RELATION BETWEEN BIOFUELS VERSUS FOSSIL FUELS

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Contents

Summary

Biofuels are fuels of bio origin, most frequently obtained from crops. The most important biofuels are ethanol, obtained from sugarcane and corn, and biodiesel,

obtained from oil seeds such as soybean, rapeseed and palm. As the world demand for fossil fuels increased substantially in the last decades, combined with the fact that fossil fuels are considered more expensive and claimed to be the main factor responsible for global warming, biofuels are considered as an alternative. This chapter presents in some detail the production processes for the 1st generation of biofuels, ethanol from sugarcane and corn, and biodiesel from oil crops. Some alternative technologies for 2nd generation biofuels are also presented, which will allow the use of the entire plant, such as the fibers, rendering it possible to obtain a more sustainable production of biofuels with a considerably smaller impact on the environment. In addition, some considerations regarding biofuels and some aspects comparing them with fossil fuels are also presented. Finally, the authors present the most important research challenges regarding biofuels production and use, and the potential they have to become at least part of the world effort to reduce GHG emissions and global warming.

1. Introduction

The so-called "biofuels" are, in fact, fuels of "bio" origin derived from plants, animals and microorganisms. In a certain way, the fossil fuels also fit into this given definition with the difference that, according to geologists, they are derived from the decomposition of organic matter for several million years. However, what is defined as biofuel today is more specifically the derivatives of plants or animals that are considered renewable, that is, which can continuously be produced.

In the definition of biofuel, materials such as firewood, methane gas, agricultural residues, vegetable or animal oils are included, as well as modern biofuels, such as ethanol and biodiesel. Still today, in many countries of low economic and social development, firewood and other biofuels such as biogas and even animal dung are intensely used as the base for their energy matrix. However, nowadays, the term biofuels in general is related to liquid biofuels, more specifically to ethanol. Ethanol, also known as ethyl alcohol, is a colorless flammable liquid, also found in alcoholic beverages. Its chemical formula is C_2H_6O, the same as dimethyl ether. Biodiesel is a biofuel obtained from oils and fats of animal or vegetable origin, with an alcohol, either methanol or ethanol, in the presence of a catalyst, in a reaction known as transesterification. It can also be obtained by cracking or esterification processes.

Countries such as Brazil, the U.S.A., Germany and France, throughout decades, have constructed an industry directed to the production and use of significant amounts of ethanol and biodiesel, incorporating them into their energy matrices. However, as will be discussed, when biofuels are considered and used on a global scale, the main objective is the possibility of reducing fossil-fuel utilization and reducing its correspondent greenhouse gas emissions (GHG). Therefore, the amount of renewable energy that can be produced by unit of fossil-fuel energy utilized in the entire biofuel production process becomes critical. This rate is called "life cycle".

2. Increase of the Greenhouse Effect and Atmospheric Temperature

What makes the world today consider the production and use of biofuels on a wide scale is the high level of atmospheric pollution caused by the intensive use of fossil fuels.

Since the industrial revolution in the XIX century, humanity and, more specifically, the developed countries, have based their development model on non-renewable sources of energy such as petroleum, natural gas and coal. The use of these fossil-fuel sources emits gases such as carbon dioxide (CO_2), methane (CH_4) and other hydrocarbons, increasing the so-called greenhouse effect and, consequently, provoking an increase in the atmospheric temperature of our planet (Figures 1 and 2).

The atmospheric greenhouse effect has been a well-known physical phenomenon since the studies of Lord Kelvin at the end of the 10^{th} century, and systematic measurements of GHG densities in the atmosphere were performed already in the fifth decade of the 20^{th} century. Nevertheless, except for a small portion of the scientific community, the entire world population was, until the eighties, completely unaware of possible menaces or harmful consequences such as climate changes and global warming.

