Chapter 19

An Overview of Biodiesel Production in Mexico

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Additional information is available at the end of the chapter

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1. Introduction

In Mexico, the primary energy is constituted of 88.5% oil and natural gas, 3.6% coal, 1% nuclear and 6.9% renewable energy as is illustrated in Figure 1. Renewable energy is comprised by 1.7% geothermal, solar, wind; 1.3% hydro and 3.9% biomass [1].

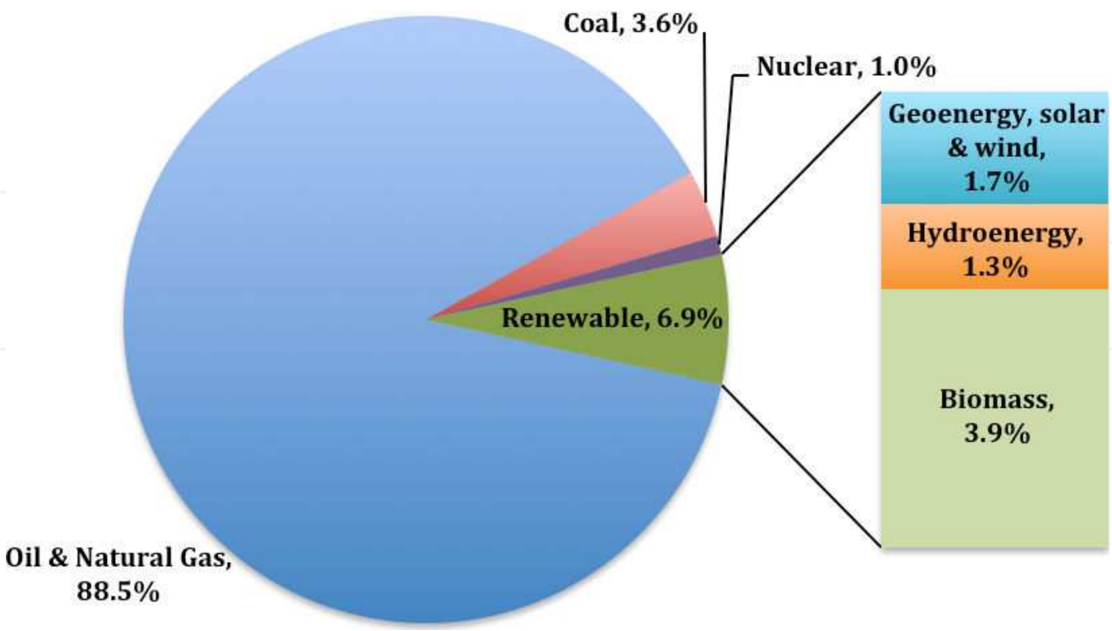

Figure 1. Primary energy of Mexico.

