

**Technical note:**

## *The development impact of biodiesel: a review of biodiesel production in Mexico*

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Received Date: 2 Feb.; 2011

Accepted: 14 Apr.; 2011

### **ABSTRACT**

Although in Mexico the cases and the experiences in bioenergy production are limited, at a worldwide level the knowledge in this area has grown up significantly. For example, unlike Argentina and Brazil, Mexico has only recently begun its bioenergy production from agricultural crops. So this paper will present a review of the actual conditions encountered in Mexico as far as biofuels production is concerned, in particular biodiesel. In this regard, the driving forces and barriers (economic, political and technical) to the introduction of biodiesel into the Mexican energy matrix are evaluated. In particular, the study has been directed toward the use of biodiesel as the transport fuel, since this productive sector consumes roughly 30 per cent of the Mexican energy resources, hence the use of biodiesel as a possible substitute for some fossil fuels is gaining more interest and it is foreseen as a strategy for the future. The study also presents the production processes of biodiesel most utilized in Mexico as well as their advantages and drawbacks. At the conclusion of this review, some well-grounded suggestions needed to make decisions with respect to the sustainable introduction of biodiesel in the energy matrix are included, bearing in mind the reality of the country.

### **Keywords**

Biodiesel, bioenergy, law for the promotion and development of bioenergy, PEMEX

### **1. Introduction**

Mexico is ranked, at worldwide level, in the sixth place as crude oil producer and in the eighteenth place as natural gas producer as in 2009 [1]. The marketing of hydrocarbons is a determining factor for the generation of foreign exchange. On top of that, Mexican government relies upon earnings from the oil industry (including taxes and direct payments from the state-owned oil company) for about 40 percent of total government revenues [1]. Historically the economic development and the country's energy scenarios have relied mainly on fossil fuels. In

this respect, the 2009 annual report (the last one published) on fuel demands indicated that the demand for gasoline increased noticeably in comparison to other fossil fuels; it accounted for 32.8% of the total energy demand. By contrast, diesel accounted for 16.0 %, electricity 14.4% natural gas 11.3%, liquefied petroleum gas 9.5%, wood 5.8%, coke crude oil 2.8%, kerosene 2.4%, fuel oil 2.8%, cane bagasse 0.2%, and others 3.1% [2]. From these figures, it is obvious that there exists a significant dependence on fossil fuels yet.

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Although Mexico is a producer of crude oil, there are serious problems as far as the supply of finished petroleum products is concerned. To put it succinctly, the nation is unable to meet the growing demand with its domestic production only; hence it imports a large amount of finished energy products. Primarily, the origin of this problem comes from, on the one hand, the lack of investment to increase refining capacity in the country and, on the other hand, the lack of energy sources diversification. The upshot of this difficult situation is that each year there are deficits in the hydrocarbons trade balance.

In regard to energy consumption, Mexico has undergone a considerable increase in its energy demand as a result of the population growth and the economic development [3]. In 2008, the final total energy consumption in the country reached 5.1 EJ, from which 2.4 EJ were used by the transportation sector [4]. According to the 2008 National Energy Balance [4], transportation sector consumption increased a 12.4% with respect to 2007. This scenario resulted from the fact that trucks and passenger transportation consumed 269.6 PJ more than that in 2007 [4].

In the same sector, gasoline is the largest energy input with a share of 67.3%, diesel 23.3%, liquefied petroleum gas 1.8%. Moreover, sector demand grew by 7.8% compared to 2008 [4]. The net balance in the trade balance for diesel in 2009 indicates that it had to import 99.08 PJ of this fuel with a 33.2% decrease in imports, compared to 2008 [4]. The imported diesel fuel accounts for roughly 13.56% of the total diesel consumed in Mexico. What is more, it is expected that oil and other liquid fuels demand will increase more rapidly in the transport sector than in any other sector within the next 25 years [5, 6]. Hence, energy diversification is particularly important in the transport sector, which depends entirely on hydrocarbons at the present time.

