisis, which left the gross domestic product (GDP) stagnant, while the population continued to grow. This caused the country to have growth rates lower than projected in the last decade, remaining stagnant when it comes to availability/consumption of energy and its consequent contribution to the quality of life.

The Human Development Index (HDI) – used by the United Nations (UN) and which considers life expectancy, education and gross national income – is another index that can be correlated with energy consumption. Brazil was classified in 2016 as a country of high human development, occupying the 79th position, with an HDI of 0.754. In 1990, the country had an HDI of 0.611. In 2002, this figure had already reached 0.699, passing through a period of fall and stagnation until 2006, when it began to recover and it reached its current level in 2013, followed by a new period of stagnation.

Steinberger (2016) presented a comparison between the HDI and per capita energy consumption using data for the year 2012. In this comparison, Brazil had an HDI of 0.74 and a per capita energy consumption of 63 gigajoules (GJ).

The author states that a high human development was reached, going from 50 GJ per capita, which equals an HDI above 0.7. The data shows that the energy consumption correlates with the HDI, as there is a saturation in which an increase of energy does not lead to significant HDI increases, and also that for the same energy consumption there is a great variation in the HDI, influenced by cultural factors in each country.

Brazil is already a prominent country in the production and use of renewable energies: 41.5% of the energy comes from sources such as hydroelectric reservoirs, wind (wind farms), sugar cane products (ethanol, bagasse and vinasse), oleaginous crops, animal fat and waste (biodiesel production), and firewood (thermal energy) (Balanço..., 2017). The data show that hydroelectric power generation has been stagnant in the last 10 years, during which there was a reduction in the consumption of firewood, a significant increase in the use of sugarcane and biodiesel, and a strong expansion in the production of wind energy. In recent years, photovoltaic energy has started being used and it tends to grow rapidly in the coming years. However, despite the increase in the use of renewable sources, there is still a need for public policies that prioritize investments in renewable and clean energy sources, seeking to achieve target 7.2, which addresses the increase of these sources in Brazil's energy matrix, from the promotion of research to the use of the newest technologies in the world.

Regarding access to energy, data from the 2010 IBGE Census indicate that of the 57,324,185 households in Brazil, 550,612 had some energy source other than the distribution company, while 728,512 had no access to energy (Table 1). The North region stood out from other regions of the country, both in the lack of access and in other ways to obtain energy.

The data show that access to energy in Brazil is, first of all, hampered by geographic issues and, secondly, by the population's own income, since in the absence of an electrical distributor, private solutions are adopted (Table 1).

In this case, government has to facilitate and cheapen access to distributed generation technologies compatible with each region. It should be noted that the existence of a specific solution to the energy supply, or even access to the energy of the electrical distribution company, does not necessarily provide adequate conditions to promote regional development on the basis of energy-dependent technologies.

Table 1. Households in Brazil with and without access to electricity.

Brazil and regions	Permanent private households	Existence of electric energy				Energy from another source (%)	No energy (%)
		Total	From a distribution company	From another source	No access		
Brazil	57,324,185	56,595,007	56,044,395	550,612	728,512	0.96	1.27
North	3,975,533	3,724,295	3,547,426	176,869	251,207	4.45	6.32
Northeast	14,922,901	14,583,662	14,460,942	122,720	339,087	0.82	2.27
Southeast	25,199,799	25,133,234	24,937,720	195,514	66,211	0.78	0.26
South	8,891,279	8,859,224	8,829,870	29,354	31,979	0.33	0.36
Midwest	4,334,673	4,294,592	4,268,437	26,155	40,028	0.6	0.92

Source: IBGE (2010).

Final considerations

Brazil has plenty of land and water, proven by its great agricultural production. In addition, it has plenty of sun light and wind in much of its territory. Agribusiness can produce biomass and waste that can be used for energy generation, which, together with wind and solar generation, allow energy to be generated away from the large centers of consumption and production (distributed generation).

In addition, the universalization of public electricity services has been addressed by the government since 2002, starting with the Programa de Incentivo às Fontes Alternativas de Energia (Incentive to Alternative Energy Sources Program – Proinfa) and in 2003 with the Programa Nacional de Universalização do Acesso e Uso da Energia Elétrica (Universal Access and Use of Electric Energy National Program – Luz para Todos), until recently becoming a responsibility of the respective local energy concessionaires/distributors.

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Chapter 3

Biomass and its participation in the Brazilian energy matrix

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Introduction

This chapter is linked to target 7.2 of SDG 7: By 2030, increase substantially the share of renewable energy in the global energy mix. This target seeks to provide cleaner energy through renewable energies and, at the same time, allow more people to have access to energy.

This chapter presents contributions from Embrapa to the research and promotion of new biomasses for use in the country's agriculture, as well as studies focused on waste produced in the various Brazilian agribusiness chains as sources of renewable energy.

Energy crops

Energy cultures, or crops, are those in which biomass can be directed toward energy production. Some examples are forests, sugarcane and forage, oilseeds (such as soybeans, African oil palm, and macaúba palm), and microalgae.

Crops with energy potential have been stimulated as more environmentally sustainable alternatives. Several of Embrapa's researches focus on understanding and minimizing the impact of agro-industrial activities on the environment and, in turn, the impact of these activities on these crops, against the possibility of climate change and related biological processes. Examples of these technologies developed by Embrapa: integrated production systems – integrated crop-livestock-forestry systems (ICLFS); eucalyptus varieties (BRS 9402, BRS 9801, BRS 8801, SCSBRS 0201), elephant grass (Cameroon, CNPGL F 06-3, BAG 02), and castor bean (BRS Energia and Gabriela).

