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Biofuels as Sustainable Technologies: Perspectives for Less Developed Countries

ALFREDO CADENAS and SARA CABEZUDO

ABSTRACT

The future outlook of biofuels is beset by uncertainty. Key factors for the adoption of biofuels as alternative technologies are policy decisions by governments in terms of regulations, such as government procurement schemes and fuel specifications, along with financial and economic instruments, such as subsidies and preferential taxation. In this framework, the present analysis is a prospective as to the future development of a biofuel program in the European Union and the hypothetical role of developing countries as suppliers in this new market. The focus of this article is, exclusively, on liquid fuels. © 1998 Elsevier Science Inc.

1. Biomass Energies: Liquid Biofuels

Biomass refers to all the matter that can be obtained from photosynthesis. Most vegetable species use solar energy to create sugars from carbon dioxide and water. They store this energy in the form of glucose or starch molecules, oleaginous, cellulose, and lignocellulose.

Biomass appears to be an attractive feedstock for three main reasons. First, it is a renewable resource that could be sustainably developed in the future. Second, it appears to have formidably positive environmental properties, notably the recycling of carbon in the biological processes, resulting in no net releases of carbon dioxide and a very low sulphur content. Third, it appears to have significant economic potential provided that fossil fuel prices increase, quite substantially, in the future.

ALFREDO CADENAS is Professor at the Autonomous University of Madrid, Dept. of Development and Structural Economics, Faculty of Economics, Madrid, Spain.

SARA CABEZUDO works at IADE, Faculty of Economics, Madrid, Spain.

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Address correspondence to Alfredo Cadenas, Dept. of Development and Structural Economics, Universidad Autonoma de Madrid, Ctra. de Colmenar Viejo km. 15, 28049 Madrid, Spain.

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The great versatility of biomass as a feedstock is evident from the range of materials that can be converted into various solid, liquid, and gaseous fuels using biological and thermochemical conversion processes. Four broad categories of potential biomass feedstocks can be identified: (1) organic urban or industrial wastes; (2) agricultural crop residues and wastes including manure, straw, bagasse, and forestry waste; (3) existing uncultivated vegetation including stands of trees, shrubs, bracken, heather, and the like; and (4) energy plantations, which involve planted energy crops either on land brought into production for that purpose, land diverted from other agricultural production, or as catch crops planted on productive land.

Due to the historically poor status of biomass-related R&D, and its neglect on the part of planners and development agencies, it has been very difficult to change biomass energy systems in terms of their production, harvesting, and energy conversion structures to changing socioeconomic and environmental pressures. Fortunately, this is now changing somewhat, so that there is an opportunity to use biomass efficiently for the production of modern energy carriers such as electricity and liquid fuels and to improve the lack of efficiency associated with traditional biomass fuels such as wood and charcoal.

Ideally a successful biomass program should be sustainable and economical, taking into account all costs and benefits, especially spillover and indirect effects, including environmental and health aspects. The focus of this article is, exclusively, on liquid fuels. The term *biofuel* is used mainly to refer to liquid fuels.

There are several reasons for biofuels to be considered as relevant technologies by both developing and industrialized countries. They include energy security reasons, environmental concerns, foreign exchange savings, and socioeconomic issues related to the rural sector. Many of these aspects are discussed in this article.

2. Technical Applications

Biofuels in their liquid form, for the purpose of this article, can be classified as follows:

1. Vegetable oils
   —Unmodified vegetable oils
   —Modified vegetable oils
2. Alcohols
   —Bioethanol
   —Biomethanol
3. Oxygenated components

2.1 VEGETABLE OILS

Pure vegetable oils, especially when refined and deslimed, can be used in prechamber, indirect-injected engines such as the Deutz model and in swirl-chamber diesel engines such as the Ellsbett diesel model. They are also usable when mixed with diesel fuels. Pure vegetable oil, however, cannot be used in direct-injection diesel engines, such as those regularly used in standard tractors, since engine cooking occurs after several hours of use. All engine types allow additions of vegetable oils mixed with fuels in reduced and small proportions, but residues and cooking negatively affect short-term engine performance. Some vegetable oils also find application as lubricants and as hydraulic oils. In addition, they can be used in saw machines. In general terms, it is possible to substitute mineral oils for vegetable oils provided that appropriate additives are included.

Vegetable oil can be obtained from more than 300 different plant species. Oil is contained mainly in fruits and seeds, yet still other origins exist. The highest oil yields can be obtained from tree crops, such as palms, coconuts, and olives, but there are a number of field crops containing oils. Climatic and soil conditions, oil content, yields and the feasibility of farm operations, however, limit the potential use of vegetable oils to a reduced number of crops.

Apart from the previously mentioned semirefined oils, vegetable oils can also be used in the esterificated form. Diesel engines malfunction if an excess of carbon is present in the combustion process. It becomes necessary to split the glycerides causing an excess in the carbon composition. This can be achieved by treating oil with alcohol-transesterification or by cracking procedures. Ideally, transesterification is potentially a less expensive way of transforming the large, branched molecular structure of the bio-oils into smaller, straight-chain molecules of the type required in regular diesel combusion engines. The so called biodiesel fuels are oil esters of a biological origin. Rape oil methyl-ester (RME) and sunflower methyl-ester (SME) are two biodiesels derived from their corresponding oil seeds.

2.2 ALCOHOLS

Ethanol is a volatile liquid fuel that may be used to replace refined petroleum. It can be obtained from different feedstocks. Among them are cereals, sugarcane, sugarbeet, and tubers as well as cellulose materials, namely, wood and vegetable remnants, although production in these cases is much more difficult [1]. Attention has been focused lately on other plants such as Jerusalem artichokes, which contain inulin (a fructose polymer), and on converting lignocellulosic materials into glucose to obtain ethanol. The ethanol yield from these products depends mainly on the content in fermentable glucides and on per-hectare yields.

Ethanol from biomass can readily be used as a blender in gasoline. To elaborate ethanol, the biomass feedstock is first separtaed into its three main components: cellulose, hemicellulose, and lignin. Cellulose is hydrolyzed into sugars, mainly glucose, which are then easily fermented into ethanol. Hemicellulose can also be converted into sugars, such as xylose, but it is difficult to ferment to produce alcohol. Lignin cannot be fermented, but it can be used to provide energy for fermentation processes. There is no chemical difference between ethanol derived from biomass and fossil origin ethanol. Another advantage of ethanol is that is can lower the production of aromatic products found in high octane gasolines. Ethanol is currently produced in two separate ways: synthetic ethanol produced from ethylene derived from hydrocarbon, which is perferred for industrial uses due to the pureness attained (which can reach values of 99.9% in alcohol), and ethanol obtained from the fermentation of plants rich in sugar or starch, a process that is clearly advantageous when using gasoline as a fuel.

