**Review Article**

**Food versus Fuel: Toward a New Paradigm—The Need for a Holistic Approach**

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A key objective of this paper is to provide an assessment of the current and future situation on the “food versus fuel” debate and to contribute to possible alternatives to minimise or avoid future conflict. The debate has centred on three main areas: (i) food versus biofuel production, (ii) their positive and negative effects (i.e., GHG, climate change, and the broader environment), and (iii) a socioeconomic impact. The debate has been controversial because it has largely been driven by politics, ethical/moral considerations, and vested interests rather than by science. The paper focuses on food prices, land competition, GHG, energy balance, and energy subsidies and concerns with the rapid expansion of bioenergy for electricity and heat, climatic changes, the role of agriculture as a key factor, the potential of biomass energy resources, and the various alternatives to minimize or avoid conflict between food and fuel production. Biomass for energy is both “part of the problem and part of the solution.” It proposes a holistic approach: a new paradigm that takes full account of the diverse and complex nature of biomass energy sources and states that the fundamental underlying causes are social injustice, inequality, waste, and so forth, rather than land competition for food and fuel.

1. **Summary**

A key objective of this paper is to provide an assessment of previous work on “food versus fuel,” a contentious topic, which is shaping the future of biomass for energy, to provide an analysis of the current and future situation, and to contribute to possible alternatives to minimise or avoid future conflict.

In recent years, energy security concerns and growing commitment to address climate change has sparked off significant interest and debate on biomass for energy, particularly liquid biofuels. The debate is not new and in fact goes back to the 1970s. The nature of the debate has three major components: (i) liquid biofuels (biofuels), (ii) solid biomass (bioenergy), and (iii) adverse climate-driven impacts (i.e., current drought in the US). The overall debate has global origins and implications but has three main geographical connotations: Brazil, EU, and US, with a disproportional emphasis on the US. Further, the debate has a narrow focus based on a handful of feedstocks, for example, maize, cereals and sugarcane.

The biofuels debate in particular has centred around three main areas: (i) food versus biofuel production, (ii) their positive and negative effects (i.e., GHG, climate change, and the broader environment), and (iii) a socioeconomic component. More recently the debate is also focusing on the rapid expansion of solid biomass for electricity and heat generation and potential adverse impacts of climate change, driven primarily by the current US drought.

The debate on biofuels has been particularly controversial because it has largely been driven by politics, ethical/moral considerations, and vested interests rather than by science. One of the stormiest issues is land use (direct and indirect). Land area required and the land category of using biomass for energy is at the heart of the debate. Indirect land use (ILUC) has added uncertainty to benefits and impacts of bioenergy and biofuels because the methodology is still in its infancy and its application can lead to wrong policy decisions with serious consequences for this sector.

Biomass for energy, particularly biofuels, has been plagued by unprecedented scrutiny while largely ignoring the
consequences of other energy sources particularly fossil fuels; it is essential to have a fair playing field for all energy sources. Large uncertainties remain, for example, long-term productivity and sustainability of energy crops production, the effect of population growth and changing diets, global markets for food and animal feed; efficiency of biomass conversion technology, increasing demand for water and fertilizers, demand for other non-energy uses of land; and climate change, and so forth. However, these are long term issues difficult to predict [1]. Biomass for energy represents many opportunities, challenges, and risks that require to be thoroughly investigated (see [2]). There are not simple answers to the potential problems posed by increasing demand for energy, including biomass.

The spike in food prices of 2007-2008, and presently, is the result of a complex web of factors, stated in Section 3.1. The way land competition has been portrayed is in many ways superfluous because, quite simply, physical availability of land ignores social inequality, huge food waste (some $165 billion annually in the US alone!), low productivity, and so forth. GHG impacts, as explained in Section 3.3, are being constantly challenged as new data come into light and this is welcome. However, a particular weak point is that many studies overlook the impacts of other energy sources, particularly fossil fuels. The same principle applies to the energy balance and subsidies.

The paper also examines in detail the more recent concern with the growing use of biomass for electricity and heat, for example, it is estimated that by 2020 pellet consumption (used mostly in co-firing and small domestic applications) could range between 23 Mt to 80 Mt. However, a more vigorous debate relates to the implications of adverse climate-induced changes.

This paper argues strongly that the use of biomass for energy in a large scale must go hand-in-hand with a modern, diversified, and scientifically driven agricultural sector. Superimposing a biofuel industry, for example, without fundamental changes in agriculture could spell disaster as it will be impossible to provide the huge additional demand on agriculture, efficiently and sustainably, as stated in Section 6.

Biomass energy has been heralded as a key instrument for promoting social and economic development, but as indicated in Section 7, this very much depends on much wider political and social factors. Biomass could, however, make a huge contribution to future energy requirements (Section 8). Biomass is not the panacea for solving our energy problems but given its enormous potential (a minimum of 100 EJ to 300 EJ, with a technical potential of about 500 EJ), it can make a significant contribution to the world’s future energy needs. The key challenge is to ensure it is environmentally and economically sustainable.

Section 9 points to possible alternatives to minimise or avoid food and fuel conflict. There are no easy answers to pressing problem posed by overexploitation of natural resources by an increasing and demanding population, particularly the more affluent societies, with little regard for future generations.

Biomass for energy is both “part of the problem and part of the solution”. This paper argues for a holistic approach to biomass for energy. A new paradigm is required to take full account of its diverse and complex nature, given its technical, economic, social, and political ramifications, particularly for agriculture. Food security and biomass for energy can be mutually complementary rather than exclusive if the right policies are in place.

2. Introduction

Broadly speaking the food versus fuel debate has three important differences: (i) a historical debate on liquid biofuels (ethanol and biodiesel for road transport), (ii) emerging concern with the use of solid biomass (bioenergy) for electricity and heat, and (iii) climate-induced concerns.

The debate is not new (see [3]) although intensified significantly in 2007 and 2008 partly because of the sharp increase in food prices largely attributed, rightly or wrongly, to biofuels. Also, new evidence has emerged questioning the overall greenhouse gas (GHG) benefits of biofuels though there is little consensus. In addition, there are widely and diverging views on the sustainability of the current and future biofuels (e.g., see [4–10]).

Section 3 focuses primarily on the food versus fuel debate, including impacts of food prices, land competition, GHG, energy balance, and energy subsidies. Section 4 looks at the concerns posed by the rapid expansion of bioenergy for electricity and heat; Section 5 examines the problems posed by adverse climatic changes. The role of agriculture, a key factor in the success or failure, is covered in Section 6. Section 7 considers, briefly, the social impacts, and Section 8 assesses the potential of biomass energy resources which can make a huge contribution to future energy needs. Finally Section 9 examines various alternatives to minimize or avoid conflict between food and fuel production.