Energy forests

In Brazil, forest biomass, represented mainly by firewood, was the main source of primary energy for over 450 years. In the 1950s, wood accounted for 75% of the total energy consumed in the country. Currently, due to the technological availability and the low cost of petroleum products, in addition to the large-scale production of electricity, forest biomass contributes only 8% to the national energy matrix.

Brazil has shown important characteristics to become a reference in energy production from forest biomass. It is located in a tropical region and has climatic and soil conditions suitable for the establishment of forest plantations, and extensive areas with potential for abundant biomass production.

There are currently 8 million hectares of planted forests in Brazil, of which 64% are eucalyptus forests present in over 500 Brazilian cities (Indústria Brasileira de Árvores, 2015). Current Brazilian demand is around 350 million cubic meters of wood, with eucalyptus forests accounting for only a third of the total annual demand. The use of planted forests in Brazil has grown significantly in recent years, mainly in the cellulose and paper segment and in the charcoal industry. Brazil has a broad technological domain on planted forest silviculture, with national and international recognition.

Embrapa develops research aimed at diversifying the potential species for biomass production, increasing productivity and reducing the impacts arising from this activity. This puts Brazil at a competitive advantage in global renewable energy production. However, it is still necessary to promote more actions to sustainably develop its production chain. This necessarily involves the prospecting, analysis and development of technologies aimed at increasing the production and quality of biomass, together with improving the processing, transformation and applications of its energy products. However, there is a lack of consolidated long-term public policies to leverage the use of bioenergy in Brazilian agribusiness. Currently, there is hope in this field with the implementation of the Política Nacional de Biocombustíveis (National Biofuels Policy – RenovaBio, Law 13,576/2017), announced as a new legal framework for biofuels in Brazil. According to the Ministry of Mines and Energy (Brasil, 2017), the RenovaBio program is a state policy aimed at drawing up a joint strategy to recognize the role of all types of biofuels in the Brazilian energy matrix, both for energy security and to mitigate and reduce greenhouse gas emissions.

In recent years, although Embrapa has participated in advances in technology development, there are still important challenges to be faced, such as: a) supply of germplasm to implement forests adapted to the different realities of the Brazilian territory; b) increased silvicultural knowledge to raise crop productivity, both in integrated and non-integrated systems; c) improvement of the technological level usually adopted in traditional forms of converting wood into energy, such as firewood and charcoal; d) advancement in the knowledge and development of technologies of high added value, such as wood alcohol, bio-oil and others. All this is aimed at the production of more elaborate energetic products destined to more specific applications from the wood.

Sugarcane and fodder

Sugarcane (*Saccharum officinarum*) and some other fodder can be used as biomass to produce renewable energy, mainly ethanol. Brazil has already mastered the technology to produce the first-generation ethanol (1G ethanol) and has the industrial infrastructure and knowledge necessary to implement the production of second-generation ethanol (2G ethanol) from sugarcane biomass. The major challenge in this regard is biomass recalcitrance, that is, the rigidity provided by the chemical structure of biomass components, which prevents the release of fermentable sugars. Thus, it is necessary to investigate and develop new varieties of plants that have less recalcitrance in their biomass.

In this context, Embrapa Agroenergy has been a pioneer in the development of new biotechnological tools to develop new sugarcane varieties with greater accumulation of biomass and less recalcitrance. The use of gene-editing technology, which does not involve the creation of genetically modified organisms (GMOs), has been developed and used for the genetic engineering of sugarcane with the aforementioned characteristics (Waltz, 2016). In addition, the development of new varieties that have greater efficiency in the use of water has also been carried out at the Embrapa Unit. This is an essential factor for the cultivation of sugarcane in marginal, poorly irrigated areas that are not intended for food crops. Besides cane, other fodder species have also been studied to produce biofuels.

The genetic variability of tropical fodder found in Brazil allows the study of several genotypes that can be used to produce ethanol, together with integrated industrial processes that fit into the reality of the sugarcane industry. The integration of these processes also involves the cogeneration of energy, such as the electric energy generated in the sugarcane bagasse mills. The development of these processes at Embrapa is through public-private partnerships with the sugar-energy sector, and this will enable the viability of cellulosic ethanol on a commercial scale. In addition, events with the participation of political actors are also in the strategic plans of Embrapa, for an expansion of scientific knowledge combined with public policies that may lead to a substantial increase in Brazilian participation in the development of renewable energy in the global energy matrix.