According to this framework, public concern on fossil fuel conservation has begun to gradually increase in the last decade. Hence the importance of complete conventional energy sources with other alternative sources of energy. In Mexico, alternative energy sources, excluding hydropower, have had a slight participation in the total energy supply for electricity generation, transportation and rural residential sectors in comparison

to the hydrocarbons share [6]. For example, the use of biomass as primary source of energy has been decreasing since 1965, when it used to be 15.3 % of the total primary energy supply [7].

In particular, the use of biofuels as a source or energy for the transportation sector is being seriously considered in the domestic energy portfolio of Mexico. Hence, in 2008, the Mexican Secretariat of Energy enacted the Law on the Promotion and Development of Bioenergy in order to achieve energy diversification and sustainable development in the production of energy [8]. Particularly, biodiesel is drawing attention from government since it can be a notable factor for promoting regional development in the country. Actually, it is forecasted that by 2031 the infiltration of biodiesel in the energy consumption of the transport sector will reach roughly 9% of the total consumption. In other words, biodiesel is expected to replace 7.8% of conventional diesel fuel consumption [6].

In general, the reasons of using renewable energies are manifold. First to preserve actual oil reserves, this would avoid turning Mexico into an energy-importer country in future years. Second, to turn renewables into a fundamental piece in the development of a sustainable energy system. Third, to contribute to the reduction of greenhouse gas emissions as well as to promote the generation of new jobs in rural areas and the improvement of income distribution [7]. However, it is clear that renewable energy sources will not substitute fossil fuels entirely; but they will have to be used concurrently and integrated with other sources. Therefore, as part of this ever-greater promotion of the use of biofuels as sources of energy, the present paper particularly reviews the production of biodiesel in Mexico. So technical and economic feasibilities, barriers, advantages and disadvantages of producing biodiesel are reviewed. Finally, suggestions for introducing biodiesel into the Mexican energy matrix in a sustainable way are made.

## 2. Diesel oil demand trend

In order to consider the introduction of biodiesel into the Mexican's energy matrix, it is necessary to have a perspective of how the diesel oil demand will move in the following years. It has

been commented previously that the oil demand will depend strongly upon the vehicle fleet evolution in the coming years [6]. So it is forecasted that vehicle fleet will consume 1543 PJ by the year 2031 [6]. For comparison, according to the 2005 energy prospective, the transportation sector will be consuming roughly 1531 PJ by the year 2030 [9]. These projections are quite similar; hence it is evident that production of diesel oil will continue to a worrying rate. At worst, according to Fig.1, Mexican diesel consumption would keep exceeding production as tendency shows from 1994 to 2007. This scenario would turn Mexico into a diesel oil importer and undoubtedly cause an unsustainable energy system. Thus, one of the alternatives is to become a producer of biodiesel since Mexico presents a great potential of sources to do so.

### 3. Bioenergy resources

In general, the production of biomass energy from wood and/or energy crops has been the worldwide point of discussion because it is argued that these compete against food crops for land and fresh water [11]. Furthermore, their cultivation could bring about pollution problems due to the fertilizers and pesticides used for the intensive farming of these crops [11,12]. However, an interesting and promising alternative to circumvent this hurdle is to use crop residues that are compatible with both food and energy production [11].

In this regard, biodiesel can be produced from vegetable oils, animal fats or recycled fat (e.g. fat from the food industry or from the solid residues released in the tendering processes).

In fact, Mexican studies have determined that production of biodiesel can be competitive if the following crops are used as feedstock [5]:

- Oil palm tree
- Sunflower
- Soy
- *Jatropha curcas*

Likewise, studies on the viability of biodiesel have come to the conclusion that the use of recycled oil and fat as raw material is feasible too [3].

Accordingly, some country' states such as Michoacan, Chiapas and Oaxaca have recently been working on important projects focused on biodiesel production from energy crops. In particular, the most striving project has been proposed by the Government of Michoacan. In order to achieve the goal of the project it is fostering the castor-oil plant growing in about 2 thousand hectares, although more than 30 thousand hectares has been identified as likely arable land. Interestingly, the biodiesel plant consumes as raw material 220 tonnes of avocado residues [13].