3. The Food versus Biofuel Debate: A Narrow Debate Focused on a Handful of Crops and Driven by Media, Ethical Concerns Rather Than by Science

Energy security concerns, high oil prices, and growing commitment to address climate change sparked off a debate on potential implications of large scale use of biofuels. This section focus on the main areas of the biofuels debate: food price increases, land completion, GHG/environmental issues, energy balance, and subsidies, which have all been at the core of the debate.

Much of the criticism of biofuels focuses on “first generation” (G1) which uses technologies that will likely continue to prevail for at least the next decade until second generation technologies (G2) become more widespread. The other major problem has been the narrow focus in a handful of feedstocks (i.e., maize, sugarcane, and cereals). There has also been a failure to fully understand the potential economic implications that additional demand for biofuel feedstocks places on agriculture commodity prices and human wellbeing. However, biofuels can bring considerable benefits if they meet the basic conditions of low GHG emissions from
the whole supply chain and not, or very limited competition, with food crops. But they can also cause serious problems if these conditions are not met. Biofuel production and food security needs to be complementary.

The food versus fuel debate emanated first in the US and in the EU. The use of corn in the US has particularly been the subject of a vigorous debate for a combination of reasons such as the existence of a strong pro and against biofuels lobby, large scale use of corn (a very poor ethanol feedstock), the powerful farmers’ lobby, and vested interest groups. This debate is muddle in politics and hardly driven by science, confusing the ethanol/gasoline consumers for example, see the Biofuel Digest.\(^\text{2}\) The intensity of this controversy in both the EU and US can also be partly explained by the existence of specific policies put in place to subsidise large-scale use of biofuels. The aim is to diversify energy supply, cut reliance on imported oil, and improve the environment (i.e., reduce oil-derived air pollutants in the transport systems).

The EU has been at the forefront of biomass for energy development. However, proposed policy changes could have a major impact on the future of biofuels in the EU. A recent proposal\(^\text{[11]}\) suggests that the EU should limit the use of crop-based biofuels following concerns that the technology is not as effective at cutting emissions as previously thought and may conflict with food production. The proposal says that subsidies should only continue where there are clear and substantial emissions savings which are not offset by ILUC. This view is further strengthened by a study by the International Council on Clean Transportation (ICCT), http://www.theicct.org/\(^\text{3}\), which says that “European biofuel mandates are unlikely to deliver a significant reduction and could even increase GHG emissions unless land use factors are considered.” Accordingly, the paper states that “if not revised to address ILUC, the Renewable Energy Directive could be expected to deliver a carbon saving of only 4% compared to fossil fuels, with a 30% chance actually of causing a net emissions increase” (see also http://www.lowcwp.org.uk/).

It is unclear what this potential policy change could mean for biofuels, but it could be serious. This policy change seems to be a seriously short-sighted based on flawed science, as the ILUC methodology suffers from many shortcomings. The reaction from the industry has been quite strong, accusing the European Commission of “a masterpiece of irresponsible policy making,” arguing that The European Biofuels industry has made investments totalling 14 billion Euros, providing 100,000 direct jobs which will be put in jeopardy.\(^\text{4}\) If implemented, this could lead to dramatic fall and waste of investments in biofuels.

The EU has been playing a key role in ensuring bioenergy/biofuels sustainability partly because the European Commission is acutely aware of social, environmental, and policy implications if biomass for energy was to be imported in large scale. This leading role will be seriously undermined by constant policy shifts.

In Brazil, bioethanol is not perceived as a problem because the country has a large agricultural area and sugarcane is an exceptionally good feedstock. In most other countries, however, except perhaps in China, this issue is hardly debated; in fact, most countries see the expansion of biomass for energy as an opportunity rather than a threat if produced and used sustainably. Hence, there is not any universal held view on this matter.

The biofuel debate has taken two main forms, media and scientific. There are, basically, two main schools of thought: (i) the antibiofuels lobby and (ii) the probiofuels lobby. In a synopsis, the “antibiofuels” lobby argument goes, as showed below, (see [1, 12])\(^\text{5}\).

(i) It is, simply, morally wrong to use land to produce biofuels instead of food.

(ii) Large scale production of biofuels will lead to food insecurity worldwide.

(iii) Increasing food prices will disproportionately affect the poorest people in developing countries, already overwhelmed with high food costs.

(iv) Land competition, including ILUC, will increase with demand for food and nonfood products, leading to deforestation, ecosystem destruction, loss of biodiversity and erosion of social rights.

(v) Many of the social and environmental benefits of biofuels are not yet fully proven.

(vi) Large scale production of biofuels will increase soil erosion, decrease carbon stocks, put stress on water resources and on other ecosystem services.

(vii) Biofuels offer poor GHG benefits.

(viii) Biofuels, in general, have a poor or negative energy balance (e.g., see [13–15]).

Contrary, the “pro-biofuels” lobby arguments are as follow.

(i) There is sufficient land available to produce both food and a reasonable portion of biofuels (i.e., 5–20% of transport fuels demand) without affecting food supply, with good and modern agricultural management practices. Large scale biofuels production at global level is highly unlikely; the focus will be in the most favourable geographical areas; physical availability of land is “per se” meaningless as there are many other nonphysical issues for example, social inequality, productivity, policy, and so forth.

(ii) Food insecure countries that do not have their own fossil fuel reserves allocate a significant portion of their national income to pay for oil imports. In such cases, biofuels are a good alternative to fossil fuels and would free up foreign exchange for other investments.

(iii) Nearly 2,000 million people live without access to modern energy systems. Agriculture in developing countries needs more energy in absolute terms and bioenergy availability can actually enhance food production.

(iv) Multifunctional agricultural production systems already exist in most countries, are mutually beneficial
and can produce both food and nonfood products in a sustainable and socially balanced manner.

(v) Certain biofuels crops can be utilised to prevent soil degradation and can utilise or reclaim so called “marginal” or “degraded” land.

(vi) The social, economic, and environmental benefits of biofuels outweigh potential negative impacts, if good management practices are applied.

(vii) Bioenergy can spark off new investment in agriculture, increasing modernization, diversification, and consequently productivity (e.g., [16, 17]).

(viii) Crop yields are, in general, very low and can be greatly enhanced.

(ix) Biofuels can play a significant role in modernising and diversifying agriculture, for example, as in the case of Brazil.

3.1. Food Prices. The potential impacts of biofuels in food prices came dramatically to light from 2007 to 2008; this has been further ignited recently by the current USA drought, the worse in 50 years. Food prices are not static but fluctuate constantly in response to supply and demand situations. But the fact that the rapid development of biofuels coincided with increases in food prices has not helped this industry. The similarity with the evolution of crude oil prices is also particularly striking. Thus, food price increases are the result of a complex web of factors that need to be incorporated in any debate.