Oilseeds

The implementation of the Programa Nacional de Produção e Uso de Biodiesel (National Program for the Production and Use of Biodiesel – PNPB) in Brazil in 2005 led to the partial and progressive replacement of fossil fuels for heavy vehicles in Brazil (Brasil, 2005). Oils and fats are the core renewable raw materials for the production of biodiesel (Othman et al., 2017). The immediate availability of renewable fatty source in Brazil relied on soya, Brazil's main agricultural crop. However, dependence on a single crop, whose oil yield per planted area is low (approximately 500 kg/ha), has led to the need for alternative sources with higher energy density. Multidisciplinary and multi-institutional projects were and are being conducted by Embrapa, in order to create technologies for other oil bearing plants with high yield potential. The researches encompass the domestication of native species such as the macaúba palm (*Acrocomia* spp.), which has an oil production potential higher than 4,000 kg/ha (Cardoso et al., 2017) and can be cultivated as a single crop as well as agroforestry and livestock integration systems in several biomes, such as the Semiarid region and *Cerrado*. The domestication of exotic species such as the physic nut (*Jatropha curcas*) and tung tree (*Vernicia fordii*) are also being studied. Projects to increase palm cultivation (*Elaeis guineensis*, of African origin; *Elaeis oleifera*, of American origin) – which, despite the traditional cultivation and high oil yield (Brazilian average of 3,500 kg/ha), is restricted to areas of high rainfall found in the Amazon and Recôncavo Baiano regions – are underway and involve from genetic improvement to the use of waste. Germplasm banks of macaúba palm, physic nut and African oil palm make up important assets of Embrapa to subsidize studies with these species.

In addition to Embrapa Agroenergy, several other Embrapa Centers are working together in these studies, in order to strengthen this line of research, development and innovation. As a result of this effort, the macaúba productive chain was promoted in the states of Mato Grosso do Sul, Minas Gerais and in the semi-arid state of Ceará (Sousa et al., 2019). Commercial scale macaúba plantations are being established in Minas Gerais (Cipriani, 2017), and public policies for extractive exploitation have been established and already benefit family farmers (Brasil, 2014). Annual crops are also under study. An example, is the work for the tropicalization of canola (*Brassica napus*), envisaging its cultivation in Central Brazil (Laviola, 2017).

Microalgae

Embrapa has also been active in algae research. For example, the Nextbio Project has as a target, in addition to oilseed plant species, the improvement and algal culture systems for the production of lipids (Laviola, 2017).

There is great global interest in exploiting the biotechnological potential of microalgae. However, one of the major limitations in the production of this type of biomass on a large scale is the high cost of the nutrients needed to formulate the culture medium.

The use of livestock effluents as an alternative source of the culture medium is adequate for the growth of microalgae and can be promisingly applied for large-scale biomass production. Concurrently with the microalgae production process, the nutrients present that may potentially cause eutrophication of the water bodies are partially removed, reducing or eliminating the environmental impacts from livestock activities.

The microalgae produced during the treatment of effluents are collected and can serve as feedstock for the production of ethanol (at 0.5 g/g of sugar per microalgae), animal feed (contains 56% proteins), and/or methane when algae are used as substrate for anaerobic digestion generating 0.6 L/g of methane per microalgae.

Therefore, effluent treatment systems based on the production of microalgae can become a sustainable and economically attractive option, presenting itself as an interesting opportunity in the agribusiness business portfolio.

Waste

Waste from agribusiness production chains, including industrialization and even the end consumer, poses a major threat to the environment, and the health and quality of life of people. However, with the use of appropriate technologies, they can be harnessed in distributed energy production, thus generating clean, renewable and quality energy in places normally far away from the large production centers.

Use of agricultural, forestry and agro-industrial waste

Wastes are raw materials that do not have viable uses yet, both from a technical and an economic point of view. The challenge is to transform the byproduct of one process into another, providing the full use of resources, generating income and jobs, reducing pressure on the environment, and increasing the profitability of the enterprise. Embrapa's Research and Development (R&D) and Technology Transfer professionals have always been involved in the search for technological solutions applied to the conversion of waste into products with higher added value.

The generation of energy with organic waste can take place via thermal or biological processes, universally known as bioenergy and biofuel. Agricultural wastes are related to crops for the production of food, fiber or biofuels, such as sugarcane straw, rice straw, ratoon cotton, etc. Livestock wastes are mainly animal manure, chicken litter, etc. Forest wastes are the remains of forestry, such as thin branches, leaves, bark, etc. The industrial residues are sugarcane bagasse, vinasse, rice husk, tallow, sawdust, shavings, black liquor (cellulose industry), the result of oil extraction by pressing, coconut husk, corn husk and cob, peanut shell, etc. Municipal solid wastes (MSW) are the organic fraction, sludge from sewage treatment plants, used frying oil, pruning of urban trees, etc.

To quantify agricultural waste, there are indexes that relate the agricultural production of each product to the amount of waste generated. For example, for rice it is 30% of husk, considering rice production in the shell (IBGE, 2015). According to Balanço... (2016) the following information is given: for coconut, an average weight of 500 g per unit is considered, with 60% waste; for livestock waste, there are also amounts of manure per animal head; for MSW there are several studies, and the average value in Brazil is about 1 kg/inhabitant/day. In the case of sugarcane bagasse, which is widely used in cogeneration (heat and electricity), the country produced 121 million tons in 2016 and consumed all of this to generate energy; another waste is the black liquor, with 16 million tons produced that year and consumed for energy generation (Balanço..., 2016). Figure 1 presents several agricultural products characteristic of Brazil with their respective production and generated residues.

