BIOFUELS ECONOMICS AND POLICY

Agricultural and Environmental Sustainability

edited by
Adele Finco

FrancoAngeli

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If I know a song of Africa, of the giraffe and the African new moon lying on her back, of the plows in the fields and the sweaty faces of the coffee pickers, does Africa know a song of me? Will the air over the plain quiver with a color that I have had on, or the children invent a game in which my name is, or the full moon throw a shadow over the gravel of the drive that was like me, or will the eagles of the Ngong Hills look out for me?

Karen Blixen, *Out of Africa*, 1937

Alla mia mamma
Il grazie di tutta una vita

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INTRODUCTION

by *Adele Finco*

The use of vegetable oils for engine fuel may seem insignificant today. But such oils may become in course of time as important as petroleum and the coal tar products of the present time (Rudolph Diesel, 1912).

The dramatic increase in world oil prices in the last year, coupled with awareness of greenhouse gas emissions and energy security concerns, have led to a sharp increase in biofuels production and related policy measures. Increases of fossil fuel prices already happened in the past, the most notable during the 1970s as a consequence of the energy crisis. The perception, however, is that these trends will persist for a much longer time frame.

The global transport supply chain has been largely based on the oil industry (petroleum), with gasoline and diesel consumption the predominant fuel source. In fact, petroleum products account for 97% of fuel consumption in the world.

The transport sector is a significant contributor to GHG emissions in most countries, representing 23% (worldwide) of CO_2 emissions from fossil fuel combustion. In Europe the transport sector is responsible for 20% of all greenhouse gas (GHG) emissions which contribute to climate change. In this context, agriculture has provided a substitute for vehicular transportation fuel. Biofuels production from agricultural biomass, hold the promise of playing a relevant role in the renewable energy sources panorama, given the opportunity to achieve multiple goals such as security of supply, reduction of greenhouse gas emissions an alternative market for agricultural products and diversification of energy sources.

Renewable energy may create positive externalities insofar as it reduces GHG emission and it reduces the import of energy thus reducing the political dependency on foreign countries. In other words, the production of biofuels are a positive externality. As such, they require internalization process by the government to avoid market failure.

In Europe about 80% of biofuels used in transportation is essentially biodiesel. Bioethanol represents only 20%. Actually biofuels represent 5% of the total fossil fuel consumption use in the transport sector (USDA FAPRI, 2011).

The world biofuels production reached almost 92 billion liters in 2009 and over four-fifths of this global production of liquid biofuels consists of ethanol. However, the share of biodiesel is rapidly increasing due to the emergence of new producing countries in South East Asia and increased biodiesel production in other producing countries. The United States and Brazil are the largest ethanol producers with 54% and 34% of global ethanol respectively; while the European Union accounts for 57% of global biodiesel production. In 2010 European Union produced about 10 million tons of biodiesel. Germany and France are the biggest producers, followed by Spain and Italy.

Currently available biofuels are made from sugar crops and starch crops (sugarcane, sugarbeet, potatoes) for ethanol production, oilseed crops (soybean, sunflower, rapeseed, palm oil, etc.) and animal fats for biodiesel production. Second generation biofuels, or cellulosic biofuels, are made from cellulose, which is available from non-food crops and waste biomass such as corn stover, corncobs, straw, wood, and wood byproducts. Third generation biofuels use algae as a feedstock. Second and third generation biofuels are not yet produced commercially, because of high costs of production and low energy efficiency.

The development of the biofuel industry alters the linkage between agricultural feedstock and energy markets (Tyner and Taheripour, 2008[1]). As a result of the integration between energy market and agricultural market, energy prices now affect food prices in two ways: directly by raising the cost production of agricultural products and indirectly by diverting land away from food to biofuels (Khanna *et al.*, 2010; Serra 2011[2]).

Several authors have raised concerns about the environmental benefits and social implications of first generation biofuels production, such as underlying uncertainties over the life cycle emissions of greenhouse gas emissions, possible deforestation for feedstock production, degradation of soil and air quality, increased water consumption, possible loss of biodiversity, possible competition with food production, and other potential social imbalances. Land-use change (LUC and ILUC) is considered one of the most important environmental impacts to address in terms of GHG emissions, in particular, when biofuels production on current land and use of biomass in a given region, induce displacement of activities elsewhere (Gnansounou, 2011; Ajanovic, 2011; Lora *et al.*, 2011[3]). Therefore the net contribution of biofuels

[1] See reference Chapter 2, 5.

[2] See references Chapter 1.

[3] See references Chapter 6.

may be less than expected, but the current trend towards the promotion of biofuel production and use is expected to continue (Yano *et al.*, 2010).

The European Union and several countries have adopted different initiatives for biofuels (Certification schemes) to respond to these growing concerns and to address the sustainability issues derived from the expanding production of biofuels.