Food prices increase has, unfortunately, a disproportional impact on the urban poor because they already spend a very large part of their income on food (from 40 to 80%) compared to 5–10% in the more affluent societies. Perhaps consumers have to get used to the idea that, as with oil, cheap food belongs to a bygone era. The most important factors influencing prices include the following.

(i) Changed consumption patterns lead to higher demand. Improved living conditions, particularly in developing countries such as Brazil and China, have led to an increase in demand for meat as consumers with growing wealth move away from cereals to meat. This increases the demand for cereals and land since, for example, it takes 8 to 10 kg of wheat to produce 1 kg of meat. It has been estimated that moving from animal to plant protein could lead to 3 to 4-fold reductions in agricultural land and 30- to 40-fold reductions in water use [18].

(ii) Distorted agricultural markets are caused by rich countries subsidising domestic agricultural production and off-loading surplus production on the world market.

(iii) Sustained low levels of investment in agriculture; in the 1980s about 17% of international development aid was for agriculture, but in 2005 this was just 3%. This has been exacerbated in the last decade by low commodity prices as farmers struggled to survive (see Lynd and Woods [19]).

(iv) Many countries cut their reserves, making them more vulnerable to temporary market fluctuations and shortages. In addition some producing countries banned exports to protect their domestic market exacerbating the problem even further. For example, between 2007 and 2011, 33 countries imposed export restrictions on food exports, representing 45% increase in food prices in 2006–2008.

(v) Increase of crude oil prices from $50 to over $140 per barrel which had a major impact on all chain of food production and distribution, thought prices are currently much lower.

(vi) Unequal income distribution and poverty; most people abstain from buying food not because there is not food around but because they cannot afford to buy it. There is evidence that “as a result of agricultural intensification, more food is produced today than needed to feed the entire world population and at prices that have never been so low.” [20].

(vii) Increasing cost of inputs such as fertilizers and pesticides (linked to higher oil prices). Although in industrial countries the cost of raw materials plays a comparatively small role in the retail food price since price increases are largely determined by commercial marketing structure, this might not be necessarily the case in poorer countries.

(viii) Rapid increase of feedstock demand from the biofuels sector was also a significant contributing factor.

(ix) Speculation by the financial sector in agricultural commodities. Increased interest from investors and traders in commodities makes price development much more sensitive, exacerbated by the low value of the US dollar.

Some international organizations (see [21]) said that biofuels were responsible for 3% to 30% of food price increase from 2002–2008, which turned out to be wrong. The role of speculators in the spike of food prices has been hotly contested but a recent study by Lagi et al. [22] has thrown new light and shows the impact of speculators in price increase has been greater than previously thought, as illustrated in Figure 1.

Lagi et al. [22] updated their previous work (2011), constructed for the first time a dynamic model that quantitatively agreed with food prices, based on the FAO Food Price Index time series from January 2004 to March 2011, and updated to February 2012. The results showed that the dominant causes of price increases during this period were investor speculation and ethanol conversion. The model included investor trend following as well as shifting between commodities, equities, and bonds to take advantage of increased expected returns.

Among the contradictions is that higher agricultural prices have both positive and negative impacts. Higher incomes will allow farmers to invest more in agriculture and bring new lands under cultivation. Moreover, about 70% of the world’s poor live in rural areas and could therefore benefit
from price increases if they are net food sellers. However, the urban poor and net food buyers in general face a grim future if prices remain high. This will require concerted policy action on the part of governments [12].

Recently, some politicians have also been emphasising the benefits of producing food locally as a solution to food security. This argument is misleading and flawed since the same argument applies to almost any traded good. Food production does not know country boundaries—it depends on who and how land is controlled. Protectionism, tariffs, subsidies, price fixing, and so forth will not feed more people, it simply will benefit rich countries. Of course, there are considerable benefits to produce and consume local products but should not be at the expense of competition and variety and as a back door for protectionism.

3.2. Land Competition (This Is Discussed Further in Section 8.1). Land area required and the land category for growing biofuels has also been at the heart of the debate. The estimates of land use for biofuels, current and future, vary widely depending on the source and assumptions, multiple demands on land, and so forth. Estimates range from a 40 M ha to 800 M ha. What seems certain is that estimates of future demand of land for biofuels production remain highly uncertain. It seems therefore that it is almost impossible to provide any reliable estimates at this point on time.

There is, however, some consensus that the potential for improving crop productivity is large and hence to base potential production on existing amount of land, without taking fully into account all the intertwined factors, is often meaningless. For example, Conway, Vice-Chairman of Cargill, stated recently “average production is far below the known potential that this argument about whether the earth’s potential (to feed people) is trapped out is almost irrelevant”. The debate needs to embrace the potential for increasing crops, complexity of biofuels, energy, resources, productivity, technological developments, and so forth.

Although land expansion for biofuel feedstocks production is likely to play a significant role in meeting increased demand, the intensification of land use through improved crop technologies and management practices needs to be at the core. For example, average global productivity of main sugarcane growing nations ranges from 60 to 85 t/ha/yr. The commercial maximum achieved is 148 t/ha/yr and 212 t/ha/yr (98 dry t/yr) in experimental plots [23]. In Brazil, ethanol yields have been increasing steadily since 1975, from approx 2,000 L/ha to 7,000 L/ha in 2009, and even in some cases close to about 8,000 litres/ethanol/ha in 2011. Increase in productivity will increase ethanol production tenfold without affecting food production, according to Goldemberg and Guardabassi [24].

A major component of the land use debate has been the “indirect land use change” (ILUC) impacts; this has added uncertainty to the biofuels industry. ILUC has hardly been driven by science, but rather by attempts to solve wider issues of climate change, GHG emissions, and loss of habitats with high biodiversity. Although ILUC offers the prospect to reduce negative effects, it must be applied equally to all products and fuels to have an equal level playing field. ILUC methodology is still in its infancy and its application can lead to wrong policy decisions with serious consequences for the development of biofuels.

A large body of studies have investigated the ILUC impacts on biofuels expansion, but with large discrepancies [8] IPCC, 2011 [25–29]. For example de Sá et al. [30, 31] have investigated the impacts in Brazil from sugarcane expansion into pasture lands, specifically in the Sao Paulo state, and question the desirability of such expansion as this can have a significant impact in other crops (see also [31]). A World Bank [32] study also notes that about two-thirds of the area into which sugarcane expanded came from converting pasture land with the remainder coming from substituting other crops (32%) and from converting natural vegetation (2%). Tsao et al. [33] also found that Brazilian sugarcane and soybean biodiesel including ILUC, have much larger life-cycle emissions than conventional fossil fuels for six regulated air pollutants.

Brown and Brown [17] have challenged Searchinger et al. [8] theory on ILUC regarding the negative impacts caused by US corn-based ethanol production. Because US allocate more corn to ethanol, other countries need to expand their production to other areas leading ultimately to increase environmental impacts. They suggest that there is not sufficient evidence to show ethanol production is causing deforestation. Their views are further strengthened by Dumortier et al. [34] who also argue that ethanol production has smaller environmental impacts than previously presented.