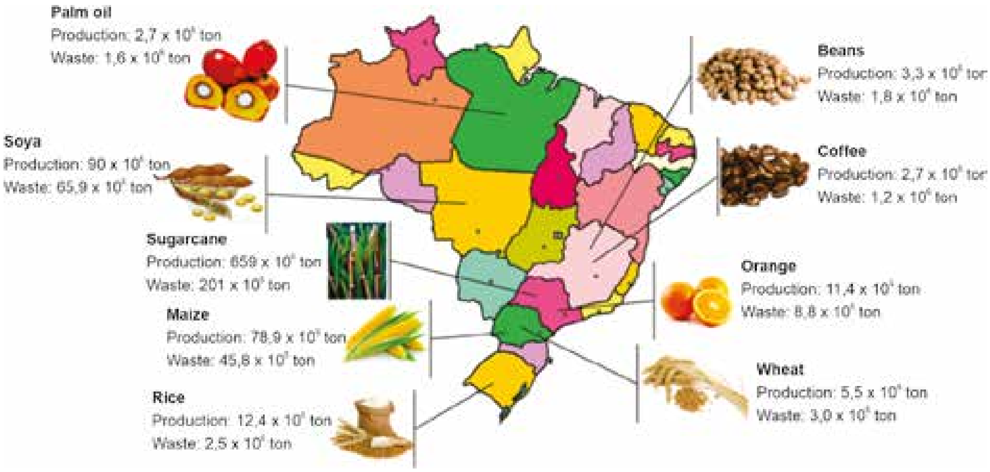

Figure 1. Estimate of agricultural production in Brazil and its respective waste production.

Source: Conab (2017).

Cogeneration technologies are well known and use steam cycle boilers, steam and gas turbines. Compaction by baling, briquetting or pelletizing can be used as a logistics solution. Waste with high moisture content, such as manure, vinasse, and municipal solid waste, can be used as a substrate for anaerobic fermentation in a biodigestor to produce biogas with a high methane content, to converse into energy (electric or thermal), as well as producing biofertilizers.

Livestock waste

Animal production in Brazil has undergone several changes in the last 3 decades, migrating from subsistence systems to industrial systems based on animal confinement (Kunz et al., 2009). This trend has placed the country as the second largest producer and world leader as an exporter of chicken meat, with 13 million tons produced and 4.3 million exported in 2016 (Associação Brasileira de Proteína Animal, 2017). Regarding egg production, it has surpassed 39 billion units, and, for turkey meat, there were over 367 thousand tons in 2016, of which 38% were exported (Associação Brasileira de Proteína Animal, 2017). According to the Central de Inteligência em Aves e Suínos (Poultry and Swine Intelligence Center), Brazil stands out as the fourth largest producer and exporter of pork in the world, surpassing 3.7 thousand tons of protein produced annually (Embrapa Suínos e Aves, 2017). In addition, the intensive raising of dairy cattle is in full development (Mao et al., 2015). Between 1996 and 2013, there was approximately 40% increase in milk production in Brazil (Cavicchioli et al., 2015). The Brazilian production of this product in 2014 was 35.2 billion liters (IBGE, 2015).

Thus, based on its large production volumes as an important economic source, intensive livestock production is highly representative of waste generation. Animal waste and other waste related to the production of these animals need alternatives for treatment and disposal to mitigate the environmental impacts. As a comparison, by rule, a pig has a polluting potential equal to ten people (considering nitrogen). Among the treatment routes, we note its potential as a source of energy in a consortium with the use of nutrients in soil fertilization (Kunz et al., 2009).

The biological route is a highlight in this context, especially due to the opportunity to convert organic matter from cattle and pig waste into biogas, but there is also an opportunity for thermal energy use (e.g., poultry and/or turkey litter, litter bed overlapping of pigs or even byproducts of cattle *compost barn* systems). Although it currently accounts for only 0.9% of the Brazilian renewable electricity matrix, it is estimated that the biogas generation potential from animal waste is higher than the generation capacity of the Itaipu hydroelectric plant. The challenge consists of logistics for the use of this raw material, which has been instigated through public policies such as the Plano de Agricultura de Baixo Carbono (Low Carbon Agriculture Plan – ABC) (Brasil, 2016) and the RenovaBio Program (Brasil, 2017), with direct contributions from Embrapa through technical-scientific information.

Embrapa has developed research to improve the energy use of these wastes through laboratory structuring and networks coordination, such as the Rede BiogásFert. This network, for example, has been studying and organizing information regarding technologies to produce and use biogas and fertilizers from the treatment of animal waste under the Agricultura de Baixa Emissão de Carbono (Low Carbon Emission Plan – ABC) and is, therefore, directly linked to SDG 7.

Final considerations

Embrapa has been active on several fronts, seeking to obtain and optimize energy sources from plant biomass, which can be called energy crops. New varieties developed and adapted to the different Brazilian biomes have been studied with very promising results.

From the perspective of agricultural waste, due to its tropical condition, our country is immensely competitive when compared to other nations (e.g., the European community), and this potential has been addressed by adapting and developing alternatives to Brazilian conditions.

Therefore, the increase in the share of renewable energies in the energy matrix has a direct impact by reducing emissions and, because of their distributed nature, by bringing energy to more needy regions.

Embrapa's future challenge is to continue current research and offer other types of crops with which farmers can generate more income in the field, making it possible to use this biomass as an energy source.

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Chapter 4

Energy production processes

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Introduction

Renewable energy sources are those that have a continuous existence and availability. Examples of these sources are solar/photovoltaic, wind, geothermal, tidal and biomass energy. For example, it is possible to have this energy in the form of electric energy, or in the form of biofuels.

Wind energy is obtained by the use of wind turbines, while photovoltaic energy is obtained by the use of materials that convert photon energy into electricity; and the conversion of biomass to energy takes place through the use of industrial processes, in which several operations are linked, from the conditioning of the raw material to the final products.