Another interesting project is underway by the Government of Chiapas. Its strategy is to sow roughly 120 thousand hectares with oil palm, *jatropha* and castor oil plant for intensive production of biodiesel.

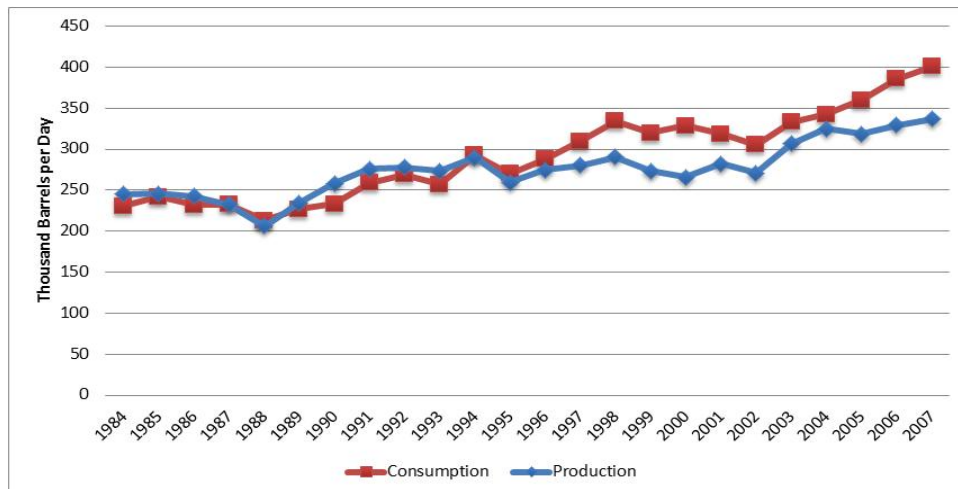


Fig. 1: Mexico diesel oil consumption and production by year. Source: own calculations based on data from [10].

As far as production costs is concerned, it can be mentioned that the palm oil-derived biodiesel costs would be less than US\$ 0.64 per litre, whereas the cost of the biofuel from jatropha would not be higher than US\$ 0.45 per litre. In the particular case of the biodiesel obtained from the avocado residues its costs would be about US\$0.345 per litre [13].

Accordingly, it can be seen that Mexico is bestowed with a huge amount of natural resources so as to become a great producer of biodiesel as most countries are nowadays. From an economical point of view, its cost is quite competitive since it is lower than the cost of the conventional diesel cost, US\$ 0.79 per litre as of 2011. However, there are barriers that have halted the massive production of biodiesel, these will be studied later.

#### 4. Technology stock

At industrial level, there are several sufficiently advanced technologies for transforming these crop residues into utilizable liquid fuel and can be implemented immediately.

The leading process for biodiesel production on large scale is the transesterification reaction based on either homonogeneous, heterogeneous or enzyme catalysts. However, a variety of these production process can be found in literature, see Fig.2.

Algae are another source of triglycerides. Algae are more productive than corn or soybean, as every cell is a factory. Unlike corn, algae need not be grown on arable soil and also can be grown in water bodies like ponds, lakes and even seas and oceans. Therefore, there are no food related issues with algae. Algae not only reduce a plant's global warming gases, but also consume other pollutants [32]. However, harvesting algae and extracting oil present technical and cost hurdles yet that need to be side stepped. In this context, it can be said that many Mexican universities, research laboratories, private companies and else are carrying out research on biodiesel using most of the processes commented above. So Mexico does not need to focus most of its struggles on processes but to work on solving the problem of how will it support or guarantee a sustainable and plentiful feedstock supply (i.e. to focus on the development of next generation of biodiesel). As one of the main barriers for the potential production of biodiesel from crops (e.g. biodiesel from oil seeds) is the disapproval for increasing food prices and food insecurity, something that affects primarily the population of developing countries [33]. Besides there is the likely impact on the biodiversity, the soil quality and the natural resources of the region because of the land use changes and intensification of cultivation derived from the increasing demand for biofuels.