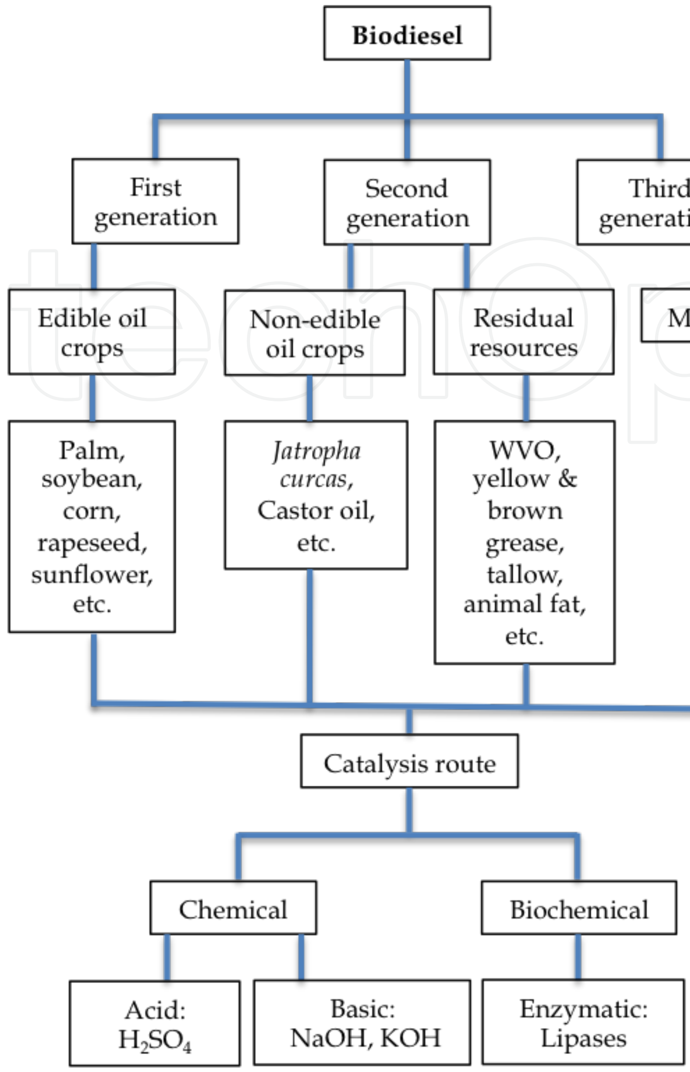

Figure 2. Classification of biodiesel and catalysis routes for its production.

The dependence on fossil fuels joined with the deteriorating environment caused by greenhouse gas (GHG) emissions, climate change, and rising and volatile oil prices are the energy challenges whose answer can be given by the development of renewable energy. Hence, Mexico has established an ambitious target to reduce 30% of GHG emissions by 2020 [2].

In the search of alternative to the fossil fuels, Mexico has developed technologies for biodiesel production. Biodiesel is an eco-friendly and renewable alternative fuel to diesel and can be obtained from oil crops or waste vegetable oils (WVO) generated as a result of productive activities. It is classified as first, second or third generation biofuel depending the feedstocks by which is produced. It is known as first generation biofuel when it is obtained from competing food resources e.g. sunflower, corn, safflower, canola, and soybean. Second generation when it is produced from waste biomass or non-edible energy crops e.g. WVO, yellow and brown grease, tallow, *Ricinus Communis*, *Jatropha Curcas L.*, and finally third generation biofuel from microalgae. The Figure 2 shows the classification of biodiesel according to the different biomass raw materials and the catalysis routes to produce the biofuel.

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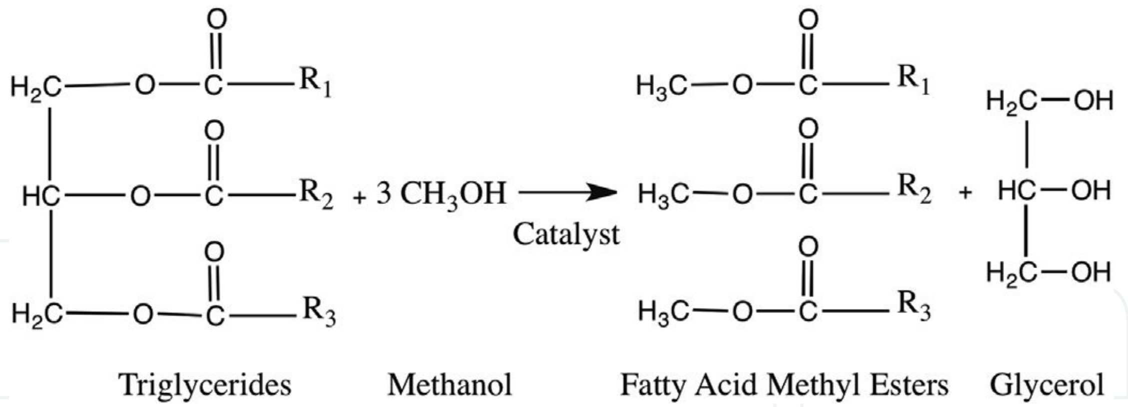

Figure 3. Transesterification reaction to obtain biodiesel.