In this chapter, several processes developed by Embrapa for the conversion of biomass, cultivated or from waste, into energy will be presented, as well as photovoltaic and wind energy applications implemented by Embrapa, considered as contributions to reach target 7.1 of SDG 7: By 2030, ensure universal access to affordable, reliable and modern energy services.

Biogas energy

Biogas originates from the anaerobic digestion of organic matter present in biomass. It is a product obtained from the biodigestion of agro-industrial waste, usable in the generation of heat, electric energy or even as vehicular fuel.

Among the constituents of biogas, there is methane: a combustible gas that can be used for thermal recovery, electric power generation or even as fuel for motor vehicles. In thermal use, biogas is the main substitute for liquefied petroleum gas, coal and firewood, especially in rural areas and small communities. In these places, small-scale biodigesters, which use animal waste as raw material, enable the use of biogas in the preparation of food, in the heating of water for sanitation, in addition to allowing the processing of food from family farming and avoiding health problems caused by the aspiration of smoke/soot derived from the burning of charcoal or firewood. In industrial scale, the use of waste allows the use of biogas in steam generators, reducing production costs (waste treatment and substitution by other higher value fuels), which is reflected in the mitigation of the cost of preparing the final product.

Besides its thermal use, the generation of electric energy from biogas is already a reality in Brazil. With the creation of Aneel Normative Resolutions 414/2010, 482/2012 and 687/2015 (Agência Nacional de Energia Elétrica, 2012, 2015, 2016), it became possible to access microgeneration and distributed minigeneration to the distribution electricity systems and the energy compensation system. This allows the conversion of biogas into electricity by a generator set connected to the distribution network. This possibility strengthens energy security in rural areas, allowing greater availability of energy to distant regions, as well as increasing the competitiveness of agro-industrial processes by reducing energy costs.

An important alternative is the possibility of using biomethane (purified biogas) instead of natural gas. The recent Resolution 08/2015 (Agência Nacional do Petróleo, Gás Natural e Biocombustíveis, 2015) regulated the use of biomethane for injection in the natural gas network and also its use as a vehicular fuel. Industries ranging from metallurgy, ceramics, textiles, fertilizers to food processing utilize natural gas, which comes from outside sources, causing direct dependence on other countries. The possibility of using biomethane, despite its higher costs, allows an increase in the energy autonomy of these industry sectors.

As a source of raw material (biomass) for the generation of biogas, the sugar-alcohol sector (vinasse) and the agricultural sector (animal waste) stand out as huge carbon source suppliers. Embrapa has collaborated directly in the production of knowledge and implementation of biomass to biogas transformation technologies (Cestonaro et al., 2016; Steinmetz et al., 2016). The challenges are to know the availability of biomass in Brazil, to adapt the digestion process to the regional and socio-environmental conditions, as well as to search for logistic and digestion destination (e.g., water reuse, soil fertilization) solutions (Miele et al., 2015; Bilotta et al., 2017). We highlight the Rede BiogásFert, created in partnership with Itaipu Binacional, to offer to society technological solutions for the integrated production and use of biogas and organic and organomineral biofertilizers from animal waste in the different agricultural production systems. Rede BiogásFert has a partnership with several universities, rural extension agencies and innovation centers such as CIBiogás (Centro Internacional de Energias Renováveis – Biogás).

Other small-scale investigations are also underway at Embrapa, involving several types of biomass/waste (such as banana pseudostem, glycerol, green coconut bark, palm oil) (Leitão et al., 2009, 2011, 2012a, 2012b, 2013; Viana et al., 2012a, 2012b; Costa et al., 2014a, 2014b), different types of bioreactors, various biomass pretreatment methods for increasing conversion efficiency in biogas (Costa et al., 2013, 2014a, 2014b; Silva et al., 2014), etc. There are some researches in biodigestion with a focus on obtaining hydrogen (another fuel gas) (Viana et al., 2014; Vasconcelos et al., 2016) and compounds such as butanol and organic acids (Guilherme et al., 2016), or even from the conversion of methane itself into other products, such as hydrogen (steam reforming).

Biodiesel energy

Biofuels have played a very important role in the country's energy matrix. The energy supply from biomass is almost double the energy from oil products (8.0% from the first one against 4.8% from the second) (Balanço..., 2016). In the case of biodiesel, in 2016, 3.8 million cubic meters of biofuels were produced in the country (Agência Nacional do Petróleo, Gás Natural e Biocombustíveis, 2017).

Since the addition of biodiesel to the national energy matrix in 2005, several types of research have been carried out, either about the availability of raw materials, the efficiency of the production process, also seeking catalysts that allow a lower generation of effluents, or about product quality, which extends from the storage to the end consumer.

Embrapa Agroenergy conducted investigation on improving the quality control of the product and its production process, e.g. the process of refining oil from macaúba pulp and in the process of obtaining high quality crude oil from macaúba pulp, either by a chemical or enzymatic route, from raw materials of high acidity, such as palm oil. Following the chemical route, the hydrodeoxygenation processes have been investigated in addition to the transesterification to create hydrocarbons with chain similar to biodiesel.

Working in partnership with other research centers and regulatory agencies in developing methods to guarantee the quality of biodiesel, Embrapa is contributing to provide reliable energy access. In turn, the research related to process improvement seeks to reduce the negative impacts on production, in favor of sustainability, in addition to increasing efficiency, thus contributing to the achievement of target 7.3.