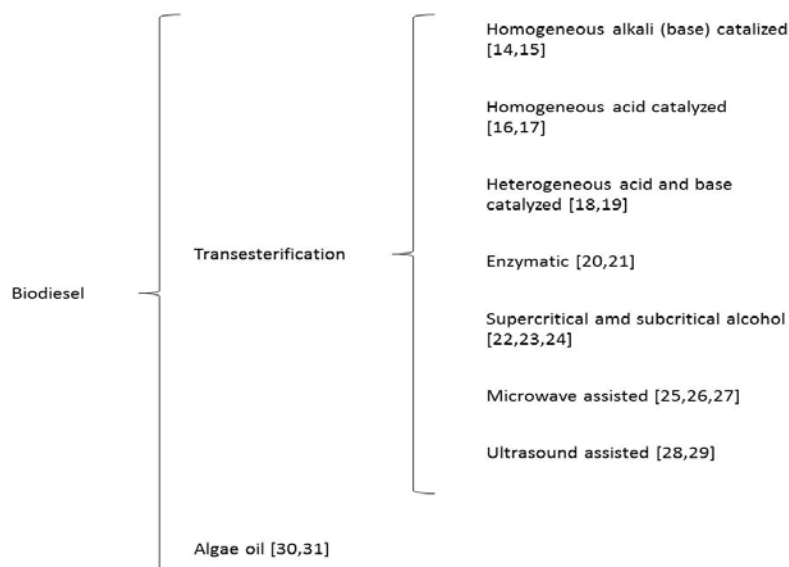


Fig. 2: Biodiesel production technologies.

## 5. Key constraint sandbusiness opportunities

Natural resources in Mexico are vast; however, their exploitation has been shadowed for many years because of the exclusive exploitation of petroleum. Since then the oil sector has become a crucial component of Mexico's economy. The predictable depletion of fossil fuels, however, has obligated to take steps to maintain Mexico's historical energy sovereignty solid and consistent.

However, exclusive exploitation of petroleum has not been the only cause that the country has not focused on other alternatives for energy supplying. There has been a series of barriers which are worth commenting and analysing. For the sake of simplicity, these barriers can be summarized as follows

- 1) Political
- 2) Legal
- 3) Organizational
- 4) Economical
- 5) Technical
- 6) Capacitated Human resources
- 7) Social

### 5.1 Political obstacles

It is an important barrier when it comes to carry out initiatives focused on promoting the use of energy renewable. This is because most of the promoters are not politicians and therefore they do not have political weight when final decisions are taken

### 5.2 Legal obstacles

In this context, it is important to highlight that there exists a monopoly that is in charge of producing most of the fuels consumed in Mexico. Most importantly, their costs are subsidized. This situation makes that biofuels are not competitive in comparison with conventional fuels.

Besides, there is a considerable lack of laws which regulate their exploitation. In the case of biodiesel from vegetable oils, there is no law which regulates the use of land for growing energy crops as in the case of Europe. Or, in the case of biodiesel from cooking oil, there is no law which regulates the purchasing cost of the cooking oil.

### 5.3 Organizational obstacles

In this context, it is worth commenting upon the excessive bureaucracy which hinders the establishment of new enterprises. There is still an unsolved problem when it comes to think of to whom it may be sold. Many have turned to the transport sector, but, as explained above, there is no a legal framework which regulates its use as co-fuel or fuel in the transport sector. In fact, the current institutional framework for promotion and use of biofuels is limited.

Another important obstacle is the absolute ignorance from the private sector in relation to the likely exploitation of the biodiesel. So, great efforts must be done so as to run information campaigns throughout the country. As a proposal, students involved in energy (any form of energy) from Mexican universities may be the conductors of these campaigns. Indeed they are who can take all of the knowledge into all public sectors. There is an urgent need of working on cooperative mechanisms.

### 5.4 Economical obstacles

Indeed conventional diesel costs do not take into account environmental costs, social costs or healthy costs. On top of that, most of the conventional fuels are subsidized. Circumstances that make biodiesel not a competitive alternative and companies reluctant to invest in biodiesel production plants.

Hence further restructuring is necessary if the companies concerned are to achieve viability and be competitive enough to operate under normal market conditions, especially those concerning competitions.