In 2005, it was published in Mexico the Law of Sustainable Development of Sugarcane for the utilization of agro-energy, particularly ethanol as fuel and to oxygenate gasoline from initial honey and molasses, and exploiting sugarcane bagasse for electric cogeneration and syngas production [3]. Law for the Promotion and Development of Bioenergy (LPDB) was published, in order to contribute to energy diversification and sustainable development in 2008. This law considers promoting bioenergy production inputs, from agricultural activities, forestry, algae, biotechnological and enzymatic processes, without jeopardizing food security and sovereignty of the country [4]. Based on these regulations, Mexico initiated a series of actions to rule the internal market for biofuels and reduce the GHG emissions.

Biodiesel is among the bioenergetics considered. The leading standard setting organization ASTM International, formerly ASTM (American Society of Testing and Materials) defines biodiesel as a fuel comprised of mono-alkyl esters of long chain fatty acids [5]. Biodiesel is produced by transesterification of vegetable oils or animal fat, with a short chain alcohol in the presence of a catalyst, according to the following reaction shown in Figure 3 [6].

The main reason to convert the oil or fat into biodiesel is to reduce its viscosity and to obtain similar properties to diesel. While biodiesel is a lipid-based fuel, diesel is a mix of paraffinic, olefinic and aromatic hydrocarbons derived from the processing of crude oil.

Mexico has a great potential for biodiesel production because it has high biodiversity, intensive agriculture activity and waste biomass resources not exploited productively. For example, it was estimated that the potential of biodiesel production from WVO is between 7.8 PJ and 17.7 PJ nationally [7].

The development of the biodiesel industry in Mexico shows its first steps, relying on first and second generation biofuel technologies. Currently, universities, government agencies and research centers are conducting biodiesel research and development focused on process optimization, new catalysts, new raw materials for biodiesel production and the impacts of biodiesel on materials. The ongoing investigations imply the production of first, second and third generation biodiesel. Also, biorefineries projects at pilot level are conducted. Therefore, this chapter presents an overview of biodiesel production in Mexico and its current efforts for the development of this industry.

2. Biodiesel production plants at industrial scale in Mexico

At present Mexico has six industrial biodiesel production plants located in the states of Chiapas, Michoacán and Nuevo León, as illustrated in Figure 4, which were designed to process palm oil, *Jatropha Curcas L.*, castor oil, WVO and animal tallow and convert it into first or second biodiesel generation. Table 1 summarizes the information of the installed biodiesel production plants in Mexico.