Concerning methanol, although it can be produced from a wide range of raw materials (namely, wood, dry biomass in general, coal, etc.), at present, it is mainly obtained by synthesis from natural gas or gasoline. The technology for the production of methanol consists of "gasifying the cellulosic raw material to obtain a synthesis gas followed by the traditional processes used for fossil fuels whereby the gas is purified and its composition is adjusted for the synthesis of methanol" [2].

Biomass sources are preferable for methanol, than for ethanol (unless ethanol is used for specialized sectors such as agriculture). The final energy result is more positive when producing methanol because ethanol is a high-cost, low-yield product with problems derived from storage and effects on soil. Also, methanol is less volatile, thereby less dangerous in case of a traffic accident. Unexpected combustion could be extinguished with water, it pollutes less, it has no sulphur content, and it could be tranformed into a high octane gasoline that may be used in countries not ready to employ engines that are fed directly with methanol. That transformation implies a cost, but it would not be excessive. However, the problem with the production of methanol from biomass remains the optimum size of the present manufacturing units, which, having been designed for fossil fuels, are not readily suitable for a very different raw material.

2.3 OXYGENATED COMPONENTS

European legislation exists to promote the use of unleaded gasoline in the European Union (EU), but one of the technical problems that this gasoline faces is its decreased octane due to the reduction in lead content. This reduction in octane coincides with a demand for higher octane fuels on the part of the consumer. One of the options for solving this is to use oxygenated components of mineral origin as additives that ‘‘are characterized by a high RON in relation to petrol and have a high sensitivity (RON–MON)’’ [3]. To compensate for their high volatility compared to gasoline, one of the elements of the mix has be eliminated (generally butane). This fact implies added costs for the refinery since it must separate the butane from the gasoline, the refinery being obliged to sell the butane in another market at a lower price.

3. European Public Policies Influencing the Production and Utilization of Biofuels

3.1 EUROPEAN SCIENCE AND TECHNOLOGY PROGRAMS AND INITIATIVES

Obviously, the evolution of biofuel technologies depends as much on economic opportunities and public policies as on enhanced technological options. It is evident that much of the advancement in technological capabilities, at least in the EU, will be provided as a consequence of research and development actions, either collectively promoted by the EU or separately devised by a member country’s institutions and firms. There are, basically, three different R&D programs that might affect the future technological evolution of biofuels. They are the non-nuclear energy, the environment and climate, and the agriculture and fisheries research and development programs, all pertaining to the Fourth Science and Technology Framework Programme of the EU.

Research and development actions in the field of non-nuclear energy (Joulie-Thermie Programme, 1994–1998) are, primarily, aimed at energy security in the broadest sense, that is, ensuring durable and reliable energy services at affordable costs and conditions and, also, recognizing that the main concern today is the protection of the environment and to reduce the impact of the production and use of energy, in particular of CO_2. The Joule-Thermie Programme also aims to contribute to the achievement of other important EU objectives such as strengthening the technological basis of the energy industry and contributing to cooperation with third countries, particularly, developing countries [4].

This program is divided into five areas: energy R&D strategy, rational use of energy, renewable energies, reduction of environmental impacts of fossil fuels, and dissemination of energy technologies. The energy strategy area includes several sections ranging from global analysis of energy R&D policy options to socioeconomic research in order to understand those factors that foster or hinder the innovation processes of energy technologies. Also included in this area is the goal to find methods for the promotion of new technologies, that is, to provide efficient tools for the dissemination of R&D results—based on market assessments and evaluation of actions, technologies, or instruments—and to elaborate training programs for using new energy technologies. Within this strategy area, important studies on the future of biomass energies, including liquid biofuels, are contemplated with special emphasis on technology dissemination.

The rational use of energy area concerns energy efficiency on the demand side of the energy sector. It covers the reduction of energy consumption and stimulating market penetration of innovative, efficient, and clean technologies with a view to reducing dependency on external supplies of energy products and to improving the impact of the use of energy on the environment.

The area relative to renewable energies has as its main objective to enable and stimulate the introduction of renewable energies into the energy system, which offer substantial advantages from an environmental protection standpoint, CO_2 emissions, and long-term security of energy supply. In addition, new initiatives will be taken to enhance the integration of renewable energies into the economy and society. Included in this area are sections on the integration of renewable technologies in social issues and research on energies from biomass and waste. The main objective of this last section is to increase the utilization of biomass for energy supply in the EU on as large a scale as possible.

Another R&D Program with implications for the future of biofuel technologies is the Environmental and Climate Program. This program aims to improve the scientific knowledge and technical competence for conceiving and carrying out environmental policy while stimulating sustainable growth. It includes multisectoral and interdisciplinary activities focusing on three main objectives: first, to strengthen the scientific base needed to implement the EU's environmental policy and permit it to reconcile the notions of human health and safety, environmental protection, and the sustainable management of resources with development and economic growth; second, to contribute to world programs of research into global change; third, to contribute to the development of environmental technologies, techniques, products, and services that meet new needs and could contribute to sustainable economic growth. A number of R&D possibilities for systemic factors pertinent to the future evolution of biofuels production and utilization might be provided within this planned action program [5].

A third R&D program relevant to biofuels in the EU, with implication for third countries, is the Agricultural R&D Programme [6]. Prominent among the objectives of the program are the forestry and nonfood sectors of agriculture and their links with the processing industries, together with rural activities, the end-user, and the consumer. Worth mentioning among the planned activities are the sections on integrated production and processing chains, and scaling-up and processing methodologies, both dedicated principally to the nonfood sector and especially to the use of plant raw materials, such as timber, fibers, carbohydrates, oils, proteins, and specialty chemicals contained in new and traditional crops and trees. Included as the first section in the integrated production and processing area are the biomass and bioenergy chains. In addition, the scaling-up processing methodologies refer to biomass energy as well. They concern the processes for designing and operating large-scale systems on the basis of the results of experiments with small-scale or laboratory models, which permit a better evaluation of both technical and feasibility costs. Additional objectives are to address the problems associated with the transfer of basic or applied research and technology from the laboratory level to the development steps of industrial scale. Obviously, as underscored previously, this is of great relevance for the future development of liquid fuels derived from biological sources due to the fact that the transfer step is normally characterized by major problems and bottlenecks, such as a lack of homogeneity and quality in the raw material supply and a lack of understanding of the basic physical and chemical characteristics and relationships of the biomaterials being processed and produced. Problems such as fluid dynamics, product recovery, heat transfer, flocculation, and so on are common when applied and basic research models are scaled up in the development or pilot-scale phase of R&D.