Until 2010, the development of biofuels in EU has been driven by incentives in both the agricultural and energy sector. Without the set of subsides for the production of energy crops (Common Agricultural Policy – CAP), tax reduction and exemptions, production increases are much more limited. Actually, at EU level, the consumption of biodiesel is encouraged only by blending targets (percentage of biofuel incorporated in conventional fuel) and by mandatory sustainability criteria imposed by the Directive 2009/28/EC (Renewable Energy Directive, RED).

On the other hand, in Brazil, the ethanol sector is supported by the Financing Programme for Storage of Ethanol and by policy incentives for flex fuel cars, in order "to internalize the market price of the environmental benefits provided by the vehicle that uses or can use only ethanol". In order to expand the participation in the ethanol market share, Petrobras (Brazilian State Oil Company) invested US$ 1.5 billion into biofuels, between 2008 and 2012, and 46% in pipelines.

The book covers a wide range of issues that have emerged with the advent of biofuels:

- The wider economic, social and environmental impacts of first generation biofuels;
- The policy arrangements for biofuels;
- The role of biofuels for the reduction of greenhouse gas emissions;
- The different agro-energy supply chains (biodiesel biogas and vegetable oil).

Further, another objective of the publication is to provide a review on the latest developments on the main initiatives and approaches for the sustainability certification for biofuels. A large number of national and international initiatives lately experienced rapid development in the view of the biofuels and bioenergy targets announced in the European Union, United States and other countries worldwide.

The book, containing the results of a national research project (PRIN, 2007, Ministry of University and Scientific Research), is based on the analysis of international literature and on the general overview on biofuels sector. The focus has been placed on European and Italian biodiesel production, in particular from rapeseed and sunflower as a feedstock.

The volume is structured as follows.

Chapter 1 describes the drivers for biofuels, the various types of biofuels, and some of the emerging technologies. It also provides a historical perspective on biofuels. Chapter 2 gives an overview of biofuel economics and policy in the US. Chapter 3 is a review of the various policies that are influencing the evolution of biofuels and their economic implications. Chapter 4 provides an overview of the potential energy biomass production at the European and Italian level. Chapter 5 develops an economic assessment of the Italian biodiesel industry during 2010. The aim is to provide relevant data on the performance of the biodiesel sector and to show how political intervention and the measures adopted by the government have influenced it. Chapter 6 analyzes actual issues of biofuels impacts, focusing the attention on the impacts of first generation biofuel production on food prices and on the environment. The main certification initiatives are analyzed too, including certification schemes, at global level. Certification has the potential to influence positively direct environmental and social impact of bioenergy production. In Chapter 7, the use of equilibrium models to assess biofuels impacts are suggested. Over the last several decades Applied General Equilibrium (AGE) models have become an important tool for analyzing economic issues. In this chapter a version of GTAP developed by Hertel, Tyner and Birur in 2010, has been applied in order to analyze the impacts of the US and EU biofuels programs from the economic, social and environmental points of view. Chapter 8 aims to identify environmental criteria to evaluate and compare the impacts of biodiesel and fossil fuels production chains, through an exploratory meta-analysis of scientific and technical reports. The information from the comparative meta-analysis enabled the design and implementation of a multi-criteria methodology to identify and support the choices of public policy aimed at obtaining a sustainable development strategy. Chapter 9 evaluates the environmental impact at micro-scale level, in terms of GHG emissions, from the production to the use of rapeseed biodiesel, comparing the results with the ones related to conventional diesel, using the life cycle assessment methodology (LCA). Finally, Chapter 10 considers the two most important alternative agro-energy sources: straight vegetable oil (SVO) and biogas. The economic convenience of a vegetable oil and biogas plant is carried through a financial and economic analysis, which is based on the comparison between all cost components and benefits derived from the sale of electricity generated.

Part I

Policy Instruments and Biofuels Scenarios

1. BIOFUEL SECTOR OVERVIEW

by *Adele Finco* and *Monica Padella*

1.1. Introduction

Bioenergy is the conversion of biomass resources such as agricultural and forest residues, organic municipal waste, and energy crops into useful energy carriers including heat, electricity, and transportation fuels.

The Renewable Energy Directive defines bioliquids as "liquid fuel for energy purposes other than for transport, including electricity and heating and cooling, produced from biomass" and biofuels as "liquid or gaseous fuel for transport produced from biomass".

Biofuels are the main substitute for gas and diesel used in transportation in ordinary vehicles and with a large-scale availability. The use of biofuels such as biodiesel, bioethanol and, to a lesser extent, biogas is an important way of promoting more sustainable energy consumption in transportation and reducing dependence on fossil fuels. Biofuels generally have a better greenhouse gas (GHG) performance than fossil fuels and can potentially help the EU countries to meet their obligations on the reduction of greenhouse gas emissions.