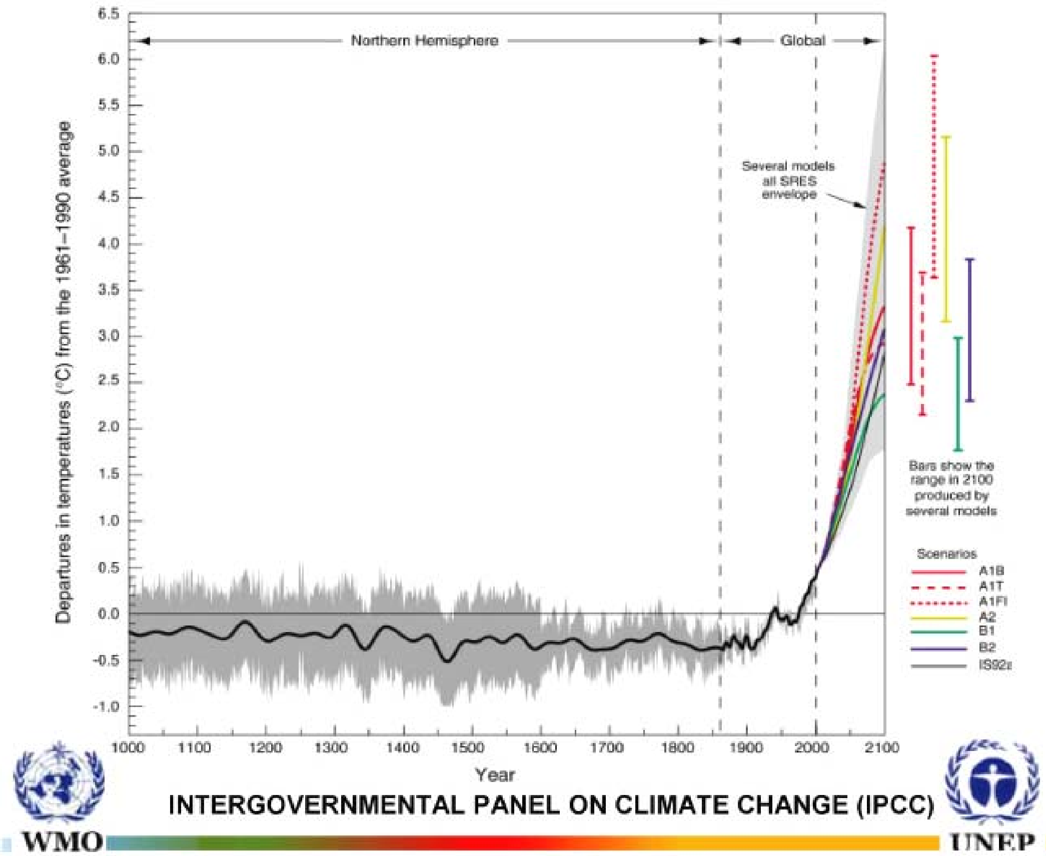

Figure 1. The IPCC GHG (Intergovernmental Panel on Climate Change - Greenhouse Gases) and atmospheric temperature correlation **(IPCC, 2001)**

Definite confirmation of the change in GHG densities came with studies of variation in the composition of the atmosphere during the last centuries. These data were obtained through measurements of GHG content in bubbles of air imprisoned in polar ice (source: http://www.aip.org/history/climate/co2.htm).