3.2 EUROPEAN PUBLIC POLICIES ON ENERGY

Potential import demand of the EU for biofuels produced in less developed countries will be influenced very strongly by future developments in concerned public policies. To ensure further uses of biomass fuels and to exploit fully their projected potential, a coordinated multisectoral approach has been advocated. This should provide an effective assessment of the interactions among policies related to agriculture, energy, transport, and the environment and, it is hoped, will avoid contradictory measures.

3.2.1 Energy Policy

The rise of world oil prices due to the 1973 and 1979 oil crises stimulated the formulation and implementation of new energy policies, so that new renewable energy sources became attractive alternative fuels. The current priority axes of the EU energy policy are:

- to improve energy efficiency,
- to secure energy supplies,
- to protect the environment,
- to push technological innovation,
- to guarantee economic and social cohesion, and
- to develop international cooperation [7].

These goals are similar to the ones set out by the European Energy Charter [8], a pan-European forum, whose goal was "to improve security of energy supply and to maximize the efficiency of production, conversion, transport, distribution and use of energy, to enhance safety and to minimize environmental problems on an acceptable economic basis."

Security of energy supplies results not only from a greater independence from foreign sources but also from the replacement of gasoline by other kinds of energy as a way to secure improved price stability and protection from fluctuation of international energy shocks. Diversification of energy sources and a higher percentage of locally produced energy are goals that can be satisfied by biofuels. Nevertheless, if those biofuels are to be imported from developing countries, even if their use will foster diversification of sources, the EU will still depend on foreign sources.

The inexhaustible nature of biofuels as an energy source is also an important asset for their future potential from the security standpoint. In contrast to fossil fuels, their social acceptance will probably increase in the future provided that some negative possible impacts on the environment are avoided or carefully kept under control. The European Energy Charter advocates a number of policies to enhance all kinds of renewable energies but cautions about unchecked broad utilization.

Technological innovation seems to be the best way to achieve objectives that otherwise might seem contradictory: meeting increasing demand, improving the environment, and ameliorating the supply security [7]. This technological effort should be focused not only on fossil fuels and their capability to reduce consumption but also on exploring new energy paths and alternatives.

One of the major themes concerning environment and energy is the proposed directive [9] that establishes a carbon tax on fossil oils in order to keep CO_2 emissions levels down. The exact amount of the tax is still under discussion, although most commentators estimate it will reach $10 per barrel of oil (a 50% hike on current prices). This tax needs to be so high in order to compensate for the lack of price responsiveness on the market [10]. The final goal would be to maintain CO_2 atmospheric emissions in the year 2000 at the 1990 level, CO_2 being the main cause of the greenhouse effect. Nevertheless, introduction of this regulation is facing strong constraints since the EU's competitiveness might be reduced if similar steps are not taken by other Western economies such as the USA and Japan (the USA has also demonstrated a willingness to reduce its carbon dioxide emissions from the use of fossil fuels). Besides, this carbon tax might have less impact on fuel consumption than expected since fuel price elasticity is known to be quite small [11].

The ALTENER program [12], which is the main initiative of the EU to support renewable energy, sets three objectives for renewable energy sources in Europe by 2005:

- increase the renewable energies market share from 4% to 8% of EU primary energy needs;
- triple the production of renewable energy, excluding large hydro schemes;
- and secure a biofuels share of 5% of total fuel consumption by motor vehicles [13].

Nonetheless, even when considering optimistic penetration rates such as the one quoted, biofuels cannot solve the security supply problem, since fossil fuels will continue to be the main energy source. Typical ALTENER projects deal with breaking down barriers or establishing new legal, administrative, organizational, economic, or managerial systems.

3.2.2 Agricultural Policy

A strong link between agriculture and biofuel development exists in most developed countries facing over-production-related problems. The European Common Agricultural Policy (CAP) reform [14], for example, represents a radical shift in the EC management of agriculture. The broad aim is to alter market support schemes—high intervention and public buying—and likewise to allow lower agricultural prices to come closer to international levels.

Several important trends in connection with biofuels are worth mentioning. Thus, a reduction in crop price predicted in accordance with the long-term goal of meeting world prices implies a decrease in crop costs that will surely improve biofuel competitiveness. This possible event is analyzed shortly.

A second feature of the EU agricultural policy is the scheme to provide aid for the withdrawal of land from production (set aside). This measure concerns farmers with large extensions who are obliged to leave 15% of their arable hectares as fallow land if they are to benefit from the Community compensatory payments. If this measure, implemented since 1988, has not met the objective of reducing surplus foodstuffs, this is due to the fact that farmers are leaving fallow their less productive lands and intensifying cultivation on the remaining 85% in order to maintain their former output and revenues. Currently, those fallow lands can be used to produce crops for nonfood uses such as biofuels. To foster this development, farmers will receive not only the compensatory payment but also revenues from raw material sales. The U.S. Government is also paying growers not to produce, withdrawing several million hectares from food-crop cultivation under the Acreage Reduction Program. Supposedly, this measure will also enhance cultivation of energy crops and short rotation wood (SRW).

There are at least two ways in which the utilization of biofuels and the cultivation of fuel crops can help rural and retarded economies:

- The represent one additional possibility for the utilization of farm resources, with the end result of raising income and direct employment on the farm.
- The manufacturing and commercialization of fuel crops need to be based on the rural communities.

Cultivating crops for energy use provides an opportunity to increase the demand for agricultural commodities. This new income will surely improve the material welfare of rural communities and might result in a further activation of the local economy. In the end, this will mean a reduction in emigration rates to urban environments, also a very important goal of the new provisions of the CAP.

The net employment created is computed as the sum of the direct jobs created on the site of the process and in agriculture, and the induced jobs created in associated sectors, minus the loss of jobs in the sectors of traditional energy distribution [15]. The French Farmers' Association (AGPB) has funded a study that concludes that direct new employment per each million of hectoliters produced would be around 700 jobs, taking as a reference a farmer cultivating 80 hectares of set-aside land. In addition, indirect employment would increase to nearly 300 new jobs.

