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Excerpt
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Part One

Global overview

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Biofuels at the confluence of energy security, rural development, and food security: A developing country perspective

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Abstract

First-generation biofuels, such as bioethanol and biodiesel from food crops, have been identified as potentially viable substitutes for conventional transport fuels, with several countries mandating the blending of biofuel with conventional transport fuel. A number of policy concerns ranging from energy security to climate mitigation and economic development have been identified as driving forces behind biofuel expansion. Even though energy security is usually the overarching policy driver of biofuel expansion, depending on the local context, other policy concerns, such as rural development, are becoming important shapers of biofuel policies, particularly in developing nations. This local context is also a major determinant of the extent to which biofuel production and use are beneficial to the environment and human well-being. This chapter initially identifies the main drivers of biofuel expansion in developing nations and proceeds to discuss three highly interlinked socioeconomic impacts associated with biofuel production and use: energy security, rural development, and food security.

Keywords: biofuel expansion, energy security, food security, rural development

1. Introduction

Biofuels are a class of liquid fuels derived from biomass through diverse chemical processes (e.g., transesterification of vegetal oils, fermentation of sugar and starch-rich crops). Different biofuel classifications have been proposed in the past decade, with the most enduring being first-generation and second-generation biofuels.[2] Owing

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[2] An emerging classification distinguishes *conventional* from *advanced* biofuels (IEA, 2010a).

to the wide range of feedstocks and technologies used for biofuel production, as well as their varied impacts (e.g., greenhouse gas (GHG) emissions, competition with food), there is sometimes disagreement as to what constitutes a first-generation or a second-generation biofuel (IEA, 2010a). For the purposes of this edited volume, we define *first-generation biofuels* as those biofuels that are produced from "sugar, starch and oil bearing crops or animal fats that in most cases can also be used as food and feed" (IEA, 2010a: 22). *Second-generation biofuels*, conversely, are those that are produced from cellulose, hemicellulose, or lignin (IEA, 2010a).

In this classification, the likelihood that a biofuel will directly compete with food competition constitutes the major criterion for determining whether it is a first- or second-generation biofuel. We adopt this classification because the "food versus fuel" debate has been at the core of the biofuel polemic, especially in developing nations.[3]

The most common types of first-generation biofuels are bioethanol and biodiesel, which are usually used as substitutes for conventional transport fuel (IEA, 2004a). Other uses of first-generation liquid biofuels include cooking and rural electrification (FAO, 2009a).

Energy security, climate change mitigation, foreign exchange savings, and rural development are usually perceived as the principal driving forces behind past and present biofuel expansion (Yan and Lin, 2009). Energy security is in most cases the overarching policy concern for biofuel expansion in places as diverse as Brazil (Chapter 6), the United States (U.S. House of Representatives, 2007), the European Union (EU, 2009), China (Chapter 10), India (MNRE, undated; Zhou and Thomson, 2009), and Indonesia (Zhou and Thomson, 2009). For some countries, particularly those located in sub-Saharan Africa and Southeast Asia, trade balance and rural development have played more significant roles as motivators for biofuel development (Jumbe et al., 2009; Bekunda et al., 2009; Zhou and Thomson, 2009). Conversely, climate change mitigation has influenced marginally, if at all, developing countries to pursue biofuel production (e.g., Zhou and Thomson, 2009).[4] In fact, with the exception of the EU member states, no country has ranked climate change highly as a justification for its biofuel policies.

Brazil, with its Proálcool program, has been since the mid-1970s a pioneer of large-scale biofuel production and use for transport purposes. Thanks to several interconnected factors, the Brazilian biofuel experiment is generally seen as a success (Abramovay, 2008; Fischer et al., 2009) (see Chapter 6) and consequently a number of countries across the world are trying to imitate the Brazilian experience (see Chapter 12). To achieve this, various policy instruments are being put in place to promote biofuel expansion, with the most common being blending mandates (Section 2.3).

[3] Oil from *Jatropha curcas* is a common biodiesel feedstock, particularly in China, India, and sub-Saharan Africa. While it is not edible, it is derived from an oil crop and is therefore technically a first-generation biofuel. This is why it is discussed in this volume (see Chapters 10 and 13).