3.3. GHG/Environment Impacts. One of the greatest challenges currently facing humankind is the potential impact of climate change. Biofuels have been widely promoted as a partial solution to GHG problems. However, what role can biofuels play in limiting the level of GHG emissions? The answer depends upon the specific feedstock (e.g., sugar cane, maize, vegetable oil, or lignocellulosic crops) and the circumstances of production and processing [7]. Each crop has its pros and cons that need to be considered.

For ethanol, the highest GHG savings are recorded for sugar cane (70% to more than 100%), whereas corn can save...
up to 60% but may also cause 5% more GHG emissions [35]. Seabra et al. [36], though there remain strong disagreements (see [33]). The highest variations are observed for biodiesel from palm oil and soya. High savings of the former depend on high yields, those of the latter on credits of by-products. Negative GHG savings, that is, increased emissions, may result in particular when production takes place on converted natural land and the associated mobilisation of carbon stocks is accounted for.

Some G1 biofuel crops provide net GHG benefits only under certain conditions such as use of abandoned or degraded lands (involving no direct or ILUC), utilization of coproducts, adoption of sustainable production practices (excluding use of nitrogenous fertilizers), and so forth, [37, 38].

The conclusion of most of the scientific literature published in the recent past indicates that in a life cycle analysis basis, biofuels provide a net GHG benefit (30–100% compared to petroleum fuels), when use of coproducts are included and GHG emissions from land conversion are excluded in the analysis.

These findings are, however, constantly being challenged as new data comes into light. For example, a recent study by Pehnelt and Vietze [39] has questioned the EU GHG values established by the EC on biodiesel from rapeseed oil. Their study indicates that in most of the scenarios, rapeseed biodiesel does not reach the GHG emissions saving values using the formula contained in RED, that is, 35% threshold required by the EU Directive. The authors calculate a GHG emissions saving value far below the 35% threshold ([39], see also [40]). However, the EC is constantly improving the methodology in reducing GHG impacts (i.e., http://www.biograce.net/).

Although the focus has been on the transport sector as one of the main responsible of CO₂, new evidence is coming into light demonstrating livestock products are responsible for about 32.56 Gt/yr of CO₂e or about 51% of global CO₂ emissions [41]. If their argument is right, this implies that replacing livestock products will be even better strategy to combat climate change.

3.4. Energy Balance. The energy balance expresses the ratio of energy contained in a fuel relative to the energy used in its production. A fossil energy balance of 1.0 means it requires as much energy to produce a litre of fuel as it contains. An energy balance of 2.0 means a litre of fuel contains twice the amount of energy as that required to produce it. Conventional petrol and diesel have energy balances of around 0.8–0.9, because some energy is consumed in refining and transporting it. If a biofuel has a fossil energy balance exceeding these numbers, it contributes to reducing dependence on fossil fuels; in general, all biofuels today have energy balances that are greater than fossil fuels, although not necessarily including land use impacts, [1].

Balances for biodiesel range from around 1 to 4 for rapeseed and soybean feedstocks, whereas palm oil is around 9. For crop-based ethanol, balances range from less than 2 for maize to around 2–9 for sugar cane (8 to 10 in the case of Brazil, see [35, 42, 43]). Sugar-cane-based ethanol, as produced in Brazil, depends not only on feedstock productivity, but also on the fact that it is processed using biomass residues from the sugar cane (bagasse) as energy input. The energy balances for cellulosic feedstocks tend to be even higher.

The energy balance of biofuels production is nevertheless still a contentious issue, particularly for ethanol from corn [13, 44, 45]. It is often oversimplified, given the complex web of economic, technical, and political factors that need to be taken fully into consideration; different assumptions and calculations can, therefore, lead to different results. There is also a tendency to use old data which do not necessarily incorporate latest improvements (technical, managerial, etc).

The energy balance is not static but changing continuously. However, some consensus is emerging on the overall energy balance for several biofuels. Major improvements (i.e., reducing energy consumption, greater energy self-sufficiency and greater use of bioenergy, developing new coproducts, etc) will further improve the energy balance. US maize is, however, one of the least efficient feedstocks for ethanol production especially when compared to sugarcane which has far higher energy balance, as previously indicated.

3.5. Bioenergy Subsidies. Subsidies given to biofuels have been sharply criticised but need to be examined within a wider context. Government subsidies have supported energy production, both for fossil fuels and renewable energy, for many decades. The size of these subsidies varies considerably from country to country. Historically subsidies given to fossil fuels and nuclear energy have been orders of magnitude greater than for biofuels. The main problem with current fossil fuel subsidies is that their hidden environmental costs are not internalised and neither their potential climate impacts.

The International Energy Agency (IEA) has conducted many studies on the effects of energy subsidies and the benefits of removing them. For example, in 2008, the amount of subsidies given to fossil fuels totalled $557 billion, representing 2.1% of these countries GDP ($312 billion for oil; $204 billion for natural gas, and $40 billion for coal).

In the US, the General Accounting Office reported that the petroleum industry received between $135 billion and $150 billion in tax breaks from 1968 to 2000 alone, excluding foreign investment tax credits estimated cost to Treasury a further $7 billion per year. This compares to $7.7 billion to $11.6 billion given to the ethanol industry from 1979 to 2000.

Also, a study by the Environmental Law Institute [47] shows that fossil fuels benefited from about $72 billion from the Fiscal Years 2002 to 2008, compared to $29 billion for renewables over the same period (about $16.8 billion for corn-based ethanol). $70.2 billion went to oil and coal and just $2.3 billion to carbon capture and storage (CCS).

Critics suggest that the subsidies to biofuels distort the market, while ignoring large subsidies given to the energy sector in general and oil in particular. Oil, primarily diesel and gasoline, is still heavily subsidised in many developing countries, especially in oil-producing countries. What is needed is to have a fair playing field for all energy sources, not just for biomass for energy.
4. Bioenergy Debate (Heat and Power)

Contrary to liquid biofuels, the concern with solid biomass is more recent and has its origins in the growing demand for heat and power generation in Europe but also in Southeast Asia, such as Japan and South Korea [48–50]. This is because solid biomass is far more widely available and can use a wide range of feedstocks including, potentially, large amount of residues and wastes which are currently mostly wasted. For example, a conservative global potential of residues has been put by the CCC [18] at between 300 TWh to 18,000 TWh.

The key markets at present are primarily co-firing with coal in power plants (potentially the largest market), and the development of heating systems (all types). There is a large body of literature for the reader to explore further (see http://www.bioenergytrade.org/; [49–52]).