These calculations allow us to extrapolate a global European rise in employment in the context of biofuels production of between 1.5 and 2.5 million of tons. As a result the employment increase would fluctuate between 23,600 and 40,000 new jobs. Still, those numbers need to be adjusted, and employment losses in other related sectors, such as in oil refining, must be contemplated. In summary, biofuels could offer a possible technical solution to the agricultural overproduction problem by diversifying crops and uses and increasing demand, instead of the public purchases currently implemented.

3.2.3 Environmental Policy

The unequivocal acceptance of industrial growth and economic expansion has brought humankind to a threshold in the earth's ability to absorb pollution and in the exploitation of its scarce resources. Included in these resources are air, clean water, the seas, the land, and many human cultures. Following the 1987 report of the Brundtland Commission, the need for change is discussed in terms of "sustainable" development, but there is little agreement on the concept and on operating procedures and criteria. Appropriate management is required on a global scale, which means on national, regional, and community bases.

In this framework, energy sources can no longer be developed without deep considerations for their implications for the environment. This applies at all stages of the energy chain from the time energy is produced, through its transportation and use, and to waste disposal [16]. As countries move to adopt more stringent environmental standards, environmentally friendly energies are indirectly fostered.

Three broad categories of issues that can provide a guideline for analyzing the contribution of biofuels towards sustainability are energy balances, environmental balances, and biodiversity effects. In terms of energy balances, many studies have shown that the weight of evidence available supports the view that biofuels result in positive energy balances. How positive depends on the way these products are used and processed beyond their raw production stage. "It would be strange indeed if the contrary were the case, since plants absorb energy photosynthetically from the sun producing natural (energy) products as a result. Nevertheless, energy auditing of the production and use of biomass should be continued in order to improve and further understand where energy economies can be made'' [17].

With regard to environmental balances, the conclusion put forward by the interservices Working Group of the Commission of the EU is more ambiguous than the one relating to energy. There are a number of reasons for this fact, which can be summarized as follows: (1) There is no measure with which to make an overall judgment; (2) there can be no certainty about long-run effects; (3) environmental variables interlink in complex ecosystems; and (4) most research is based on pilot projects and demonstration experiences, which generate incomplete and inconsistent data and fragmentary results.

Several environmental factors and trends need to be accounted for in the framework of biofuel production and consumption. Legislation related to air emissions will not only affect biofuel development but also the environmental regulations applicable to traditional agriculture. Concentrations of lead, sulfur dioxide, nitrogen dioxide, ozone, carbon monoxide, and particulate matter are regulated both in the USA, by the National Ambient Air Quality Standards set by the EPA, and in Europe, by several directives and regulations [18]. Since biofuels are crop based, soil depletion, effluents, pesticide, and fertilizer consumption are also aspects to be considered in any environmental assessment.

Cultivated feedstocks for biofuels share with agricultural production a variety of shortcomings, usually criticized by environmentalists. These include soil erosion, occupational hazards, loss of ecosystems, excessive fertilizer and pesticide use, monoculture production, and the deterioration of landscapes. Nevertheless, if biofuel crops replace old foodcrops or natural vegetation, the net effect might be nil or insignificant. Moreover, it should be noted that in addition to short rotation forestry (SRF) and those plants frequently used at present in the more developed countries (corn, wheat, sugar beet, oil seeds, etc.), there are a number of other vegetable species with lower agricultural input requirements and, therefore, with lower pollution effects. Sorghum, for example, only requires 50% of the fertilizer used on corn fields and less water. Other relevant species are *Miscanthus*, certain sugar canes and groundnuts, *Cynara,* and *Arundo donax.*

The level of emissions is also relevant in this regard. Emissions of CO_2, which translate into a greenhouse effect, is a feature of most fuels. If biomass energy is used instead of fossil fuels, however, there is normally a net reduction in CO_2 emissions. The extent of this reduction depends on the fossil fuel displaced and the efficiency with which the biomass energy can be produced, which can be measured in terms of energy balances. A reduction of 180 million tons in carbon emissions by the year 2005 could be achieved with a biofuels market penetration of 5% of the total consumption in combustion engines. To produce this quantity of biofuels, 11 Mtep, 7 million hectares would be needed [19]. This, of course, only holds true to the extent that the overall source of biomass is a constant or increasing one and that the production of biofuels does not simply represent a diversion of existing crops.

Sulphur dioxide is a major pollutant causing extensive damage to forests, buildings, health, and so on. Fortunately, SO_2 emissions from using biomass energy tend to be considerably lower because relevant plants and trees contain only trace quantities of sulphur compared to much higher emissions from coal, gasoline, and even some natural gas.

This drop in SO_2 is accompanied by a fall in the level of the other traditional motor pollutant emissions such as carbon monoxide, unburned hydrocarbons, and particulates, but these reductions are less easily quantifiable. However, there is an increase in the release of nitrogen oxides [20] and aldehydes. There is no clear advantage to any one of the liquid biofuels, and choices between them will depend on local priorities. If the aim is to move to lower intensity forms of land use, wood production is likely to have significant advantages. If emission abatement per hectare is a priority goal, the liquid fuel with the greatest potential is ethanol from sugar beets [21]. Life-cycle analyses of different options are needed to conclude objectively whether biofuels obtained by biotechnological processes are less pollutant than fuels from gasoline [22].

In addition to energy and environmental balances, the effect on biodiversity is a third component of the sustainability issue, as mentioned several paragraphs ago. Again this is a complicated issue because biomass production could, theoretically, reduce biodiversity around the world. Although more research is urgently needed on the issue to reduce the uncertainties involved, biomass fuel proponents retort that, yes, ‘‘inappropriate plantation will result in a loss of biodiversity, but on the contrary, environmentally sensitive plantation, including such techniques as nitrogen fixers, judicious use of cloning and keeping a proportion of the habitat in a natural state, can actually improve biodiversity. Furthermore, biomass is made up of a very large variety of genetic cultures which, if judiciously used, need not result in difficulties’’ [17].

We may conclude that biofuels may be able to contribute to the attainment of a variety of environmental objectives such as the aim of reducing both local air pollution and greenhouse gas emissions and the environmental concerns of maintaining agricultural land in production with a possible move to lower intensity production of crops [21]. Blended alcohol fuels are sufficiently similar to nonalcohol gasoline to allow most vehicles to be able to use them without modifications in engine designs, a fact that constitutes an important advantage for its market penetration. From an environmental point of veiw, however, blended fuels consist primarily of gasoline or diesel fuel, which limits the potential benefits in both emission control and efficiency [23].