First- and second-generation ethanol

Bioethanol is proven to be a renewable substitute for gasoline from petroleum. Its world production in 2016 was 97 billion liters, with 57% being produced from corn and 27% from sugarcane, the two main raw materials for this commodity (Renewable Fuels Association, 2017). This bioethanol is commonly known as first-generation ethanol. In Brazil, the production of bioethanol occurs mainly from sugarcane, the main raw material in the manufacture of sugar (sucrose). However, contrary to what is reported regarding energy versus food competition, much of the ethanol produced from sugarcane uses a byproduct as a carbon source: non-crystallizable molasses, from which it is not possible to produce crystal sugar and therefore cannot be traded at competitive prices.

In addition to bioethanol produced from simple sugars such as sucrose, the world today is looking for technologies to produce this fuel from lignocellulosic materials, the so-called second-generation ethanol. It should be noted that there are some industrial plants in operation in the world, such as the DuPont plants, the Spanish Abengoa, and Poet-DSM, located in the United States. However, the economic competitiveness of this type of ethanol still leaves a lot to be desired. Embrapa has been developing research on the production of first-generation ethanol from rice, sorghum and sugarcane juice (Pacheco et al., 2014; Almeida et al., 2017), and has also been active in research on the production of second-generation ethanol, mainly from sugarcane bagasse. Research aimed at the development of new enzymes, such as the following: catalyzed cellulose hydrolysis process by immobilized cellulases; filamentous fungi producing efficient enzymatic complexes for the hydrolysis of sugarcane bagasse pretreated by vapor blast; filamentous fungus genetically improved for the production of cellulases and hemicellulases; genetically modified filamentous fungus for increased production of polysaccharide degrading enzymes; lineage of Komagataella phaffii (*Pichia pastoris*) producing xylonic acid; new fermenting microorganisms; as well as improvements in the pretreatment process efficiency of lignocellulosic materials such as: organosolv process applied to lignocellulosic biomass; lignocellulosic biomass pretreatment process by autohydrolysis (hydrothermal treatment). The higher the production of biofuels at fair prices and in larger quantities, the less and less dependent on oil Brazil becomes. Thus, Brazil may have access to more clean, renewable and safe energy sources since the production and use of bioethanol is a cyclical chain.

Solar and wind energy

The exploitation of soil and water has given economic support to the Brazilian rural environment. Other resources, such as labor that is being replaced by mechanization, have made our country a powerhouse in agricultural production. The greater demand for energy increases production costs, which may determine the need to exploit other unused resources for its feasibility.

Normative Resolution 482 of Aneel (Agência Nacional de Energia Elétrica, 2012), enabled the possibility of electricity consumers connected to the grid being energy generators, and that generated energy can be commercialized in the form of credits with the distributor. Therefore, other rural energy sources, such as hydric, biomass, wind, and solar radiation, may be better and more easily harnessed as power generation on the property.

Solar energy, which is the main source of energy in the rural environment, is both capable of generating thermal energy as well as electricity directly. Depending on the equipment, this inexhaustible source can supplement the income of the rural property, which has the necessary conditions for it, because the space and availability for solar radiation are abundant. Photovoltaic panels, which are the main equipment for transforming solar energy into electrical energy, have semiconductor cells that, when illuminated, generate a potential difference by releasing available electrons as electric energy. Panels that take advantage of solar thermal energy are devices that, by heating liquids, like water, serve as an energy source for various utilities.

Wind energy, which is the kinetic energy of displaced air masses, is dependent on the pressure differences created basically by the difference in the radiation balance and is influenced by the movement of the earth and the friction with the earth's surface. It is an inexhaustible source of energy, proportional to square the wind speed. It has long been used for electricity generation and water movement.

With the evolution of technologies and legislative norms, Embrapa sees the possibility of increasing the income of the property with the use of these resources there. Historically, agricultural research monitors agrometeorological variables for its own use. For this reason, Embrapa has a collection of meteorological data capable of evaluating the conditions of electricity generation in rural areas. Besides this collection, it has a large number of researchers and laboratories specialized in agrometeorology, as well as a network of partnerships in all the states of the country.

With the necessary conditions to evaluate the energy potential in the rural environment, the Embrapa is able to evaluate the performance of equipment inserted inside the property, in order to verify the technical and economic feasibility of the existing technology and to recommend the correct use.

To serve as an instrument capable of informing public policies and a guide for the use of viable techniques to generate income in a rural property, Embrapa has approved projects to teach the producers about a new form of production. Results have shown the feasibility of using electric generation techniques. Despite restrictions on the quantity generated, changes may favor the producer to make these solutions more important, especially to the family producer (Figure 1). It has also been shown that in properties with areas smaller than 50 ha, it is possible to generate, with small facilities, twice as much as the largest thermoelectric plant in the state of Rio Grande do Sul.

Through partnerships with research and teaching institutions, Embrapa has conducted research that can improve the living conditions of the rural producer, such as an automatic solar irrigator made with used bottles or a solar collector to disinfect substrates and produce healthy seedlings, making electricity generation a source of income and, this generation, the new Brazilian agricultural product.

Photo: Paulo Lanzetta

Figure 1. Photovoltaic power generation unit (Embrapa Temperate Agriculture).

Final considerations

Embrapa is seeking new processes to implement energy generation technologies that can be used by the Brazilian rural environment, in the case of photovoltaic and wind energy and biogas production. Another facet is the development of the biogas and first- and second-generation biodiesel and ethanol attainment processes.