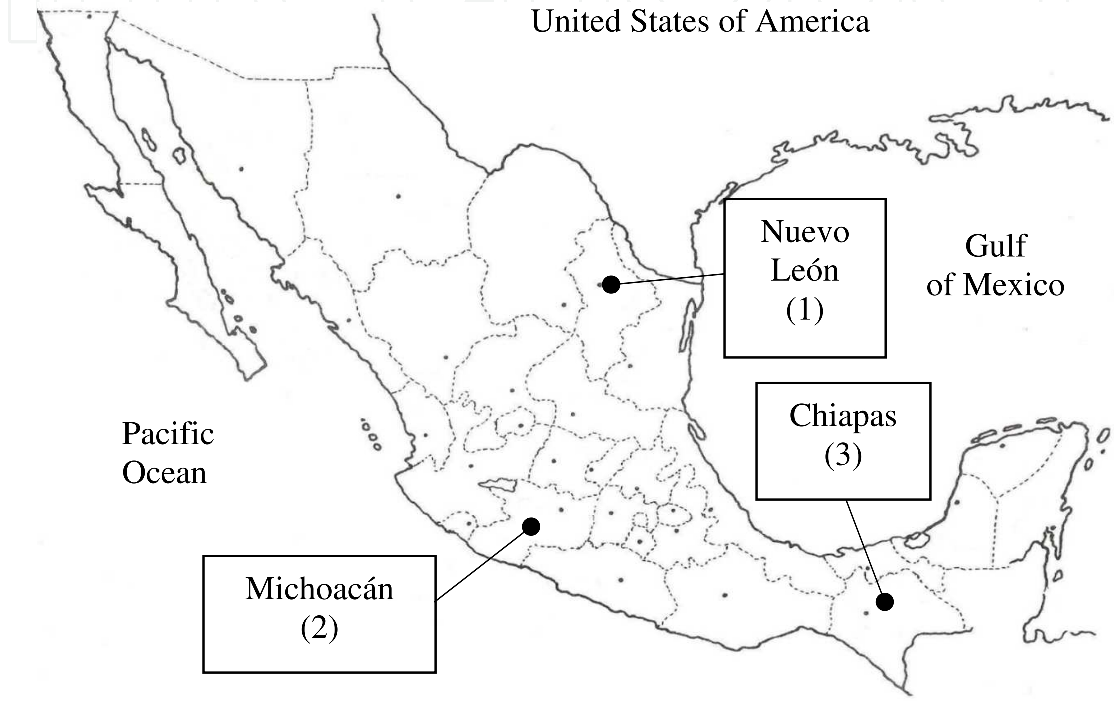

Figure 4. Biodiesel production plants in Mexico.

In 2004, the first biodiesel production plant in Mexico initiated activities in the state of Nuevo León. The installed capacity was 50,000 L/day, to process beef tallow and WVO. It operated in full capacity until 2009 and part of 2010, when it had a selling contract with Mexican Petroleum to supply biodiesel and use it as lubricity enhancing additive for diesel [8]. The biodiesel production plant ceased operations because the company that acquired the biodiesel finished his purchase contract. Due to the lack of market, the biodiesel plant stopped producing the biofuel. Then, the facilities were divided into two modules, one to produce open fuel flame and other for asphalt production [9].

In 2006, the company Moreco, located in Michoacán, launched a project to collect WVO and yellow grease for subsequent conversion into biodiesel. Currently, Moreco collects such waste in restaurants, produces biodiesel and supply it to several companies in Morelia for consumption as fuel in vehicles [10].

The biodiesel production facility located in Lázaro Cárdenas, Michoacán, called Bioenermex opened in 2007. The initial goal was to generate approximately 9,000,000 L of biodiesel

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per year, in addition to employing a thousand people. Nowadays, the plant is not in operation [11-13].

Location	Capacity (L/day)	Feedstock	Beginning of operation
Cadereyta, Nuevo León	50,000	Beef tallow WVO	2004
Morelia, Michoacán	Not reported	WVO	2006
Lázaro Cárdenas, Michoacán	24,600	*Jatropha Curcas*	2007
Tuxtla Gutiérrez, Chiapas	2,000	*Jatropha Curcas* African palm oil WVO	2009
Puerto Chiapas	8,000	*Jatropha Curcas* African palm oil WVO	2009
Puerto Chiapas	20,000	*Jatropha Curcas* African palm oil WVO	2009

Table 1. Information of biodiesel production plants in Mexico.

In the case of Chiapas, the development of the biodiesel program was called Chiapas Bioenergético and included the establishment of crops, oil extraction and the construction and operation of biodiesel production plants. The raw materials selected to supply these plants were oil from *Jatropha Curcas L.*, palm oil and WVO. The installed production capacity of biodiesel in Chiapas is 30,000 L/day, distributed in a plant located in Tuxtla Gutiérrez of Swedish technology, producing 2,000 L/day; another in Puerto Chiapas consists of two modules of Colombian-Mexican technology, producing 8,000 L/day and one module of English technology, producing 20,000 L/day. The plants began operations in 2009 and closed due to an insufficient supply of raw materials [8, 14].

According to Vega [14], the development of bioenergy in Mexico faces some barriers, including: a) the lack of a program to introduce biofuels for transport, b) standards of quality and sustainability of biofuels under the LPDB were not issued, c) funds for bioenergy program of the Secretariat of Agriculture, Livestock, Rural Development, Fisheries and Food, were used for other purposes.