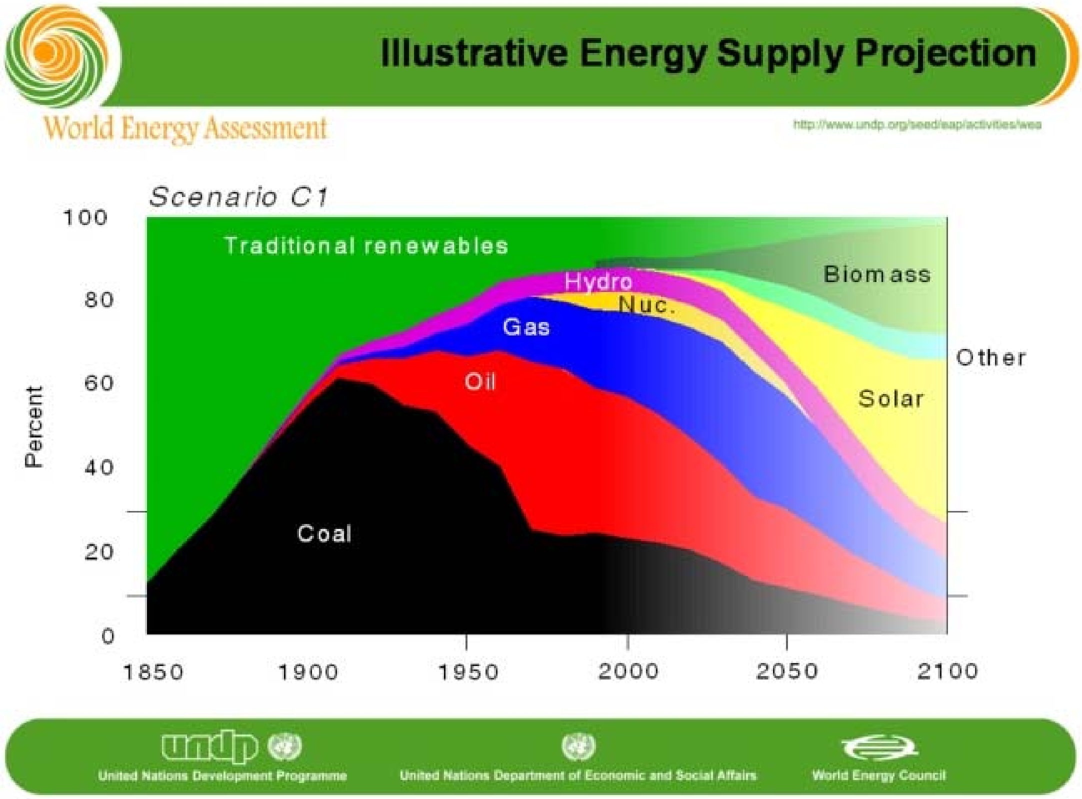

Figure 2. Use of energy sources (consolidated and forecasted) from 1850 to 2100 (Nakicenovic, N. et al. 1998)

Today, a consensus exists in the scientific community that the intensive use of fossil fuels releasing CO_2 can irreversibly modify the climate on the planet unless drastic measures are taken to mitigate or to reduce the emissions of this pollutant gas.

Carbon dioxide gas measurements carried out at the Mauna Loa Observatory showed that the 313 ppm (parts per million) of CO_2 concentration in 1960 increased to about 375 ppm in 2005. This observed CO_2 level exceeds the geologic CO_2 record (~300 ppm) registered in ice samples (Hansen, 2005).

Based on an extensive revision of scientific literature, the Intergovernmental Panel on Climate Change - IPCC concluded that "most of the increase observed in the average global temperatures since the middle of the XX century is most probably due to the observed increase in the emissions of anthropogenic greenhouse gases" (http://www.ipcc.ch/SPM2feb07.pdf).

We may conclude that there are two sources for the so-called greenhouse gases: one that is generated by natural causes and another that is generated by Mankind, (or of anthropogenic origin). It is this last source that has been indicated as responsible for the rise of atmospheric temperature and the cause of global climatic changes in these last two centuries.

3. History of the Technology and Use of Biofuels

Until three centuries ago, navigation basically used the winds, ocean currents and frequently human energy to move boats. In the field, the most employed forms of energy were solar energy, used to dry agricultural products, the water falls and the windmills, allowing the pumping of water and the milling of grains. The animal-traction age also allowed the preparation of the soil, the transport in wagons and the birth of an agri-industry. Meanwhile, biomass resources were used to cook and warm households in cold climates. But, since the invention of the Newcomen machine in 1718, steam started to dominate and to be used in mechanical devices to develop mechanical work (Forbes, 1976). In Europe, other inventors conducted the necessary basic research for the development of a new field, today named physical-chemistry, which allowed the understanding of gas behavior and chemical reactions. Already in 1775, James Watt invented a steam engine, which provided the technological basis for the industrial revolution that was already in course.

England possessed important mineral coal mines and also had the necessity to pump water from mines. At that moment, the necessary knowledge on the thermodynamic properties of the water already existed, as well as the required advances of technologies that used combustion and that would allow the invention of James Watt's engine. His invention was applied in several areas such as the Rankine cycle, in stationary generators, in steamships, and in locomotives, providing an acceleration of the economic progress possible all over Europe and the U.S.A.

But, only by the end of the XIX century, almost simultaneously to the use of petroleum and oil in industry, the invention of internal combustion engines, mainly the Otto and Diesel engines, would create an impact sufficient to cause a revolution in transports.

Initially projected and tested with biofuels, the ignition engine (the Otto Cycle), was developed for ethanol. In 1908, Henry Ford would use ethanol in his Model T Ford, calling it "the fuel of the future".

The engine developed by Rudolf Diesel, also based on the compression and explosion of vapors, used vegetable oils as fuel. In 1925, experiments carried out in Brazil (Rodrigues, 2005), associated to the difficulties of the sugarcane producers, had led the government to create the Sugar and Alcohol Institute (Instituto do Açúcar e do Álcool – IAA). This was determined by means of a decree in 1931 that also established the 5% mixture of ethanol to all imported gasoline, initially restricted to official vehicles. In 1938, the 5% ethanol mandate was extended to all gasoline consumed in the country.

In Brazil, from then on, the addition of ethanol to gasoline never ceased. It is estimated that between 1930 and 1975, the average level of the mixture of ethanol to gasoline was approximately 7% (Nogueira, 2007).

At the beginning of the 1970s, with the first oil shock, Brazil was in a difficult economic and strategic situation. It imported 80% of the oil it consumed, which represented up to 50% of all expending with imports. Reacting to this fact, on

November 14, 1975, through the Decree no. 76.593, President Ernesto Geisel created the National Alcohol Plan, which came to be known as PROALCOOL.