A condition halting the introduction of biodiesel is that most of the cost of the resources is unknown, which increases the production costs. So it is necessary to properly estimate such costs by means of Life Cycle Costs Analysis (LCCA) [34].

On the other hand, there is a lack of competitive financial schemes (i.e. support instruments) such as feed-in tariff, feed-in premium or quota obligations like other countries are doing now to take advantage of most of their natural resources [35]. Other support instruments could be investment grants, tax exemptions or fiscal incentives.

### **5.5 Technical obstacles**

As a matter of fact there is no lack of technological knowledge, but the will of generating own technology and innovate in ways of ensuring a constant supplying of resources. Consequently, it is essential to diversify crops and to increase the efficiency of agriculture. While most of the cultivated area is fertile, the inefficient technology applied on situ makes crop yields quite inadequate. Besides, the cultivation area should be expanded, first so as to be self-reliant and secondly, to produce biofuels.

### **5.6 Trained Human Resources**

Certainly there is an evident lack of human resources capacitated in project development, engineering and power plant operators. It is urgent to carry out capacitation projects focus on the raising biodiesel production processes knowledge among technicians and engineers. As well, projects focused on the professional exchange with organizations and institutions that are involved in local developing projects.

### **5.7 Social obstacles**

Most of the people, in general, do not know the environmental benefits that renewable energies can bring. It is important to recall that renewable energies are not part of the Mexican traditions. This is a great problem that can be solved by raising environmental awareness among children and communities.

## **6. Conclusions**

In this paper a general review of the development of the biodiesel in Mexico has been carried out. Through this, it is evident that Mexico has been bestowed with an enormous potential of natural resources which must be used sustainably and wisely for its benefit.

From a technical standpoint, there is sufficient technological development in the country. Here it is important to mention that some technological developments come from overseas as technological sharing. In this regard, Mexico needs to develop its own technology which must come from researching results such as: patents, technical developments, among others. Besides, there is

still need for a regulation law which defines the characteristics that biodiesel should fulfil so as to be used as alternative fuel. From an economical point of view, production of biodiesel from Mexican crops is profitable due to the low cost of raw materials in this country. In fact, the agricultural sector is the key to the implementation of biodiesel in this country; hence it is vital to design a comprehensive plan that includes the protection of this sector, the planning of crops and distribution of crops in such a way that it guarantees the food supply and the production of biodiesel. From a political point of view, it is evident the need for making politicians listen to scientists about adopting as many green solutions as possible. In order to do so, researchers should be enrolled with politicians by means of Local Energy Sustainability Boards (LESB). These local boards should be constituted by researchers, politicians, businessmen, and government workers. Through such LESB it would be possible to direct projects of huge environmental impact, social, economic and cultural, as biodiesel production plants can be. As the production of biodiesel could imply some problems such as social, political, among others, it is necessary to get the perspective of all society sectors in order to establish national programs which foster the production of this fuel. Although the Mexican government has enacted some laws for the exploitation of biofuels, it is not clear how it will help to do so. In other words, the price of biodiesel can be higher than conventional one because this last does not take into account environmental and health costs, besides it is subsidized. So, summing all the cost mentioned above and eliminating the subsidies, the cost of biodiesel would be competitive enough. Further restructuring is necessary if the companies concerned are to achieve viability and be competitive enough to operate under normal market conditions, especially those concerning competition.

Finally, the introduction of biodiesel in Mexico would bring out several benefits such as:

- Job creation
- Expansion of the facility to rural areas.
- Development of rural economies.
- Conservation of oil resources
- Development of multiple crops.

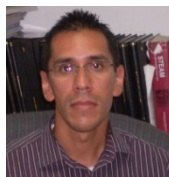
The successful launch of a biodiesel program will depend largely on a scrutiny program that considers environmental, social, political and economic sustainability.

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### Biographies



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Since 1988, he has been professor in the Mechanical Department of the University of Guanajuato working in the thermo fluids area. His areas of interest include analysis with CFD of thermal devices, aerodynamic design of vertical wind turbine and development of new prototypes of burners to the ceramic and brick-maker industry. Dr. Gallegos-Muñoz has published two book chapters, 20 articles in journals and 110 articles in congress.