Currently, biodiesel plants in Chiapas, Nuevo León and Michoacán are out of operation, however, Mexico continues to develop technologies in research centers and universities, for the production of biodiesel in higher yields [15, 16]. Several feedstocks including algae and other catalysts such as enzymes are being investigated.

3. Non-industrial experiences of biodiesel production in Mexico

In the state of Oaxaca, since 2004, José Vasconcelos University has a pilot plant for experimenting with the production of biodiesel from WVO, with a capacity of 45,000 L/year, which is used as B20 in a bus at the same university [12].

In 2005, Monterrey Institute of Technology built a first pilot plant for research purposes, to produce biodiesel from WVO, with the capacity to produce approximately 240,000 L/year [17].

In 2006, it was carried out a project entitled "Potential and Feasibility of Using Bioethanol and Biodiesel for Transport in Mexico", to determine the feasibility of producing such biofuels. In this project, it was assessed the production of biodiesel from rapeseed, soya, jatropha, sunflower and safflower oils, and the use of animal fat and WVO. The results suggest that farm input costs represent between 59% and 91% of biodiesel production costs, and as a result, animal tallow and WVO are an opportunity for biofuels production [18, 19].

In 2007, the Engineering Institute of the Autonomous University of Baja California processed the first batch of biodiesel from WVO. It counts with two reactors to process a total of 416 L of biodiesel per batch. Besides the use of WVO, biodiesel from castor oil and inedible oilseeds from Mexicali Valley has been obtained. Subsequently, there have been developed research projects on topics related to the inventory of residual feedstocks to produce biodiesel, the performance of internal combustion engines operating with diesel-biodiesel blends, as well as the study of the behavior of materials exposed to diesel, biodiesel and mixtures of both [6, 15, 16, 19-21]. Research focused on the production of biodiesel via enzymatic has been conducted as well [22-25].

In 2011, a National Laboratory of Biofuels was inaugurated in Chiapas as a result of the joint efforts by the government, the National Council for Science and Technology (CONACYT) and the Tuxtla Gutiérrez Institute of Technology. Currently, analytical services for the biodiesel production chain are offered [26].

In 2012, the Autonomous University of Puebla began initial production tests to produce 18,000 L/year of biodiesel approximately, despite reporting a production capacity of up to 72,000 L/year. The raw material used was castor oil. The production was intended to supply trucks of the university transport system. The funds were granted by CONACYT and the state government [27].

In 2012, the Pumabus of Ciudad Universitaria (CU) began using biodiesel. This occurred as a result of studies conducted by students at the National Autonomous University of Mexico (UNAM), who determined that more than 10,720 L of WVO were annually discarded by the CU restaurants [28].

In 2013, with an investment of 1.6 million pesos, a plant for biodiesel production in Zacatecas, located in the Autonomous University of Fresnillo began operations. However, the expectations were not met, since it was expected to link production and business sectors, but to date only serves for students to do practice and internship. The goal is to produce 100,000 L of biodiesel weekly [29].

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The International Energy Agency (IEA) as a result of a study on "Advanced biofuels in developed and developing countries" mentioned that Mexico has a high level of human resources in the biofuels domain. Up to the date, there are several universities, government agencies and research centers such as CIATEC, CIATEJ, UAG, UABC, CIBNOR, CEPROBI, CIBA, CICY, UNAM, INECOL, CINVESTAV, CICESE, UADEC, SAGARPA, INIFAP and UANL, among others, are working on a wide range of investigation lines and research projects related to the pretreatment of WVO by chemical and enzymatic process for biodiesel production, research and development on microalgae, study of new feedstocks for second and third generation biodiesel production, biotechnological processes and new biocatalysts development for biodiesel production [30]. Further, there are research in progress on the development of biorefineries at pilot scale plant, to optimize the use of biomass resources for the production of biofuels e.g. biodiesel and bioturbosine from *Jatropha Curcas L.* and microalgae.