The key concern with this market is the implications with the availability of sustainable feedstocks in large quantities if large-scale global market takes place; also difficulties with logistics, and support policies though this differ significantly, depending of the country or region. This rapidly expanding market can have potentially large ramifications as hundred of million tons of biomass could be traded internationally for energy.

For example, in the specific case of pellets used primarily in co-firing, the global production and consumption in 2010 has been estimated to circa 14.3 Mt and 13.5 Mt, respectively and a global installed production capacity of over 28 Mt. The global trade in 2009 was approximately 5.5 Mt, of which 3.9 Mt were exported to Europe. There is also a large inter-EU pellets trade (approx. 2.7 Mt) and other types of biomass for power and heat generation (http://www.bioenergytrade.org/; [50]). Despite considerable discrepancies, all studies point to a rapid increase in demand for pellets ranging from 23 Mt to 80 Mt by 2020, depending on the source [50]. Discrepancies are due to a set of variables on assumptions of this market which remains fragmented and uncertain.

5. Climate-Induced Changes

Fears of another global food crisis, largely based on potential adverse climatic conditions, have reigned the food versus fuels debate. The global food crisis in 2007-2008 is bringing back memories of the spike in food prices. And with the current drought ravaging crops in the US, (and also floods) in Australia, India, Russia, Ukraine, and so forth, calls are growing louder to give immediate priority to grow food not fuel.

A huge political debate is taking place in the US about the future of ethanol. A large group of US lawmakers are calling to halt or lower the subsidy rule on how much ethanol the country must use in 2012 and 2013. Though the ethanol policy retains strong bipartisan political support from those who see it as a way of improving US energy security, raising rural incomes and keeping petrol prices down, this is having a major impact in the US and beyond. Also, various U.N. agencies (Food and Agriculture Organization, World Bank, and other organizations) have added their voices to suspend ethanol quotas as a response to the impact of the worst U.S. drought on corn supplies and prices.

It is not possible to give even a partial account since this debate has embraced all spheres of politics and media in particular. The debate centres primarily in whether or not to waive or reduce the Renewable Fuels Standard ethanol blending mandate. Two main tracks are being pursued, (i) requests for the Environmental Protection Agency (EPA) to lower the mandate for this year and/or next year, and (ii) trying to pass legislation that would automatically reduce the mandate in years when the corn stock-to-use ratio falls below certain specified levels. The mandate calls for 13.2 billion/gal (c.50 B/l) of corn-based ethanol to be blended in 2012 and 13.8 billion/gal (52.2 B/l) in 2013.

Whatever the outcome, this could have major repercussions for the ethanol industry in the US and beyond. For example, waiving the mandate could have various unintended effects (i.e., investment in advanced biofuels, use of ethanol by-products, ethanol-based market)11. Also, even without the standard, a third of the US gasoline supply must contain ethanol to meet unrelated clean air rules and more importantly, ethanol is as much as $1 cheaper than other types of octane boosters. The EPA has to decide by mid-November how to proceed12.

The current drought and the record high grain prices have also strengthened considerably the antibiofuel lobby in EU, as indicated previously. For example, the EU’s executive Commission is under considerable pressure to forge a deal to help ensure that EU biofuels do not clash with food production or the environment, calling for a more flexible policy. In the EU far more than in the US, the raison d’etre of biofuel is to lower carbon emissions. Action plans drawn up by EU member states predict that biomass for energy will provide more than 50 percent of the EU share of renewable energy as part of 2020 climate goals, which may now be questionable.

It is beyond the scope of this paper to discuss the pros and cons of the climate change debate. The potential impacts are so large that it is impossible to come up with any credible answer. But one thing is certain, all scientific evidence indicate that climate change is more likely, more frequent and more extreme. How this will impact in agriculture is very difficult to predict but such effects can be devastating. The bottom line is that in the future, we will have to pay a lot more attention to potential adverse climate change impacts on agriculture, simply because so little is known of how this could affect food security and consequently biomass for energy.

6. The Role of Agriculture

While world demand for energy continues to grow, supply of cheap and clean energy are dwindling while population continues to grow rapidly together with the demand for improving living standards. What then could be the potential role of agriculture in meeting such demand without jeopardising its primary role of providing food? What would be the economic, social, political, and environmental consequences? What can be the role of biomass for energy?

How this increasingly complex situation is managed will be crucial. Biomass for energy development is strongly dependent on a modern, shriving agricultural sector. Hence
the business as usual scenario that ignores this reality can have serious consequences.

As indicated in Beddington et al. [53] excellent report, agriculture is at the nexus of three of the greatest challenges of the 21st century—achieving food security, adapting to climate change, and mitigating climate change while critical resources such as water, energy, and land become increasingly scarce. Humanity faces difficult tradeoffs in producing sufficient food to feed our growing population and stabilizing our climate system. Globally our food system is not sustainable, does not provide adequate nutrition to everyone on the planet and, at the same time, changes to our climate threaten the future of farming as we know it. Agriculture is both part of the problem and part of the solution to climate change. We must seize every opportunity to shift away from inefficient farm practices, supply chains and diet choices towards long-term sustainability, profitability and health [53].

Modernisation, diversification, and rejuvenation of agriculture are essential as it will lead to greater overall production. As Tilman et al. [54] put it, “dramatic improvements in policy and technology are needed to meet global demand for both food and biofuel feedstock.” This requires many fundamental changes for example, land ownership, fair distribution, good educational level of farmers, availability of capital, skills, finance, marketing knowledge, and so forth.

Farming cannot be seen as a backward activity, but as a science driven industry. Give the farmers the right conditions (capital, skills, access to markets, etc.) and they will be able to produce far more food, energy, and industrial products. Agriculture’s increasing global role as potential provider of many raw materials other than food products could also attract massive new investment, creating many new opportunities for innovation and diversification which could truly transform agriculture as we know it.

Investment on modern scientific research for agriculture led to dramatic yield breakthroughs in the last century for example, in England wheat yields took nearly 1000 years to increase from 0.5 to 2 t/ha/yr, but just 40 years to increase to 6 t/ha/yr [20]. Agriculture requires a renew effort on R&D at national and international level. A sustainable increase in yields can only be achieved by applying an integrated approach to resource utilization that concur to better use of water, soil nutrients and seeds, labour, and so forth to avoid intensive and unsustainable agricultural practices.

Improvements to agricultural production systems should allow more productive and resilient livelihoods and ecosystems, contributing to a more secure, sustainable, and safe food system and providing access to adequate food and nutrition, and allowing poor rural people to escape from and remain out of poverty. Sustainable agriculture lies at the heart of delivering poverty reduction [53].

For example, Africa is the continent with the largest agricultural land availability and yet remains the most enigmatic as far as food and biofuels production is concerned. Montpellier Panel [55] study has identified strengths, weakness, opportunities, and threats. Accordingly, the average cereal yields are only one ton per hectare; total agricultural R&D spending in Africa grew at only 1.9% between 2000 and 2008, although there is wide variability between countries; tenure over more than 90% of land remains outside the formal legal system. There is a large agricultural workforce: 65% of Africa’s population lives and works in rural areas; 80% of all African farms (33 million) are less than two hectares in size, which can increase transaction costs.