3.2.4 European Legislative Framework on Biofuels

On Feburary 19, 1992, the European Commission adopted a draft directive fixing a tax structure for biofuels at levels notably lower than those applicable to fuels of fossil origin. The aim was to help biofuels by reducing cost differences between both alternatives, thereby compensating for the following factors:

- the extra cost of production;
- the economic risk of the various variables to be taken into account such as the price of oil, the value of by-products, and so on;
- industrial risks in introducing new processes;
- commercial risks in the costs of distributing, promoting, and launching a new product; and
- the need to ensure a return for the investor [24].

This proposal has been modified after hearing some specific commissions and based on the results of several studies. The draft dated July 1, 1994, presented some amendments. The reduced tax would be applied to bioethanol, biomethanol, and vegetable oils without discrimination by production origin.

When asked, the Economic and Social Commission [25] proposed an amendment: the fiscal benefit would be applied only to those biofuels obtained from feedstocks produced on the set-aside lands, its goal being to coordinate the reformed CAP and this tax advantage. In the end, this amendment was not introduced in the directive due to conflicts with EU international agreements. Thus, the proposed scope covers all motor fuels from agricultural sources without distinguishing among their origins, that is, the origin of the agricultural product used to produce them or the nature of the product. The specialized Committee also pointed out the importance of transferring technology and ''know-how'' to Eastern European countries as well as to developing countries. Nonetheless, the report underlines the benefits for those countries by reducing or at least maintaining crude oil imports but not by becoming biofuel exporters.

The rate of duty to be applied to bioethanol and to bioethanol shall be not greater than 10% of the rate of duty charged on unleaded gasoline within a Member State. Reference for vegetable oils will be the excise tax on diesel fuel. As this proposal only sets a maximum percentage, each country can decide the final tax incentive for biofuels consumed in its territory.

As a matter of fact, since taxes on unleaded and diesel fuels are not yet harmonized in the EU, there would not be an equal tax for biofuels across Europe. Directive 92/82 set minimum taxes for leaded and unleaded gasoline (337 AC/1000 liters and 287 AC/1000 liters) as well as for diesel (245/1000 liters) to be applied by January 1, 1993. Nevertheless, a great step must be taken if a real harmonization of different excise duties in Member States is to be reached. In the meantime, countries with a higher fossil fuel excise duty will encourage biofuel consumption more than those with a relatively low excise duty.

The percentage applied to biofuels will be changed after the first ten years to 20%—five years later to 30%, increasing each five years until reaching 50% of the rate of duty charged on fossil fuels. In this way, biofuel procedures will enjoy a long, steady favorable taxation. The proposed directive in Article 5, however, states that every two years the European Union's Council shall review the fiscal treatment applied to biofuels, acting on the basis of reports and proposals from the Commission.

One of the amendments introduced concerned water protection against nitrate pollution fixed by directive 91/676 (December 1991). In this way, the same restrictions will be applied on agricultural crops used as feed and as fuel, in order to protect the European environment. At any rate, developing countries cannot be obliged by EU legislation to use specific agricultural methods and environmental restrictions in their cultivation and production processes.

4. Biofuels Costs and Predictions

After looking over the technically specialized literature [26], we can say that costs of producing bioethanol and biodiesel are much higher than gasoline or diesel; therefore, tax support or subsidiaries are necessary to foster wider use. With decreasing feedstock costs and improvements in processing technology, however, the costs of liquid biofuels could decrease 30% by 2010 [19]. Other studies, such as the one proposed by Rendleman [27], predict savings around 10% for the next five to ten years, basically due to technological innovations.

5. Potential European Market for Liquid Fuels

The potential European market for large-scale production of liquid fuels depends on the predicted demand from the transport sector and on the potential supply from domestic agriculture. If domestic supply is enough to meet the demand and the appropriate conversion technology is available, a strong constraint will be put on imports from the developing countries. On the contrary, if an equilibrium is not reached and demand exceeds supply, imports will be needed. As a result, cost and price comparisons between imported and domestic prices become crucial items in any analysis.

5.1 POTENTIAL DEMAND

European demand for biofuels is related to several factors such as oil fuel prices, gasoline and diesel consumption, oxygenate evolution, market penetration, and obviously, biofuel prices. The study of the current and forecasted gasoline market is essential for the analysis of any possible introduction of biofuels, since this energy constitutes the central reference for prices of other energy alternatives. Clearly, energy is firmly embedded in a rapidly evolving economic setting. Moreover, the formulation of any long-term prediction of crude oil prices entails great difficulty due to the price volatility that characterizes this market. Per barrel price estimates of crude oil published in the *Oil and Gas Journal* [28] using several sources showed an average of $29.55 in the year 2000, $36.29 in 2005, and $47.05 in 2010.

The evolution of world-wide oil prices will play an important role in determining when the break-even point for the use of bio-carburants [29] (which have to compete with hydrocarbons), has been reached. A European study [30] concluded that, for agricultural alcohols to compete in the energy sector, either agricultural prices would have to fall by 40% or the price of oil would have to rise to $40 per barrel. Nevertheless, most predictions set world oil prices by 2010 at lower levels, even if it is generally accepted that the price of oil will, over time, follow an upward trend—partly to pay for the fuel and partly to encourage further exploration. Moreover, exchange rate fluctuations could, of course, have a greater effect on what will be paid for oil than does the price of oil itself.

Forecasts of consumption and technical specifications of fossil fuels allow us to obtain a rough estimate of the potential market share for biofuels. Studies from the European Union published in the journal *Energy in Europe* conclude that gasoline demand is constantly increasing in favor of the lighter distillates. This effect will be intensified by growing demand and increasingly stringent product specifications. At the same time, conversion and upgrading refining capacity for these high-quality products may well become tighter. Availability of these products on international markets is likely to be limited.

Concern about possible shortage in the supply of motor gasoline arises also from the fact that:

- the general move to unleaded gasoline as a result of legislation can only be achieved at satisfactory octane level with some reduction in the energy yields of gasoline;
- the introduction of progressively higher octane unleaded gasolines by the major companies, as part of their strategy to increase their market share, further reduces the yield of gasoline available using existing technologies.

Both trends would push biofuels to the forefront, mainly ethanol, due to its use as an oxygenate in the mix. The lower lead content in gasoline implies a reduction in octanage, which will open a new field for oxygenates (ethanol and its derivative [ETBE] being two important additives) in addition to methanol. Furthermore, the importance of those components will increase since gasoline demand will require a higher rate of octanage in the future.