[4] Developing nations have been included in Annex A of the United Nations Framework Convention on Climate Change (UNFCCC). As a result, they are not currently legally obligated to reduce their GHG emissions by the Kyoto Protocol.

This steady demand for biofuels has resulted in global biofuel production increasing more than fivefold in the last decade, with significantly greater biofuel expansion expected to take place in the next decade (OECD-FAO, 2010). OECD-FAO (2010) predicts a doubling of biofuel production by 2020, mainly through the expansion of first-generation biofuels in developing nations. According to different scenarios, biofuel consumption in 2035 will increase by 162.9 to 505.7 percent for Organisation for Economic Co-operation and Development (OECD) countries and by 302.4 to 678.0 percent for non-OECD countries when compared to 2009 consumption levels (IEA, 2010a). For developing nations, the largest increases in biofuel demand are expected to take place in Brazil, China, and India.

At the same time, biofuel expansion has been associated with a number of positive and negative socioeconomic and environmental impacts, which are discussed throughout this edited volume. Some of the impacts include GHG emissions (Chapter 3), air quality (Chapter 3), water consumption (Chapters 4 and 13), deforestation (Chapter 5), land use change (Chapter 8), biodiversity loss (Chapters 9 and 13), and several other socioeconomic issues (Chapters 2, 6, 7, 10, 11, 12, and 13). However, perhaps none of these impacts is more emblematic in the biofuel debate than the potential impacts on food prices and food security (Chapters 2, 6, 10, 11, and 13).

By drawing on significant evidence coming from developing nations, this chapter discusses three highly interlinked socioeconomic impacts associated with biofuel production and use: energy security (Section 2), rural development (Section 3), and food security (Section 4). Given the overwhelming literature on the topic, the aim of this chapter is not to provide a comprehensive review but rather to highlight the interconnected nature of these three impacts and how it complicates efforts to understand the net impact of biofuel expansion on human well-being.

2. Energy provision

2.1. Biofuel and feedstock types

2.1.1. First-generation bioethanol

First-generation bioethanol can be derived through fermentation of sugar-rich crops, such as sugarcane (*Saccharum officianarum*), sugar beet (*Beta vulgaris*), or sweet sorghum (*Sorghum* spp.), or starch-rich crops, such as maize (*Zea mays*), wheat (*Triticum* spp.), or cassava (*Manihot esculenta*) (Fischer et al., 2009). After fermentation and distillation, ethanol can be directly blended with conventional gasoline in different proportions. For example, a mix of 5 percent ethanol and 95 percent gasoline is denoted as "E5."

Bioethanol is by far the most widely produced biofuel on a global scale, with its production having increased by 351.2 percent between 2000 and 2008 (Figure 1.1). Currently the largest bioethanol producers are the United States (from maize), Brazil (from sugarcane), the EU (from sugar beet and wheat), China (from maize), and India

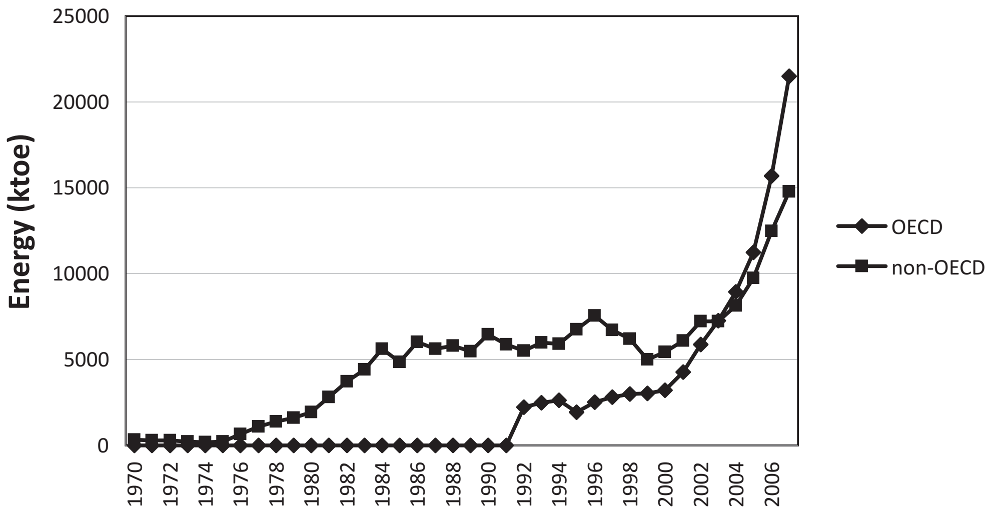

Figure 1.1. Global bioethanol production (1970–2008). *Source:* IEA (2011a).