The CONACYT and Secretariat of Energy (SENER) have supported financially many projects of consortium institutions on biodiesel research and development, and biorefinery systems through national funds programs. One of them is an ongoing project that is conducted with the objective to generate knowledge frontier at laboratory and pilot scale of a biorefinery integral system for biogas production, biodiesel from microalgae and hydrogen from algae biomass residues, by using domestic wastewater. New marine microalgae strains with the highest energy potential and vegetable oil yield are being studied [31].

4. Biodiesel legal framework in Mexico

Considering the importance and the interest of bioenergy worldwide and in Mexico, on February 1st 2008 in the Official Federation Journal was published the decree to enact the LPDB. It aims the promotion and development of bioenergy in order to contribute to energy diversification and sustainable development as conditions possible to ensure support for the Mexican agriculture and provides the basis for [4]:

i. Promoting biofuels production inputs, from agricultural, forestry, algae, biotechnological and enzymatic processes in the Mexican agriculture, without compromising food security and sovereignty of the country.

ii. Develop the production, marketing and efficient use of bioenergy to contribute to the reactivation of the rural sector, generating employment and a better quality of life for the population of high marginalization.

iii. Promote regional and rural development.

iv. Seek to reduce air pollutants and GHG emissions, using international instruments contained in the Treaties signed by Mexico.

v. Coordinate actions among Federal, State, Federal and Municipal District, social and private sectors for the development of bioenergy.

There is also the Regulation of the LPDB, which states that the SENER is responsible for issuing permits for production, storage, pipeline distribution and marketing of bioenergetics [32]. These permissions are granted for activities and necessary transformation processes of biomass fuels from organic matter in agriculture, livestock, forestry, forestry activities, aquaculture, algae-culture, fisheries waste, household waste, commercial waste, industrial waste, microorganisms and enzymes as well as their derivatives.

In accordance with the definitions in the LPDB, the Inter-Secretariat Commission for the development of bioenergy, as the entity of the highest level to promote the development of biofuels in Mexico was created [33]. The Inter-Secretariat Commission is comprised by the following secretariats:

- Secretariat of Energy (SENER).
- Secretariat of Agriculture, Livestock, Rural Development, Fisheries and Food (SAGARPA).
- Secretariat of Environment and Natural Resources (SEMARNAT).
- Secretariat of Economy (SE).
- Secretariat of Finance and Public Credit (SHCP).

The main functions of the Inter-Secretariat Commission are planning, participating in the creation of national and sectoral development plans; setting rules and guidelines to encourage public and private participation in the development of biofuels; monitoring of actions taken; and setting priorities for the allocation of public spending for the promotion and development of biofuels.

Diverse programs for the introduction of bioenergetics and bioenergy sustainable production feedstocks have been created. However, the results at the date have not been scaled industrially with success.

5. Biodiesel associations in Mexico

At present, there are few non-government associations related to biofuels in Mexico: the Mexican Network of Bioenergy (REMBIO) and the National Association of Biofuels Producers (ANPB).

6. Conclusion

The development of the biodiesel industry in Mexico at industrial scale has taken its first steps evidenced by the installation of six production plants. These plants were designed to produce first and second generation biodiesel. It has been made possible by the legal framework on biofuels. However, these industrial biodiesel production developments have been unsuccessful. Some of them were due to the lack of assurance of the availability of raw materials, others

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by the lack of agreement between existing legislation on biofuels and public policies that promote and encourage the production and consumption of biodiesel. Biodiesel productions from first and second generation in Mexico are assimilated and tested technologies in production plants. Several research-centers have projects in development regarding the third generation biodiesel from microalgae. Mexico has high-level human resources, capacities and capabilities about biodiesel production. However, the government has focused mainly its efforts on energy policy oriented to optimization of oil and natural gas industry, and to a lesser extent to renewable energy, including biodiesel. Mexico should focus its efforts on second and third generation biodiesel without jeopardizing food security.

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