The transformation of raw materials into energy products results in the simultaneous production of other commodities, which sometimes have an economic value known as *byproducts* and *coproducts*. The term *coproduct* usually refers to those products with a considerable value. When calculating biofuel costs, the coproducts' market price has been substracted from the feedstocks total cost. However, their potential demand should be analyzed.

Depending on the raw material used, different coproducts are obtained. For example, the process for obtaining ethanol from grain gives rise to a high-protein product known as *distillers' dried grain with solubles* (DDGS). DDGS is used as animal feed. If the feedstock used is sugar beet, the coproducts obtained are sugar beet pulp and vinasse. Sugar beet pulp is the nonsoluble component separated prior to fermentation, and vinasse is the liquor obtained after fermentation that can also be dried. Both products are used as animal feed. Similarly, from rape seed oil transformation, in addition to diester, rapeseed cake and glycerine are obtained as coproducts. This cake is sold as cattle feed.

Markets for these products already exist and none of the studies analyzed forecasted a decrease in their prices even if supply increases. Nevertheless, special mention should be made regarding glycerine. The joint production of diester and glycerine from rapeseed oil might alter the previously existing market for the latter. The glycerine market might reach a point of saturation resulting in lower prices. As a consequence, diester production costs would increase, worsening its position vis-à-vis gasohol. For that reason, it is important to extend the utilization of glycerine to new products in order to maintain both diester and glycerine prices.

Whatever the purely economic obstacles may be, public acceptability and market behavior can also have a major influence on the future of renewable energies. Sometimes, poor public opinion has a greater influence on choice of technology than more substantial technical and cost constraints. Consumers, through their choices, will accept or reject reformulated fuels. They could be reluctant to use renewable energies that require specialized operation and maintenance, such as gas and electricity. If bioalcohols and oil esters are melted in percentages no higher than 10% in the final mix, their use would not imply any change in behavior for consumers. This fact would favor their market penetration if there is not an economic penalty.

5.2 POTENTIAL SUPPLY

European supply constraints can arise either from domestic agriculture or from the capacity of processing plants. Still, demand for biofuels can also act as a constraint, since there is no economic significance in producing biofuel surpluses. The environment also may be an entry barrier if biofuel cultivation is intensive, accruing the use of pesticides and fertilizers.

As a first approach, the current feedstock surplus can be considered the potential European supply. Taking into account the set-aside program, the maximum number of hectares that can be considered for biofuel production purposes are those shown in Table 1.

This surplus area could satisfy more than 10% of European Community transport fuel requirements if it was completely devoted to bio-ethanol production. Great disparity exists over land availability for energy crops in the European Community, with the lower rate being the one supported by the Energy Commission, which estimates a land surplus of 4 million hectares. An analysis carried out by David Wright shows 13 million hectares.

However, even if no more lands are turned to this end use in the future, production of biofuels can increase to meet higher energy demands. To set supply calculations from its domestic agriculture, three factors must be considered: the land area available for energy crops, the conversion efficiency factor, and the calorific value of energy crops.

TABLE 1
Land Available for Energy Crops

Country	Land area (10^3 Ha)
Belgium	12
Denmark	6
Germany	5,594
Greece	1,200
Spain	1,165
France	1,394
Ireland	70
Italy	8,975
Luxembourg	1
Netherlands	500
Portugal	800
UK	2,562
Total EC-12	22,279

These areas are based on the 15% set-aside area in each country. The amount of land available for energy cropping is dependent on a number of factors, including competition from other demands. The figures presented in this table are only indicative of the amount of land that might be used for energy cropping under appropriate policy conditions.

Source: The European Renewable Energy Study, 1994 [19].

Due to improvements in the best technology available, yields of crops obtained from each hectare will rise, and a greater amount of final biofuels will be produced from the same tons of foodstock, finally pushing forward the calorific value of the fuel.

Today, scale economies have pushed down the above-mentioned installation costs, showing their elasticity to the processing capacity employed. Hence, economies of scale are vital to compete with other final utilizations and other energy resources. For example, rapeseed esters are mainly produced in small pilot plants, and few processing industries with a higher capacity exist such as the one settled in France (Compiegne) with a 20,000 ton/year capacity, the German one (Kiel) with an 8,000 ton/year production, and one in Italy (Livorno) with a 20,000 ton/year capacity. Nevertheless, analyses show that the optimum size of these processing plants would be between 40,000 and 100,000 tons/year, which would require investments between 250 and 500 Ecus per ton per year (Altener Program).

This non-neutral efficiency must be taken into consideration when devising appropriate technology adoption policies for biofuels. Conversely, revitalization of rural economies requires processing plants to be located near the lands where crops are grown, a fact that implies that this goal will be better fulfilled if a large number of small plants are built. We can, thus, conclude that some of the benefits and aims of producing biofuels are not compatible and that some political decisions need to be made.

Several constraints exist related to nonutility elements in the energy service and production systems, such as automobile makers, fuel suppliers, and energy service companies. These constraints could arise from the automobile industry and from the related retailing network (European Renewable Energy Study, 1994). Automobile industry infrastructure is geared towards cars that run on gasoline and diesel. If biofuels are melted in such a percentage that engines need to be modified, those industries may hinder the development of biofuels and engines designed to run on biofuels. Concerning refining industries, since biofuel utilization requires changes in the production processes, some barriers can be found. In addition, if alcohols are transformed into bio-ETBE or bio-MTBE, the former products derived from gasoline that were used as oxygenated additives must be removed and would no longer be produced. Changing input implies additional risks in a technological field that has always confronted an uncertain future.

6. Implications from the GATT Uruguay Round

In the medium and long term, the GATT Uruguay Round will influence the capacity of European agriculture to produce feedstocks for biofuels and also the economic incentives received by farmers in developing countries to divert food production toward nonfood uses, such as biofuel raw materials.

The Uruguay Round agreement addresses three critical issues: export subsidies, market access, and internal suppports. In each of the areas, commitments will be phased in over a six-year period beginning July 1, 1995, for developed countries. In contrast, developing countries must phase in the commitments over ten years.

Concerning export subsidies, at the end of the implementation period, budgetary outlays for export subsidies must be reduced by 36%, and quantities exported with export subsidies must be cut by 21% from a 1986–1990 base period. However, countries may phase in the export subsidy reductions in equal annual increments from 1991–1992 levels over a period of six years. The cuts cannot be made to aggregate levels for all agricultural commodities but must be applied to each specific product or product groups such as sugar, oil seeds, wheat, and wheat flour, but subsidies will not disappear. In fact, as a result of changes insisted upon by the EU in the so-called "Blair House" agreement on agriculture concluded in 1992 [31], both the United States and the EU will be able to export 8 million metric tons of grain more than they would have been able to under the original Blair House accord [32].