(from molasses) (IEA, 2010a) (Figure 1.2). Less popular feedstocks include cassava (Southeast Asia and China), sweet sorghum (China), and sweet potato (China). In addition to these countries, several other developing nations around the world (e.g., in sub-Saharan Africa; see Chapter 12) are promoting bioethanol policies, including

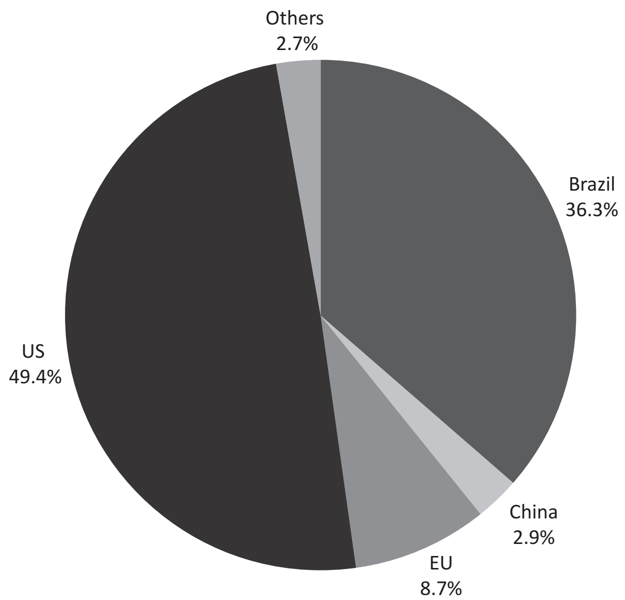

Figure 1.2. Bioethanol production by country (2008). *Source:* IEA (2011a).

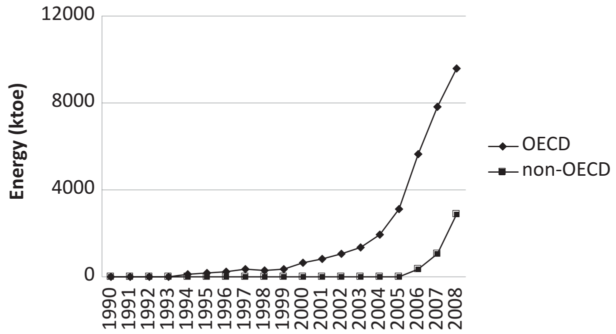

Figure 1.3. Global biodiesel production (1990–2008). *Source:* IEA (2011a).

blending mandates (refer to Section 2.3). This edited volume contains chapters specifically addressing the impacts of sugarcane bioethanol in Brazil (Chapters 6–8) and southern Africa (Chapter 12).

2.1.2. First-generation biodiesel

First-generation biodiesel is produced through the transesterification of animal fats and vegetable oils with the most common feedstocks, including oil from rapeseed (*Brassica napus*), soybean (*Glycine max*), sunflower (*Helianthus annuus*), palm (*Elaeis guineensis*), and jatropha (*Jatropha curcas*) (Fischer et al., 2009). Less popular biodiesel feedstocks include oil from coconut (*Cocos nucifera*) and castor bean (*Ricinus communis*) as well as numerous other oil-bearing crops. Following initial processing that varies depending on the type of feedstock, the derived fatty acid methyl esters are blended with conventional diesel in different proportions, for example, B5 (5% biodiesel, 95% diesel). In some cases, pure plant oil, derived from plants such as jatropha, can be used directly as a fuel for transport, cooking, and power generation (IEA, 2010a).

Global biodiesel production increased by 1,829.6 percent between 2001 and 2009 (Figure 1.3). The largest producers and consumers of biodiesel are the EU (mainly from rapeseed) and the United States (mainly from soybean). Emerging producers include Brazil and Argentina (from soybeans) and Malaysia and Indonesia (from palm oil) (Figure 1.4). India, China, and several sub-Saharan and Southeast Asian nations are showing considerable interest in the production of biodiesel from jatropha.