As for biofuels, there are a number of compelling studies that argue that because of the vast amount of idle land available, and low productivity, food security in Sub-Saharan Africa would not be significantly affected by the expansion of biomass for energy and, could actually be enhanced through economic development, by improving agriculture and reducing foreign energy imports [56, 57] Lynd and Woods [19].

6.1. Tackling the Huge Agricultural and Food Waste. Many studies, particularly the antibiofuels lobby, tend to overlook that the present agricultural production, food and feed, transportation, and so forth, is hugely inefficient and terribly wasteful. For example, it is estimated that 30 to 50% of the global food production rots away uneaten [58]. In some countries as much as 75% of the harvest is lost, particularly fresh vegetables. A recent report by the Natural Research Defence Council (see [59]), says Americans throw away nearly half their food every year, waste worth roughly $165 billion annually! Accordingly, the US discard 40 percent of the food supply every year, and the average American family of four ends up throwing away an equivalent of up to $2,275 annually in food. And what is particularly worrisome is that there has been a 50 percent jump in US food waste since the 1970s. Tackling this huge waste must be at the core of any government’s policy.

To bring our interconnected food and climate systems within a “safe operating space” for people and the planet, the Commission on Sustainable Agriculture and Climate Change has outlined seven major areas for policy action, based on robust scientific evidence from the recent assessment reports on global food security (see [53]), which could also seriously impact on biomass for energy including:

(i) integrate food security and sustainable agriculture into global and national policies;
(ii) significantly raise the level of global investment in sustainable agriculture and food systems in the next decade;
(iii) sustainably intensify agricultural production while reducing greenhouse gas emissions and other negative environmental impacts of agriculture;
(iv) develop specific programmes and policies to assist populations and sectors that are most vulnerable to climate changes and food insecurity;
(v) reshape food access and consumption patterns to ensure basic nutritional needs are met and to foster health;
(vi) reduce loss and waste in food systems, targeting infrastructure, farming practices, processing, distribution and household habits;
(vii) create comprehensive, shared, integrated information systems that encompass human and ecological dimensions.

7. Socioeconomic and Sustainability Issues

There are many questions as to the role of biomass for energy in promoting social and economic benefits. Generally, the view is that bioenergy and biofuels can help improve livelihoods, especially in rural areas, as well as contributing to rural development and poverty alleviation. However, this is far from proven although empirical evidence seems to partially support the social benefits argument, at least at the local and small scale [60].

Often biofuels have been seen as the source of many social evils and injustices. A study by ACTIONAID (see [61]) has blamed the EU policy on biofuels for many negative impacts, particularly in Africa, since the EC adopted the Renewable Energy Directive (RED). This is because no binding social criteria—which could be defined to ensure that only biofuels that do not have negative social impacts are used in the EU—are set out in the RED.

This is a simplistic argument, as social, economic, human rights, and so forth, need to be assessed within a wider political and social context, as many of negative impacts are rooted in social inequality and injustices and have strong political connotations. Selective negative reporting tends to ignore potential benefits of biofuels. This argument is specious in so far as fuel crops are not intrinsically better or worse than any other agricultural crop. Critics of biofuels often cite working conditions in the Brazilian sugarcane fields, without taking into account the wider social and economic reality prevailing in that country or region for example, see [3].

The question is should biomass for energy be different to any other commodity? For example, the inclusion of social factors (e.g., trade union rights, child labour, wages, etc) in the sustainability criteria poses serious questions as this standard is applied unequally to all sectors.

Sustainability is the key, but this has additional costs (see Fritsche et al. [62]). The costs of compliance include not only the direct costs of certification but also the costs of developing new information systems and administrative procedures and modifying equipment or management processes. Small-scale producers will have more difficulty absorbing additional costs, unless there is a level playing field [63].

Another issue concerning biomass energy is that, traditionally, it has been used and traded locally and therefore international bioenergy trade is an entirely new phenomenon (see http://www.bioenergtrade.org/; [52, 64]). This is a complex issue that goes beyond the objectives of this study. Suffice to say that bioenergy is currently traded in a significant scale internationally, particularly wood chips and pellets for electricity and heat, and biofuels (biodiesel and ethanol) for use in transport. And this can have major consequences for bioenergy. Biomass for energy has been, historically, the main source of energy until early 20th Century when it was replaced by oil and gas. Markets tend to move faster than legislative and regulatory instruments and therefore we need to understand the wider implications of this trade.

8. Biomass: A Vast Energy Potential That Cannot Be Ignored

The world faces an increasing demand for energy while traditional resources, primarily oil, are dwindling. Biomass for energy can make a large contribution to the world’s energy needs; demand is growing as a whole, both in its traditional and modern applications, although fossil fuels dominate the global energy market with an estimated contribution of 500 EJ in 2008 compared to 50–54 EJ [13] from biomass, of which 70–80% is represented by traditional applications, primarily in developing countries. Hall and Rao [65] have estimated the total earth biomass annual primary production in 220 billion oven-dry-tonnes (4500 EJ).

There have been many attempts to estimate the global biomass energy potential but they depend critically on assumptions, particularly on the availability of agricultural land for nonfood production, crop productivity, and availability of residues. Differences in future biomass supply estimates range from a few EJ to nearly 1,200 EJ [10, 18, 66–68].

The more optimistic assumptions lead to a theoretical potential of 200–400 EJ/a, or even higher; the most pessimistic scenario (using of organic waste and residues only) gives a minimum of 40 EJ/a. More realistic assessments considering environmental constraints estimate a sustainable potential of 40–85 EJ/a by 2050. In the short to medium term, projections expect biomass and waste to contribute 56 EJ/yr in 2015 and 68 EJ/yr in 2030 [18]. However, the IEA [10] study estimates range from 100 EJ to 300 EJ, with an optimistic estimate of a technical potential 500 EJ in 2050.

Dornburg et al. [69] have identified three main categories of biomass potential: (i) organic waste and agroforestry residues, with a potential of 30 to 180 EJ/yr, (ii) surplus from forest growth, between 60 to 100 EJ/yr, and (iii) biomass from perennial cropping systems, approx. 120 EJ/yr. The cost-effective biomass supply varies from 50 EJ/yr to 250 EJ/yr in 2050; this compares with a projected demand of 600 EJ to 1040 EJ/yr in the same year [69].

The German Advisory Council on Global Change (WBGU [14], 2009) estimates, however, that in the long term up to 10% of the global energy could be met from biomass. Campbell et al. [70] report that, working from a figure of 385–472 Mha of abandoned agricultural land with above-ground productivity of 4.3 tons/ha/yr, could provide around 10% of the primary energy demand of most developed nations. As can be appreciated, there is little consensus with negative policy implications.