After a description of the main pathways, this chapter contains data on the production and consumption of biofuels at a global, European, and Italian scale. The last part depicts the global biofuel commodity market and trade scenario.

1.2. Biofuels types and processes

Biofuels can be classified in two broad categories: first-generation biofuels and second-generation biofuels.

First-generation biofuels are mainly derived from food feedstocks and include: biodiesel (RME), bioethanol, ETBE, biogas/landfill gas, and straight vegetable oils (SVO). At a commercial scale, the three main categories developed worldwide are bioethanol, biodiesel and biogas, being the latter less used in the transportation sector (the principal agro-energy pathways of biodiesel and bioethanol are briefly described in Appendix 1; biogas chain is explained in Chapter 10).

In general, biofuels are produced from cereal crops (*e.g.* wheat and maize), oil crops (*e.g.* rape and palm oil), and sugar crops (*e.g.* sugar beet and sugar cane) through a variety of established technical processes.

An overview of the main production pathways, the different types of biomass used, the production process, and their final use are shown in Figure 1.1.

Figure 1.1 – Production-lines of first generation biofuels in Europe

Field	Straight vegetable oil	Biodiesel	Bioethanol	Biogas
1. Biomass	Oilseeds (rapeseed, soy, palm, sunflower)	Oilseeds (rapeseed, soy, palm, sunflower)	Wheat, barley rye, triticale, corn sugar beet	Manure, biowaste, maize, etc.
2. Processing	Extraction	Extraction, esterification and purification	Fermentation and distillation	Anaerobic digestion
3. Products and by-products	Bio oil Press cake	Biodiesel Press cake Glycerin	Bioethanol Dried Distillers Grains plus Solubles (DDGS), Corn, Gluten feed	Biogas Digestate
4. Market	Diesel (modified Engines) Cogeneration (electricity or heat)	Diesel	Gasoline E-85 (modified engines)	Biomethane Cogeneration (electricity or heat)

Recently, the use of first-generation biofuels has been subject of considerable media attention, political debate, and campaigns by civil societies that are drawing awareness to the environmental and social impacts of biofuels produced from food crops.

The increasing criticism of the sustainability of many first-generation biofuels has raised attention to the potential production of the so-called second-generation biofuels.

Synthesis biofuels (also often referred to as “second-generation biofuels” or yet “synfuels”), such as Fischer-Tropsch diesel (*i.e.* FT-diesel), dimethyl ether (DME), biomethanol or biohydrogen, have been the subject of an intensive research and development (R&D) activity for many years and are often considered to be the most promising biofuels production pathways in the medium-to-long term. However, there is no current industrial-scale facility for this type of biofuels.

Second-generation biofuels are those biofuels produced from cellulose, hemicellulose, or lignin and they can either be blended with petroleum-based fuels or dedicated for its use in slightly adapted vehicles (IEA, 2010).

Second-generation production technologies are broadly divided into bio-chemical[1] and thermo-chemical[2] processes that produce a range of biofuels such as bioethanol, synthetic biofuels, biodiesel, methane and hydrogen outlined in Table 1.1. This table also indicates what are the raw materials used in these production technologies.

Second-generation biofuels are produced from lignocellulose that is a material virtually abundant worldwide. Biomass can be obtained from natural ecosystems (like forests, grassland, or aquatic ecosystems) or obtained from the cultivation of bioenergy crops like perennial grasses or wood species. Furthermore, any kind of lignocellulosic waste like straw or sawdust can be used in the production of second-generation biofuels. In particular, feedstocks for lignocellulosic biofuels can be divided into two main categories:

- Dedicated energy crops;
- Residues.

Dedicated energy crops include fast-growing woody plant species like willow (Salix spec.), poplar (Populus spec.), eucalyptus (Eucalyptus spec.) and others, as well as herbaceous plant species like miscanthus (Miscanthus spec.), switchgrass (Panicum virgatum), Johnson grass (Sorghum halepense), and others.

Residues can be divided into primary, secondary, and tertiary residues. Primary residues are obtained from the harvest of crops or timber. They comprise agricultural residues like straw and stover, as well as forestry residues such as treetops, branches, and stumps. Secondary residues are accumulated during the conversion of crops into food products or the production of other biomass-based materials. Feedstocks in this category include nutshells, bagasse, presscake, and fruit bunches, as well as sawdust, bark and scrap wood.

[1] Bio-chemical conversion uses biological agents (enzymes and micro-organisms) to break down ligno-cellulose into its base polymers, and then into monomeric sugars including glucose and xylose, which can be fermented into ethanol.

[2] Thermo-chemical conversion subjects ligno-cellulosic biomass to severe heat in the presence of air or oxygen to make a synthesis gas which is then cleaned and used as a chemical building block to make a range of fuels.