The great challenge remaining is how to adapt these technologies and processes to the reality of our country, where often these processes cannot be transferred due to the investment capacity and understanding of its limits. This obviously creates opportunities for Embrapa to help come up with mechanisms to transduce these concepts in different situations.

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Chapter 5

Energy efficiency

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Introduction

Energy efficiency is at the heart of target 7.3 of SDG 7: By 2030, double the global rate of improvement in energy efficiency. This way, technologies that can, directly or indirectly, reduce energy expenditure and achieve the same objective, are included as a contribution to this target.

The Life Cycle Assessment (LCA) is one of the ways used to assess this gain in terms of process sustainability and is one of the themes developed by Embrapa. Here are some examples of this type of technology in which the energy expenditure developed at Embrapa is reduced: concentration of tangerine juice by reverse osmosis; concentration of watermelon juice by reverse osmosis; concentration of melon juice by reverse osmosis; concentration process of acai juice anthocyanins by nanofiltration; concentration of pineapple juice by reverse osmosis coupled with osmotic evaporation; concentration of acerola juice by reverse osmosis coupled with osmotic evaporation; microfiltration process of melon juice; concentration of grape juice by reverse osmosis.

Life Cycle Assessment methodology

The production of renewable energy and its availability must be implemented efficiently, i.e., its application should generate a greater benefit for the same amount of energy used. To have this kind of development in the first place, we must have ways of evaluating the use of energy within the various production chains. One tool available for this use is the LCA, which will be the focus of this chapter. LCA is the most appropriate tool in the environmental process and the product evaluations (Baumann; Tillman, 2004).

The main energy-related impacts are acidification, eutrophication, climate change, and water scarcity (Turconi et al., 2013). While international targets and national policies have a focus on climate change (Empresa de Pesquisa Energética, 2015), there are a number of other environmental damages caused by energy production activities. Some examples: a) the consumption of water in thermoelectric production, as well as its evaporation in hydroelectric reservoirs, can lead to water scarcity; b) nitrogen and sulfur oxides emissions released by thermoelectric plants contribute to soil acidification; c) the agricultural production of energy-rich species and the flooding of areas with vegetation cover emit nutrients that may cause eutrophication.

Thus, in order to better understand and reduce the occurrence of these impacts, guaranteeing the production and consumption of clean energy in Brazil, it is important to use environmental assessment tools to choose and improve energy-consuming production processes applied to energy-consuming companies. Among the tools available, it is worth mentioning the LCA, which has a procedure standardized by ISO 14040 and ISO 14044 (International Organization for Standardization, 2006a, 2006b).

LCA studies quantify the potential environmental impacts, considering the production chain, consumption and post-consumption of processes and products, be they in development or in use. These studies are related to a unit produced, consumed or discarded of the product, allowing comparisons between similar processes and products, identifying critical points in the processes that integrate the life cycle of a product and the evaluation of future scenarios. According to Lelek et al. (2016), the assessment of national energy systems using the LCA approach makes it possible to identify the environmental effects and consequent critical points of the electrical system.

The Brazilian energy production LCA, considering current and future scenarios for the Brazilian energy matrix, was performed by Martínez et al. (2015) and Moore et al. (2017). On the other hand, the energy consumption LCA is dependent on the user process, involving several production chains. Thus, efficiency and lower environmental impact on energy consumption depend both on energy source choices and on the production processes employed.

LCA studies carried out by Embrapa and its partners are focused on ensuring energy efficiency in production processes. These studies have supported decision-making in agricultural and agro-industrial production, in the definition of sustainable public policies, and in the technological innovation process.

Several renewable energy sources – such as sugarcane, corn, soybeans, eucalyptus, bovine tallow, agricultural and agro-industrial waste – and their byproducts – such as first- and second-generation ethanol, biodiesel, bio-kerosene and biomethane

– have been analyzed in Brazil (Folegatti-Matsuura et al., 2011, 2017; Seabra, 2011; Nogueira et al., 2014; Chagas et al., 2016; Junqueira et al., 2016; Cavalett et al., 2017; Simioni et al., 2017). These studies guide the production sector in the choice of biomass sources and less polluting production processes.

Together with the government, some studies developed by Embrapa and its partners are subsidizing public policies – such as the Política do Banco Nacional de Desenvolvimento Econômico e Social (National Bank for Economic and Social Development Policy – BNDES) for the financing of *flex* power plants, the RenovaBio Program (Brasil, 2017) and the Força Tarefa para Combustíveis Alternativos da Organização da Aviação Civil Internacional (International Civil Aviation Organization's Alternative Fuel Task Force – AFTF/Icao) (Plano..., 2013).

In the first of these studies, BNDES sought to find out the environmental performance of the integrated production of ethanol from sugarcane and corn in *flex-fuel* plants and to confirm whether this new biofuel would meet the "advanced biofuel" standard determined by the United States Environmental Protection Agency (EPA). According to EPA, biofuel is classified as "advanced biofuel" when greenhouse gas (GHG) emissions are equivalent to a maximum of 50% of fossil fuel emissions. In all the technological scenarios studied, the energy balance of ethanol was extremely favorable (ranging from 5.5 to 6.9) and the reduction of GHG emissions was higher than 65% (compared to gasoline emissions). The information produced by these studies guided the Bank's financing policy for projects of this nature (Milanez et al., 2014).