Regarding market access, all nontariff barriers such as variable levies, import bans, voluntary export restraints, and import quotas must be converted to tariff equivalents by July 1, 1995. These tariff equivalents will reflect existing import protection. For products that are already subject to tariffication, the current level of access must be maintained at low tariff rates. For products for which imports are below 5% of domestic consumption, a minimum access commitment is required. The minimum access that must be provided by imports is 3% of domestic consumption initially, increasing to 5% over the implementation period. While the agricultural commitment must be phased by industrial countries over six years, developing countries have ten year to do so. Also, cuts in market access barriers are lower for developing countries—24% on the average for all products rather than 36% for industrialized countries [33]. In the EU the reduction for some sensitive products, such as sugar and olive oil, is 20% (and not 36%). For tropical products, the reduction is higher than the general 36%, some of them reaching a 100% reduction [34]. Most believe the price effects of farm liberalization alone will be a positive contributor to developing countries, though individual countries may experience some loss in income as a result of their economy's dependency on single commodities. A freer market will, in the short term, mean higher prices for a number of developing country importers that are not yet in a position to produce enough food for themselves. In a number of these countries, higher prices will provide an important production incentive to farmers not only to increase production but also to seek export markets. According to one report cited by the GATT, the price effect of a one-third reduction in industrial country agricultural support would result in a 4.4% rise in exports of temperate food products by developing economies [32].

In the area of internal supports, trade-distorting farm subsidies must be cut by 20% from 1986–1988 base-period levels. A fourth area of agreement in the agriculture portion of the Uruguay Round would limit the use of unjustified health-related regulations that restrict trade while ensuring a country's right to protect food safety. The result of the Uruguay Round must be a more stable world trading context: specifically a ''peace clause'' has been agreed upon [35]. This clause prevents (for a nine-year period) the signatory countries from undertaking actions against other member countries' internal policies, as long as these countries respect the terms of the agreement. As a consequence, compatibility between GATT and the CAP is guaranteed [36]. The agricultural accord will help developing countries in several ways: the reduction in production subsidies will make it easier for developing countries' agricultural exporters to compete on world markets, and the increased market access world-wide (and, thus, in the EU) should enhance developing countries' export prospects. Some countries (e.g., Argentina) should be able to export more cereals as a result of reduced subsidies for wheat and maize in the EU and North America.

The CAP reform allowed the EU the possibility to approach the GATT negotiations with a margin to maneuver. There has been some convergence between market prices and support prices for agricultural production over the period ranging from 1967 to 1990. This trend has received fresh impetus from the May 1992 decisions taken in connection with the GATT trade talks, designed to reduce the level of support [37]. Developing countries may not benefit from this reduction in internal prices in the EU since their products will be less competitive. Easier access to agricultural markets for imports should help to improve the competitiveness of agricultural raw materials for nonfood use.

Finally, it may be said that the significant trade barriers to international technology transfer of nonfood products are nontariff ones. These are within the scope of GATT rules.

Price reductions on agricultural commodities that might be used as energy feedstocks will make biofuels more competitive vis-à-vis fuels from fossil origins. This might stimulate increased investments in the gasoline industry seeking to secure cost reductions and more aggressive marketing policies in order to maintain preexisting market shares.

7. Plausible Societal Benefits for Developing Countries

Despite intense research on the technical feasibility of biofuel from different origins (agricultural, forest, and cellulosic wastes), financial and economic analyses (including fuel social benefits and costs) of specific systems is rather limited. Thus, little is known about its macroeconomic impact, such as employment generation, indirect income and price effects caused by subsidies, foreign exchange savings, land use impacts, and so on. Despite these limitations, several studies have been carried out to discern some general patterns [38, 39]. As expected, generalizations cannot be made from the cited studies, and thus no representative, general pattern can be inferred or assumed.

Two main points stand out in the decision regarding land use for biomass energy: the ''technocratic'' approach and the ''ecocentric'' view. While the former exclusively concentrates on the use of biomass for energy, the latter incorporates values based on sustainable development views. The technocratic approach arises from the indispensable need for energy, which implies the identification of a biotic source and its corresponding production site. Possible environmental impacts are then considered, albeit relegated to a secondary, after-the-fact, position. This approach tends to ignore many of the local and more remote effects of biomass energy plantations and frequently neglects the knowledge and expertise of local cultures. The technocratic approach has resulted in many biomass project failures in the past. The ecocentric approach, however, considers a mixture of land-use and cropping patterns that will make optimum use of a particular plot in order to meet a broad panoply of multiple objectives, such as food, fuel, fodder, entertainment, prestige, and other social needs. This requires a full understanding of human ecology, which implies that conditioned and qualitative calculations, rather than quantitative benefit–cost calculations, are indispensible in the selection of alternative initiatives and local development projects.

The broad food versus fuel issue has been a heatedly debated subject in this respect. Making fuels from crops has a strong moral connotation, very prone to controversy. Agricultural and export policies, both in the developing and the developed worlds, are very important determining factors in world food availability. Food versus fuel should be analyzed within the framework of the world's food situation in which increasing food surpluses in most industrial countries, and in a number of developing countries, are fed to livestock while acute endemic food and fuel shortages exist in some regions. Price policies and agricultural practices should take into account these realities to attempt to remedy this unfortunate situation [40].

Bioalcohol fuel production in Brazil and eucalyptus plantations in India and Thailand have received adverse criticism, where biofuel production was only part of the overall socioeconomic problem but not the cause of the problem. Moreover, many successful biofuel experiences around the world have not been sufficiently publicized due to the price subsidization costs involved in this age of recurrently depressed crude oil prices. Despite the fact that a large range of organizations has been created in developing countries to promote the development of small-scale production of biomass energy, such institutions have generally not been very effective [39]. Maximization of output rather than capital savings and employment generation has been the main concern of many projects. High-tech, capital-intensive projects receive priority for reasons of politics and prestige in some nations. Low-priority, ineffective implementation and demonstration initiatives are very inimical to the desirable development of the biofuel initiatives.

Very significant social and economic benefits to urban and rural areas in developing regions can be obtained from the modernization of bioenergy production and use. Lack of access to reasonable amounts of energy, especially modern energy carriers such as liquid fuels and electricity, limits the quality of life of millions of people throughout the world. Since biomass is the single most important energy resource in rural areas of developing countries, it should be used to provide for modern energy needs in addition to transportation (e.g., irrigation pumps, agroindustry, lighting, refrigeration, etc.) [39, 41].