8.1. Land Use for Biofuels. Given the nature of biofuels (i.e., land requirements often used for food crops), their rapid expansion poses serious problems unless new nonfood crops are utilised in large scale. Global use of bioethanol and biodiesel, based on current projections, will nearly double from 2005–2007 to 2017 (see [10, 51] BP (2012) [18] (UNEP, 2009); see also Figure 2.
According to Global Industry Analysts Inc. [71], the global consumption of ethanol and biodiesel is projected to reach 135 billion gallons (c.511 billion litres) by the year 2018. Apart from the traditional markets (Brazil, EU, and US) this report sees the Asia-Pacific region is showing an immense potential for future growth, including bioethanol and biodiesel, and is projected to grow at an overall annual growth rate of 28.8 percent over this period. There are of course many other scenarios (e.g., [43, 72–74] 15http://www.fas.usda.gov/). The growth of biodiesel, particularly from palm oil, is tricky because of the key role it plays in human diets (see [75]).

While global liquid production has been relatively constant across the 1990’s, it has seen an exponential growth over the past decade (Figure 2). 50% of all biofuels were produced in North America (largely the US) and Brazil, followed by the EU. Biodiesel is has been centred within the EU and Asia, but with an increasing contribution from Argentina and Brazil [76].

The key question is how to harness this potential economically and environmentally without compromising food supply. FAO data shows that by 2050, 72 Mha of additional land will be needed to meet additional food demand (45% would be for food, 40% for livestock feed). FAO data also shows 700–800 Mha may be available for growing energy crops, an optimistic assumption; CCC [18] gives a range of 100 to 700 Mha.

RFA [6] has estimated the land to fulfil volumetric substitutions of liquid fossil fuels based on 10% substitution by 2020 varies from 56 Mha to 166 Mha. The variation in this case is due to consideration of co-product use and optimising of technologies to produce advanced biofuels from crops residues.

Ravindranath et al. [37] analysed crop land requirement for liquid biofuels on a crop by crop basis whereby the land use requirement is based on 100% substitution of projected demands for biodiesel and bioethanol to 2030. For bioethanol, this ranges from 24 Mha for sugarcane to 39 Mha for sweet sorghum to 50 Mha for maize. For biodiesel, the range is from 29 Mha for palm oil or 106 Mha for jatropha to 221 Mha for soybean.

In the case of Europe, the Gallagher Review [77] estimates that between 22 Mha and 31.5 Mha of land could be needed in total by 2020 to reach the EU’s 2020 biofuels needs. Assuming again that 60% of European biofuels consumption by 2020 will be imported and that proportionately the same amount of land is needed to produce a given quantity of biofuels, the amount of land needed outside of Europe for biofuels between 13 to 19 Mha.

What is of considerable concern is the diversity of estimates which confuse rather than help policy decision-making.

**9. Toward a New Paradigm—Key Factors to Minimise/Avoid Additional Land Requirements for Biomass Energy Production**

The record food prices witnessed recently are not isolated blip. Current events represent the third sharp increase in global grain prices in just half a decade, caused by many factors, including chronically tight agricultural commodity markets, growing global population, change of diets that include more meat consumption, and so forth, as indicated, compounded by droughts and floods around the world. It is critical to move beyond food-based biofuels. That means providing farmers with the resources to produce more food, feed, fuel, and so forth, for example, to provide more incentives to farmers to use nonfood land. For example, a study by Kanna et al. [78] shows the feasibility of planting energy crops in marginal lands with the right support16.

Energy is at the core of achieving high agricultural productivity. Without modern energy inputs, agriculture would not be able to feed the growing population as will have to rely on human drudgery, low productivity, and extensive
cultivation. Human civilization, as we know it, would have been impossible without considerable additional use of energy beyond the capacity of humans (i.e., see [79, 80]).

But at the same time, high energy inputs is causing concern on resource depletion, sustainability, pollution, and so forth. And it is here where biomass for energy can have an important role; consequently, we need to better understand the energy-agriculture nexus and the potential for sustainable energy systems. Thus greater emphasis should be given to energy-agriculture interrelationships, integrated management of energy, and other inputs, that is, water and to the potential of biomass for energy for different environmental and land use situations. A new approach with emphasis on finding holistic solutions to complex interconnected problems rather than just increasing yields that benefit people and the environment. Such actions would not be possible without good technical skills, investment, capital, and so forth.

A more recent trend is to use biofuels in niche markets such as air transport which is searching for viable alternatives due to high costs of jet fuel and carbon liability (i.e., a liability $1.53 billion by 2012 to meet EU Carbon Scheme). With a consumption of about 227+ billion litres/yr, this could be a more realistic market if the technical hurdles can be overcome. Currently all major world airlines are seriously looking at this alternative [11, 81, 82].

Sugarcane is the most efficient crop utilised on ethanol production, from an economic, environmental, and social viewpoint. Brazil long historical experience, know-how and availability of cheap land, and the suitability of sugarcane have been key factors in the success of its ethanol program. This indicates that the potential for increasing productivity at low investment cost is very large (see [23, 24]).

Contrary, the use of corn in large scale, particularly in the US, is more controversial as the benefits (energy, social, and environmental) are more questionable. In this case there is growing recognition that better alternative feedstocks should be pursued for example, G2 and G3 generation biofuels. The use of cereals is particularly strong in the EU, and less so in other countries such as China. Wheat is of particular interest and various studies have shown that by using all coproducts wheat is a good alternative for producing ethanol17. However, the demand for wheat as a basic staple food around the world is likely to increase significantly thus making this option highly questionable, and furthermore other feedstocks should be promoted instead18.

9.1. Avoiding Conflict. The current debate suffers from many shortcomings and should serve to learn new lessons to avoid past mistakes. In Western highly urbanised societies, with relatively efficient agricultural systems, we experience the impact of rising prices in terms of costs, not their returns on investment. Farmers in poor countries are being driven from the land because agricultural inefficiency, low productivity, and more specifically, by low commodity prices, and by US and EU grain cycles.

Hence the dilemma pointed out before an impasse on the benefits of high agricultural prices for key feedstocks versus consumers [53]; thus, it is necessary to rethink agriculture and bioenergy policies. There are many alternatives that can be put in place to minimise food versus fuel conflict, which could be grouped into three main areas: (i) agriculture, (ii) biomass for energy, and (iii) socioeconomic and environmental issues.