The program caused a great increase in the planted area of sugarcane in Brazil, multiplying the ethanol production and helping to reduce the foreign dependence on oil. Since the 1970s, Brazil has reached an international position of prominence in biofuels. Today, ethanol production is concentrated more in the Central-Southern region of the country. The predominance of the State of São Paulo and of some Northeastern regions, such as the state of Alagoas, over the other producing regions of the country is due, mainly, to the following factors: land with good fertility and topography, better organized infrastructure, more skilled human resources, better management and the more intensive use of the available technologies, as much in agriculture as in the industrial phase of the ethanol production.

Currently, the sugar-ethanol sector is responsible for the generation of approximately 1 million direct jobs in some agricultural and industrial activities. Brazil is today the largest worldwide producer of sugarcane and sugar, and the largest exporter of ethanol fuel. The Brazilian ethanol sector is composed almost entirely of property belonging to local private entrepreneurs, with a relatively small participation of foreign capital, and has a great potential to increase its participation in the national economy.

The other important producer of alcohol is the U.S.A., with a slightly larger production than Brazil already in 2006. The alcohol in the U.S.A. is extracted from the starch contained in corn. In comparison to the Brazilian sugarcane alcohol, the American ethanol from corn is highly unsatisfactory, since its life cycle, i.e., the amount of energy extracted per unit of energy invested is very low. In the sugarcane-based ethanol production, the ratio of energy produced compared to that consumed in the entire “life cycle” of the process stands at 8 to 10, whereas for the corn-based option, this index is between 1 and 1.4 according to different sources. The most trustworthy evaluation is the one presented by the “American Institute of Biological Sciences” which gives a factor of 1.1, which means that only 10% more energy is obtained over that consumed. Therefore, this process is not interesting for containment of the rise of global temperature nor for simple economic aspects. There are, however, expectations that with the advent of the commercial production of ethanol from lignocellulosic materials, corn will become economically competitive with sugarcane and more efficient as a global temperature limiter.

In the U.S.A. (http://e85.whipnet.net/ethanol.history/), also a great producer of ethanol today, the historical background kept a certain similarity to the history in Brazil. The American Congress answered to first oil shock by passing the *Energy Tax Act of 1978*, which granted an exemption of 4 ¢/gallon in federal taxes on gasoline with mixtures of at least 10% of ethanol.

In 1980, the Congress passed two other laws; the *Crude Oil Windfall Profit Tax Act* and the *Energy Security Act*. Both measures promoted the conservation of energy and new fuel development in the U.S.A. In 1982, the *Surface Transportation Assistance Act* increased the exemption granted to the federal tax on gasoline from 4 to 9 ¢/gallon. In

1984, the *Tax Reform Act* once again increased the exemption for 10% ethanol blended gas from 4 to to 6 ¢/gallon.

The *Motor Alternative Fuels Act of 1988* was enacted for additional research, development and demonstration programs for both vehicles and fuels, and provided credits to the economy with fuels for the assembly plants.

In 1990, through *The Omnibus Budget Reconciliation Act*, the American Congress extended the incentive tax given to ethanol from 1992 to 2000, but diminished the incentive from 6 to 5.4 ¢/gallon. Through the *Clean Air Act Amendments of 1990*, the American Congress, for the first time, openly informed changes in automotive fuels and their composition in order to contribute to the reduction of the exhaust pipe pollution. The Act created two new standards for gasoline emission. It required gasoline to contain oxygenated additives, such as ethanol that would produce a cleaner combustion.

The Energy Policy Act of 1992 established a national goal of 30 % for the penetration of alternative fuels in light vehicles by 2010. This also required that the federal, state and municipal governments and private fleets use alternative fuels. In 1998, the first *Transportation Efficiency Act* of the XXI century extended the incentive tax to ethanol until 2007.

Since the 1980s., activities of the American Congress have resulted in more than 3 billion kilometers driven using mixtures with ethanol fuel. By 1978, the North American ethanol industry had reached a capacity to produce almost 5 billion gallons (20 billion liters) of ethanol. One-hundred plants of ethanol fuel were installed in 20 states, with capacities ranging from 6 million to 7.5 billion liters/year.

4. Possible Alternatives to Mitigate Carbon Dioxide Emissions

Among the alternatives existing today to reduce the emission of the greenhouse gases we have:

a) Sequestration of GHG immediately after its production, and its storage or dispersion in some manner;
b) Sequestration of atmospheric CO_2 by creating new forests and plantations or capturing it directly in the atmosphere;
c) Reduction of the emissions through the adoption of measures that increase the energy efficiency;
d) Substitution of fossil fuels by other energy forms, such as by biofuels, wind and solar energy that emit less net GHG.