This edited volume contains chapters dedicated specifically to the impacts of soybean biodiesel in Brazil (Chapter 6), palm oil biodiesel in Southeast Asia (Chapter 9) and jatropha biodiesel in China (Chapter 10), and southern Africa (Chapter 13).

2.1.3. Second-generation biofuels

Second-generation biofuels are produced from cellulose, hemicelluloses and lignin (IEA, 2010a: 22). In contrast to first-generation biofuels, second-generation biofuels

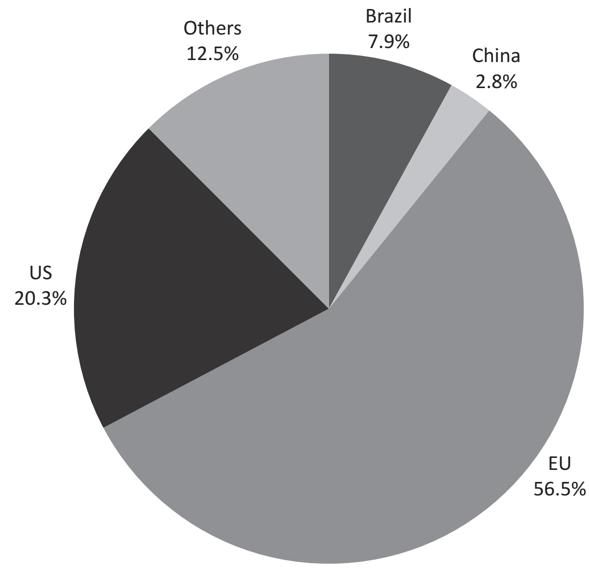

Figure 1.4. Biodiesel production by country (2008). *Source:* IEA (2011a).

can be derived from nonedible plants or from nonedible parts of food crops. Several potential feedstocks for second-generation biofuels have been identified, including the following:

- Short rotation coppice: poplar (*Populus spec*.), willow (*Salix spec*.), eucalyptus (*Eucalyptus spec*.)
- Perennial grasses: miscanthus (*Miscanthus sinensis*), switchgrass (*Panicum virgatum*), reed canary grass (*Phalaris arundinacea*)
- Agricultural by-products: straw, stover, shells, husks, cobs, bagasse, pulp and fruit bunches from different food crops such as corn, rice, sugarcane, sweet sorghum, sugar beet, oil palm, and jatropha
- Forestry by-products: treetops, branches, woodchips, sawdust, bark

For converting lignocellulosic material into liquid biofuel, two main conversion routes are currently pursued: the biochemical route and the thermochemical route. The biochemical route entails the hydrolysis of the lignocellulosic material into sugars and the subsequent fermentation of these sugars into ethanol (Gupta and Demirbas, 2010). The thermochemical route requires heating the feedstock to high temperatures (e.g., through pyrolysis or gasification) and the subsequent transformation of the gas into liquid fuel through different biomass-to-liquids processes such as the Fischer-Tropsch process (Gupta and Demirbas, 2010).

Despite its large global potential (e.g., IEA, 2010a; Chapter 2), there is currently no commercial second-generation biofuel production anywhere in the world. Furthermore, even though there are considerable relevant research activities going on in developed countries, such as the United States and the EU, with the exception of Brazil and China, plans to produce second-generation biofuels in other developing countries are almost nonexistent. This is to a large extent because of the lack of appropriate infrastructure and the shortage of skilled labor and R&D capabilities (IEA, 2010a).

Despite this lack of interest in second-generation biofuel production from developing nations, the fact remains that such biofuel practices can provide numerous economic, environmental, and social benefits. Apart from high net-energy provision and GHG savings, second-generation biofuels avoid direct competition with food production (see Section 4 and Chapters 2, 6, 10, 12, and 13), while they can be an important agent of rural development (IEA, 2010a). In this sense, second-generation biofuels can be very promising energy options for developing countries, such as Brazil, China, and India, that have the infrastructure and R&D potential to pursue their production (IEA, 2010a). Other countries, particularly those located in sub-Saharan Africa, that have much fewer resources to pursue this energy option domestically can still profit from the growing global biomass market by producing and exporting the feedstock to developed countries such as the United States and the EU. In this sense, the biofuel mandates in developed countries can be an important driver for second-generation biofuel production in developing nations (IEA, 2010a).