(i) Agriculture. Diversify feedstocks and move away from key food crops (corn, cereals), toward agricultural residues/wastes and cellulose-based feedstocks; use only the most suitable feedstocks (economically and environmentally) such as sugarcane whose productivity can largely be increased with low investment while providing all energy needed to run a plant + surpluses. Take a more holistic approach to food and biofuel production—food and bioenergy can be complementary rather than exclusive. Pay considerable more attention to crops that have more drought, heat, pest/pesticide tolerance. Bring in new and more productive crops (short cycle) so that a second harvest can be achieved and promote intercropping. For example, ongoing work on Sweet sorghum which can produce very high biomass yields with less water and fewer chemical inputs and can be grown on land not devoted to food production. Improve agricultural management practices and renew effort on R&D. Recognise that a modern and dynamic agricultural sector has to be at the core of biofuel development. Increasing crop productivity, which in many countries is extremely low for many major food crops; pay greater attention to the development of biorefineries. Also, water use improvements are essential as currently water in agriculture is used so inefficiently that most of it is wasted Water is simply too cheap (see http://www.fao.org/nr/water/aquacrop.html; http://www.fao.org/nr/water/infosres_cropwat.html). We simply have to invest far more in agriculture and to develop more new crops. Agriculture needs to be transformed to find solutions to a rapidly changing situation (climate change, increasing food demand and fuels). It is also essential to reduce/eliminate postharvest and food waste.

(ii) Biomass for energy. Avoid land grabbing for biofuels, particularly in developing countries, at the expense of staple food crops; accept the limited role of biofuels and that their impacts will be geographically very different. All alternative energy sources are needed, including fossil fuels. Help to develop a bioenergy/biofuel industrial sector in countries with a good potential but lack this capability; develop a fair and more globally accepted sustainability and certification criteria and address the serious flaws of ILUC methodology and ensure that there is a “fair playing field” for all energy sources. Need to be selective of how to use biomass resources for example, perhaps use solid biomass rather than in its liquid forms, and considers niche markets.
that, on balance, the positive factors far outwait the negative considerations to impede or delay the implementation of security.

and economically manner and without compromising food ignore. The challenge is to harness it on an environmentally future energy requirements; this is a resource we cannot than exclusive.

security, biomass energy, and environmental sustainability, but are not introducing the necessary reforms, specifically in the agricultural sector.

In the short term, G1 biofuels represent the best and most realistic partial alternative to fossil fuels, but seems extremely difficult to break the stranglehold of oil, (ii) we want cheap, reliable, and clean energy but this is an increasingly unrealistic option, (iii) we want bioenergy/biofuels to be an almost perfect fuel while largely ignoring the environmental damage of fossil fuels; there are not perfect fuels, just fuels that pollute more than others; (iv) we need comprehensive and far reaching policies on alternative energy; but most policies are not and put biofuels, for example, in an unfair disadvantage with fossil fuels; (v) we need to find a balance between food security, biomass energy, and environmental sustainability, but are not introducing the necessary reforms, specifically in the agricultural sector.

Biomass energy is both “part of the problem and part of the solution”. This paper has argued for a holistic approach. A new paradigm is required to take full account of its complexity given the technical, economic, social, and political ramifications, particularly for agriculture. Biomass for energy in all its forms, particularly biofuels, is intrinsically linked to a modern and dynamic agricultural sector. Food security and biomass for energy can be complementary rather than exclusive.

Biomass can make a large contribution to the world’s future energy requirements; this is a resource we cannot ignore. The challenge is to harness it on an environmentally and economically manner and without compromising food security.

It will be a huge political folly to allow short-sighted considerations to impede or delay the implementation of biomass for energy under the umbrella of food security since, even if we all stop using biomass, the problem will not go away as the fundamental underlying causes are social injustice, inequality, waste, political unwillingness, and so forth, rather than land competition for food and fuel.

### Endnotes

1. Biomass for energy denotes bioenergy and biofuels; bioenergy refers to solid biomass used primarily for domestic uses (heating, cooking) and industrial applications (heat and power), for both small and large scale uses; biofuels refer to liquid biofuels (biodiesel and bioethanol) used primarily in road transport.

2. See http://www.biofuelsdigest.com/bdigest/2012/06/08/perception-vs-reality-the-8-most-common-biofuels-myths.

3. See http://www.theicct.org/policy update on “Proposed amendments to EU Fuel Quality and Renewable Energy Directives”, September 2012.

4. This comment is signed by various major biofuels industrial interest, 2nd Oct/12 (see http://www.ebb.eu.org/, European Biodiesel Board, Brussels).

5. Part of this material has also been taken from Rosillo-Calle F, Pelkmans L, Nelson R, Cocchi M, Black M. (with contributions from Hess R and Walter A (2010)—Sustainable biofuels—Solution for meeting transport demand (unpublished report for IEA Task 40 (http://www.bioenergytrade.org/)).

6. Food prices are not stated but constantly changing due to large combination of factors, and primarily oil pricing.

7. See The Economist comment, Vol. 404 (8802), 15 September 2012, pp.11-12.

8. Paul Conway, Vice-Chairman of Cargill, speaking at the Oxford Research 2012 Conference (http://www.resourcethefuture.org/resource2012/); see also, The Sunday Times, 15 July 12, p. 16 (Environment).

9. The project BioGrace aims to harmonise calculations of biofuel greenhouse gas (GHG) emissions and thus supports the implementation of the EU Renewable Energy Directive (2009/28/EC) and the EU Fuel Quality Directive (2009/30/EC) into national laws.

10. See IEA-Global fossil fuels subsidies and the impacts of their removal, Office of the Chief Economist, International Energy Agency (http://www.iea.org/publications/worldenergyoutlook/resources/energysubsidies/).

11. For example, the value of the land is said to have increase considerably due to the expansion of ethanol and consequently many farmers have been able to obtain credit thanks to the revaluation this asset.

12. There is a huge amount of media covering, pro and against ethanol in the US, too large to be dealt here. Suffice to mention just a few. Drought fuels ethanol debate, United Press International (http://www.equities.com/news/), 20 August/12; Douglas L. Faulkner, “The Cleantech Conservative” Special to the Digest,
http://www.biofuelsdigest.com/bdigest/2012/08/14/new-paradigms-rising-for-biofuels/; Corn for Food, Not Fuel-Colin Carter and Henry Miller, New York Times, 30 July 2012; http://www.canberratimes.com.au/opinion/food-or-fuel—that-is-the-question-20120902-2586f .html#ixzz2SO4LmHtq.

13. There are some discrepancies with regard to the total bioenergy contribution, primarily from traditional sources which tend to be underestimated; Dornburg et al. quote 50 EJ.

14. German initials.

15. http://www.fas.usda.gov/, under “Attaché Reports (Biofuels), the reader can access many excellent reports.

16. The study investigated the price necessary to switch to energy crops (corn stover, miscanthus, switchgrass, native prairie grasses, and poplar) in Illinois, Michigan and Oklahoma. See Reference for further details.

17. ENSUS study on wheat for ethanol production (internal company report).

18. For agricultural prices/cereals, see USDA.

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