Brief comments on the alternatives above:

a) we are a still quite far from dominating the technologies of carbon sequestration from chimneys;
b) the formation of forests to store carbon does not have significant potential to reduce carbon dioxide levels in the atmosphere, nor would it be a way to reduce the emissions of greenhouse gases in a sustainable form;

c) the adoption of measures that improve energy efficiency certainly has to be adopted. Alone, however, their contribution is limited, given the dimension of the problem in cause. There is an inexorable increase in the consumption of energy in the world, particularly from fossil fuel sources, and important parts of humanity are changing their consumption levels, generating impacts on worldwide energy demand; and

d) renewable energy sources will have to be employed increasingly, becoming a part of the solution of the energy-environment problem that the world is experiencing in this XXI century. Biofuels will have a place among these alternatives, mainly in the transport sector, which still depends on liquid fuels, and this situation will possibly continue through most of the 21st century.

5. Photosynthesis and Biofuels

In nature, through the evolutionary process, plants and other organisms developed a quite ingenious capacity to use sunlight to convert atmospheric CO_2 into biomass. This is achieved through a phenomenon known as photosynthesis, which uses chlorophylls and other pigments in the process of conversion of CO_2 into biomass in a sufficiently stable form. Biomass is basically chemical energy. This occurs through a series of physical processes and chemical reactions, resulting in biomass.

6. Productive Cycle of Biofuels

The Life Cycle Analysis (LCA) is a methodology used to provide an assessment of a productive cycle from its very beginning (cradle) to its end (grave). This technique is fundamental for an adequate environment and sustainability analysis of biofuels. Throughout all their life cycle, biofuels use energy in the preparation of land, production and distribution of fertilizers in all the industrial and transport processes involved, including the energy for the construction of buildings and equipment.

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Biographical Sketches

Luís Augusto Barbosa Cortez received the B.Sc. degree from the State University of Campinas-UNICAMP, Brazil, the M.Sc. degree from Université Laval, Québec, Canada, and the Ph.D. from Texas Tech University-TTU, Texas, USA, the latter in 1989. He has been a faculty member of the Faculty of Agricultural Engineering at UNICAMP since 1988 where he is responsible for lecturing Applied Thermodynamics for agricultural engineers. In 1992 he earned the Jabuti Prize for the best book in Science and Technology Category in Brazil awarded by the Brazilian Association of Books. Other prizes…In 1997 and 1999, he was elected the Coordinator of the Interdisciplinary Center for Energy Planning – NIPE at UNICAMP. Since 2002 he is the UNICAMP International Relations Coordinator. In 2005 he was appointed university Full Professor. His interests include energy in agriculture, fuel ethanol production, sustainability, and energy for development.

Rogério Cezar de Cerqueira Leite obtained his BS in Electronics Engineering at the Technological Institute of Aeronautics in 1958 and his PhD at the University of Paris in 1962. He, then, spent 8 years at "Bell Telephone Laboratories" as a researcher specialized in lasers and solid state physics. In 1970 Cerqueira Leite returned to Brazil to direct the Institute of Physics of the recently founded State University of Campinas. Simultaneously, he created the Institute of Arts at the same University. In 1975 he became the General Coordinator of the Professional Schools of this University. Elected Rector in 1978 was prevented to take office by the military Government. From 1982 to 1986 he was the CEO of the Power and Light Company at the State of São Paulo. He created and directed several high-tech companies, was editor to "Solid State Communication" (1973-88), Oxford, England. He is, from 1978; member of the Editorial Board of "Folha de São Paulo", the largest newspaper in Brazil. Published 80 scientific papers in technical journals, 15 books, more than two thousand newspaper articles and gave more than 500 talks on technical and non-technical subjects. Received the Chair of the University of Montreal (1979), the "L'Ordre National du Merite de France" (1978) and became the first Professor Emeritus of the State University of Campinas in 1987. In 1991 an International Festschrift Symposium was held for his 60 years and a Proceeding was published by "World Scientific". He had more than 3000 quotations on impact journals (Science Citation Index), was honored with the Brazilian Grand Cross of Merit in Science and the titled of Emeritus Researcher of the Brazilian National Research Council. He is Chairman of the Board of the National Light Synchrotron Laboratory in Brazil and Member of the Working Group in Energy of the International Union of Pure and Applied Physics. He coordinates the two Brazilian largest research programs in biofuels, among others.