Moreover, biomass energy systems are often perceived as providing substantial foreign exchange savings if they replace imported petroleum products. This savings, however, is not always clear-cut since it depends on the export earnings procured by the import substitution of items that are complementary in the production and distribution processes. In countries such as Brazil, with a long history of experience with technology in bioethanol production and use, there are substantial savings in oil imports and also foreign exchange earnings from alcohol-related technology exports. Zimbabwe similarly saves foreign exchange on petroleum imports while developing technical infrastructure that leads to import substitution. Thus, consideration should be given to the net benefits for a given country if local resources used for domestic energy production could have earned more foreign exchange revenues through exports.

In conclusion, although the social benefits for developing countries that might result from the domestic production and subsequent use or export of biomass fuels are quite easily identified, their exact quantification and final effects on welfare are difficult to ascertain because of the many different values entailed and the multiplicity and complexity of the alternative choices involved. In the end, each location, feedstock, and value judgment system merits a distinctive and unique social calculation that can be obtained only through an analysis of domestic political structures and processes.

8. Potential European Import Demand of Biofuels from Developing Countries

Biomass accounts for as much as 90% of all energy supply in the poorest countries of the world. In Europe, France and Spain are among the few countries for which there are reliable estimates of wood use, where it constitutes about 4.5% of all energy demands. Wastes account perhaps for another 2%, which would be typical for the European Community as a whole (European Renewable Energy, 1994 [19]).

For the EU to import biofuels from developing countries in the short and medium term, at least three conditions ought to be fulfilled, the first being that much broader biofuel utilization is required. This possibility, although uncertain in the short run, is more likely to be substantiated in the medium term.

Furthermore, additional cost reduction can be expected from technological innovation. There are at least three EU research and development programs that will influence technological advances. Section 4.1 of this article concerns this particular issue. If the virtuous economic cycle (i.e., technological innovation to cost reductions to expanded demand to economies of scale to cost reduction to increased demand, etc.) is not stymied by cultural, sociopolitical impediments, a significantly large step ahead will be taken toward the desired substitution of fossil fuels with liquid biofuels.

A second precondition influencing the EU's import demand for biofuels from developed countries is related to the trade-off involved in the food versus green dilemma. If sustainable development principles dominate agricultural production interests, it is quite plausible that the EU's liquid biofuels import demands will increase in the medium term. On the contrary, if agricultural production goals take pre-eminence over sustainable and environmental protection issues, the foreign biofuels alternative will not be positively influenced. Undoubtedly, producers of agricultural surpluses will seek to shift operations toward energy crops and forests if appropriate economic incentives are offered through continued interventions in agricultural markets.

Another factor involved in the expansion of foreign demand for biofuels on the part of the EU and developing countries concerns prices. They are relatively lower in most developing countries. In addition, freight prices are being curtailed in proportion to full costs, but will technological improvements and induced cost reductions in developed countries, in both biofuels and fossil fuels, proceed at a lower rate than those in developing ones? The answer to this question is quite complicated since, among other reasons, predictions based on technological progress are difficult to make. Technologies are continuously improving in the more advanced countries, which in turn pass those technological advancements on to the developing world. An additional factor concerns the forecasted rise in prices of fuels of fossil origin and the fluctuation of currency parities. Energy price forecasters offer quite diverse scenarios in this respect, making any further assessments impossible.

Furthermore, EU and USA energy policies are targeted to goals in which self-sufficiency objectives raise a great predicament. In the United States, "the Environmental Protection Agency advocates requiring that 30% of oxygenates come from renewable resources, such as bioalcohols (ethanol and methanol). Were this policy fully implemented it would necessitate an estimated 500 million gallons over today's production. At any rate, this amount, anyhow, can be achieved in the US in the very short run, a fact which would not stimulate imports from the rest of the world" [41]. Likewise, in the EU, the ALTENER Programme (which, as mentioned previously, in the main initiative of the EU to support renewable energy) sets for the year 2005 the target of securing a biofuels share of 5% of total fuel consumption by motor vehicles. Coincidentally, this percentage is almost equal to that of the potential supply that might be produced from the set-aside diverted land from food production.

Moreover, there is an additional perspective under which to assess and project future evolution in trade and demand for biofuels: the capacity of developing countries to produce biomass energy, especially liquid biofuels. Proponents of the fuel solution indicate that fostering new uses for traditional crops or fuel crops could lead to the development of high-value industrial exports such as know-how incorporated technologies. These would somewhat replace the traditional low-value bulk agricultural commodities that are currently exported by the less developed countries (LDC), but, unfortunately, rather pessimistic views are frequent in the technical and economic literature referring to alternative biological energy sources. The following statement, expressed more than a decade ago, on biomass energies in general, has not been contradicted: "Since wood, agricultural residues and cattle dung are so widely used in the third world, one could say that biomass energy schemes are actually operating in every developing country throughout the world. However, since they are almost without exception not organized or managed and are inefficient to the extent that 90% of the energy is wasted in the combustion process, they are manifestly not planned bioenergy systems. Furthermore, deforestation and desertification give testimony to exactly how disorganized fuelwood use is in the third world" [42].

Whereas the European Union needs to solve its agricultural surplus problem, developing countries must confront a very different constraint: crops used as energy feedstocks compete with the cultivation of crops either to be exported to obtain foreign currency or to be used domestically to meet food demands. Surely, the trade-off relative to food versus biofuel exports can be evaluated and judged in terms other than internal fuel security versus biomass energy exports. As arable land and agricultural input allowances are always limited, political priorities should be instituted before making a decision.

An integral part of the decision about what technological process and energy feedstock to choose is correctly assessing the appropriate benefit–cost calculations. Benefit–costs analyses should first determine the value of coproducts produced simultaneously and, more important, then incorporate synergetic effects external and in addition to purely private interests. Sustainable development considerations relative to human ecology and longer run effects for future generations should be internalized before opting for any political course of action regarding biofuel public investments and incentives.

Finally, an additional remark needs to be made in connection with the not so improbable outlook of a steady-state or low import demand for biofuels in the short run by the EU's member countries and other more developed regions in the world. This negative scenario should not preclude initiating or following of the biofuel, sustainable, technology path. In the final analysis, biomass energy technologies are less capital intensive and, therefore, more labor intensive than the equivalent fossil energies. Moreover, their widely dispersed production cannot be easily concentrated, thus making it a preferable, longer run technology for peripheral and less developed regions of the world.

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