Another study supports the new Política Nacional para Biocombustíveis (National Biofuel Policy – RenovaBio) (Law 13,576/2017). In this initiative, at the request of the Ministry of Mines and Energy, Embrapa coordinates the technical group that is elaborating the methodological reference and the tool to calculate the carbon intensity of biofuels (RenovaCalc). The difference between the carbon intensity of the biofuel and the equivalent fossil fuel generates an environmental energy-efficiency score, which will give access to de-carbonization credits (CBio), traded on the stock exchange. A certification scheme is also being developed to support the program (Brasil, 2017).

The third study mentioned above aims to define a methodology to calculate GHG emissions from aviation biokerosene obtained from different technological routes (including different raw materials and industrial processes), including those with potential for production in Brazil. This research is part of the efforts of Comitê de Proteção Ambiental na Aviação (Icao's Committee on Aviation Environmental Protection – Caep) to reduce GHG emissions caused by the sector (Plano..., 2013).

Regarding the technological innovation process, LCA studies of bioproducts and their innovative production processes have been carried out to improve their environmental performance, including energy performance (Figueirêdo et al., 2012; Nascimento et al., 2016a; Freire et al., 2017). Products resulting from the use of agricultural and agro-industrial waste can be mentioned, according to the biorefinery model, as nanoparticles applied to packages.

These studies were conducted throughout the technological development process so that at the end of the second process, when innovation is offered to society, the bioproducts have less impact than similar products already available. Some examples: bacterial cellulose from soy molasses; collagen and gelatin from tilapia waste; starch, thermoplastic starch, pectin, lignin, phenols, cellulose, and nanocellulose from mango peel and core; caproic acid and lignin from sugarcane bagasse; emulsions for the controlled release of drugs from various wastes; aerogels and hydrogels from various plant fibers (Figueiredo et al., 2010, 2012; Nascimento et al., 2014, 2016a, 2016b; Freire et al., 2015, 2017).

Final considerations

Life Cycle Assessment (LCA) is an important tool in the evaluation of sustainability gains, and energy efficiency is one of these components. This assessment has received attention and relevance in recent years and has been incorporated into various policies and programs (public or private). A recent example was its use within the RenovaBio Program since it will be used directly in the calculation of decarbonization credits (CBio), in which the methodology will be able to differentiate more efficient factories or processes, which will then receive more credit.

Embrapa, due to its outstanding position in the agribusiness production chains, plays an important role in pointing out more sustainable paths for each link in the production chain. This position of prominence and influence must be cultivated more and more, and, for this, LCA must become more and more robust and reliable, and the resulting processes must be widely reported to society.

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Chapter 6

SDG 7 as a tool to improve population access to energy services

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Introduction

The Sustainable Development Goals (SDG) are an effective way of directing the efforts of nations towards reducing social differences in Brazil and in the world while seeking ways to contribute to environmental sustainability.

SDG 7 – Affordable and clean energy: "ensure access to affordable, reliable, sustainable and modern energy for all" – and its three targets: "7.1 By 2030, ensure universal access to affordable, reliable and modern energy services 7.2 By 2030, increase substantially the share of renewable energy in the global energy mix 7.3 By 2030, double the global rate of improvement in energy efficiency" (United Nations, 2017) – help direct actions regarding the relationship between energy production and its sources considering different societies.

Brazil, considering its continental dimensions and the social inequality of the population, needs to look for different solutions that better serve its different realities. Embrapa, thanks to its presence throughout the national territory, is a lead actor creating solutions for the problems found in the different regions of the country.

Perspectives and challenges

It should be noted that there is a need to increase alternatives and access to renewable energy. Federal public policies should be expanded and strengthened to reverse this situation. Embrapa has been working on the development of several cultivable biomasses, not only for human consumption but also for use in the production of energy and liquid fuels. The research tends to be related to more productive varieties, alternatives to traditional crops and alternatives for extreme climate or degraded soils regions, adding new productive areas throughout Brazil.

As agribusiness in Brazil develops, so does the production of waste in the countryside and in the cities. This waste can go through transformation processes in which clean energy is generated, offering as a bonus the treatment and disposal of waste that would otherwise be improperly disposed of in the environment, increasing the size of sanitary landfills.

Another important point is to guarantee the access to energy, preferably renewable, to the populations in regions of difficult access, mainly in the North region of the country, where 6.32% of households do not have access to energy (IBGE, 2010). There is a strong correlation between energy availability and consumption and important social indicators, such as life expectancy, infant mortality, illiteracy, and fertility rate, i.e., it is essential to bring energy to populations that do not have access to it. In addition, access to energy can enable the industrial and service sectors to settle and prosper, generating more income and employment locally.

Embrapa develops and uses tools such as the Life Cycle Assessment (LCA), contributing to evaluating the energy efficiency of various production chains products and the key points in which we can act to obtain greater efficiency gains in these chains. The development of more efficient processes applied to agribusiness also contributes to this component.

Finally, Embrapa, thanks to its vocation and presence in rural areas, is in contact with and knows the needs of the different productive chains in our country. Several technologies being developed or reported by the corporation have been helping solve problems of access to energy.

Fossil fuels continue to be available in quantities and values low enough that already known technologies cannot find a place in the consumer market. Thus, research to make agribusiness raw materials cheaper and to make processes more efficient and cheaper is necessary. With the viability of these technologies, it will be possible to provide clean (when compared to fossil fuels), renewable and distributed energy to the population.

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