2.2. Energy balances

When assessing a biofuel's viability, a key consideration is the degree to which the biofuel provides a net energy gain compared to conventional fossil fuels. Two indicators that can facilitate such comparisons are the energy return on investment (EROI) and the percentage energy improvement over conventional fuel (percentage fossil energy improvement). The EROI is defined as the ratio of the total energy supplied by biofuel combustion to the total energy used in the biofuel production process. For a given biofuel practice, an EROI higher than 1 means that the practice is a net energy provider. The percentage fossil energy improvement, in contrast, provides a measure of the amount of nonrenewable energy used during a biofuel's whole life cycle. Generally speaking, biofuel practices with high EROIs and high positive percentage fossil energy improvements provide the largest energy gains and are to be preferred if net energy gain is the sole criterion for determining biofuel viability.

Life cycle analysis (LCA) has been identified as the most appropriate tool for calculating EROI and percentage fossil energy improvement (Menichetti and Otto, 2009; Hill et al., 2006; Zah et al., 2007). Biofuel life cycles are rather complicated and include an array of different stages that range from feedstock production (essentially an agricultural activity) to feedstock transport, feedstock processing, biofuel production and biofuel distribution, storage, dispensing, and combustion (Hess et al., 2009; Delucchi, 2006). The processes adopted during these stages can have a series of environmental and socioeconomic impacts (discussed throughout this edited volume) affecting the different biofuels' sustainability performance.

Tables 1.1 and 1.2 contrast the energy content and the EROIs of different biofuel production practices from all over the world. In most cases, the energy contents and EROIs were directly taken from the cited sources. When they were not provided by the original source, we derived them using standard fuel properties.

The results of our meta-analysis show relatively high EROIs for sugarcane bioethanol, wheat bioethanol, palm oil biodiesel, and jatropha biodiesel. Conversely, corn bioethanol and certain soybean biodiesel practices demonstrate low EROIs – some cases lower than 1. The results of our meta-analysis are consistent with the results of the meta-analysis conducted by de Vries et al. (2010), according to whom sugarcane bioethanol, sweet sorghum bioethanol, and oil palm biodiesel provide the highest EROIs. Sugar beet bioethanol, cassava bioethanol, rapeseed biodiesel, and soybean biodiesel have the next highest EROIs. Maize bioethanol and wheat bioethanol exhibited the lowest EROIs.

An LCA meta-analysis conducted by Menichetti and Otto (2009) concludes that most current first-generation biofuel production practices provide – albeit to different degrees – positive percentage fossil energy improvements. Sugarcane bioethanol provides by far the highest and most consistent percentage fossil energy improvements (in the range of 80%–90%). Other biofuel production practices, such as maize–sugar beet–wheat bioethanol and rapeseed–soybean–sunflower–palm oil biodiesel, provide mostly positive, but highly variable, percentage fossil energy improvements. Finally, a comparative LCA study ranked different biodiesel production chains according to their use of nonrenewable energy as follows (in decreasing order of energy consumption): soybean (Argentina), soybean (Brazil), rapeseed (EU), rapeseed (Switzerland), palm oil (Malaysia), and soybean (United States) (Panichelli et al., 2009).[5]

Several LCAs have shown that jatropha biodiesel is generally a net energy provider, with the biodiesel production stage (transesterification) being the most energy-intensive stage (Achten et al., 2008; Reinhardt et al., 2007a). LCAs on the production and use of straight jatropha oil as a biofuel have shown significant net energy gains when compared to conventional fuels (Gmunder et al., 2010), though using straight jatropha oil as a fuel without any prior processing is not as energy efficient as jatropha biodiesel, and it can cause the combustion engine to malfunction.

Considering the findings of the preceding meta-analyses, it becomes obvious that several first-generation biofuel practices can provide significant net energy gains. As a result, it is reasonable to conclude that some first-generation biofuels meet the net energy provision criterion suggested by Hill et al. (2006) and therefore constitute feasible energy options in the short to medium term. However, certain authors have given the reminder that the moderately high EROIs of most biofuel practices are

[5] All these biodiesel practices had lower cumulative energy demand than conventional diesel.