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Review

How green is bioenergy? A review on myths, challenges, biotechnology progress and emerging possibilities

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Bioenergy is a very heterogeneous aggregation of different feedstocks, conversion technologies and end-uses, and are often promoted as a "green" alternative to fossil fuels. In the case of fossil fuels, extraction energy costs would become higher than the actual energy yield due to increased energy costs for research, deep drilling, as well as to the lower quality and accessibility of the still available oil storages. The objective of this manuscript is to discuss the main myths, challenges, biotechnology progress and emerging possibilities about the bioenergy sources throughout the world. Bioenergy production systems are sometimes claimed to be able to fill the future fossil fuel shortages as well as to decrease carbon dioxide emissions and global warming. The success of bioenergy production depends on the quantity and quality of biomass available and the ability to cost effectively utilize it for energy production. The global effects of the development of biofuel production will depend crucially on where and how feedstocks are produced. Advances in biotechnology are needed to develop bioenergy crops more adapted to adverse environmental conditions with higher growth rate and high caloric value. Life-cycle analysis and evaluation of external costs are important for assessing the social and environmental advantages and disadvantages of bioenergy system.

Key words: Renewable energy, biomass, biofuel, environment, fossil fuel.

INTRODUCTION

Renewable energy is the energy generated from natural resources such as water, sunlight, wind, rain, tides, waves, geothermal and biomass sources e.g. micro-organisms, plants, manure, sludge, and domestic organic wastes. Renewable energy sources are continually and naturally replenished in a short period of time. Solar cells, wind turbines, biofuels and other emerging renewable energy technologies are poised to become major energy sources throughout the world. Renewable energy has an important role in the industry, business and households for providing modern energy access to the billions of people in developing countries, as they continue to depend more on traditional sources of energy. Worldwide there is a growing interest in the use of solid, liquid and gaseous biofuels for energy purposes. There are various reasons for this, such as: i) political benefits (for instance, the reduction of the dependency on imported oil), ii) employment creation (biomass fuel create up to 20 times more employment than coal, gas and oil, and iii) environmental benefits such as mitigation of greenhouse

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gas emissions, reduction of acid rain and soil improvements (van Loo and Koppejan, 2008). Fossil fuels provide 85% of the US energy requirements, a figure that is similar in most countries (Scheller et al., 2010). This situation is not sustainable for several reasons; oil reserves are limited, and the increasing use of oil and coal leads to ever increasing CO_2 emissions, which carry the risk of climate change (Scheller et al., 2010). Energy demands are increasing with population growth and economic development. The use of fossil fuels is now widely accepted as unsustainable due to depleting resources and the accumulation of greenhouse gases in the environment that have already exceeded the "dangerously high" threshold of 450 ppm CO_2-e (Singh et al., 2011). To achieve environmental and economic sustainability, fuel production processes are required that are not only renewable, but also capable of sequestering atmospheric CO_2. Biofuels are therefore rapidly being developed because it is a wide area which produces energy such as power, biogas, biodiesel and bioethanol.

Some 1.5 billion people worldwide still lack access to electricity, and approximately 2.6 billion are reliant on wood, straw, charcoal, or dung for cooking their daily meals (REN21, 2010), which shows that a cheap and friendly environmental source of energy is necessary. Production of renewable energy, particularly from biomass, can provide economic development and employment opportunities, especially in rural areas, that otherwise have limited opportunities for economic growth.

It is well known that bioenergy have gained wide acceptance among policy markets, scientists, environmentalist, agricultural entrepreneurs and the general public. They are increasingly seen as a contribution towards the solution of many problems at one, ranging from the greenhouse effect to the increasing oil prices, energy dependency and rural development (Russi, 2008).

However, a careful analysis of all the related literature reveals that there is no consensus regarding the biomass potential among the researchers, but rather their assessments differ strongly. One of the most critical bottlenecks in increased biomass utilization for energy production is the cost of its logistics operations. So research is further needed to develop better methods for producing bioenergy as well as better ways of assessing and verifying the environmental performance of biofuels. Fundamental research is required to deal with the uncertainties and missing elements in current approaches for bioenergy production. The objective of this manuscript is to discuss the main myths, challenges, biotechnology progress and emerging possibilities about the bioenergy sources throughout the world.

A literature search was undertaken using the ISI web of knowledge database (http://apps.webofknowledge.com/WOS_GeneralSearch_input.do?highlighted_tab=WOS&product=WOS&last_prod=WOS&SID=3A4pHgE52e7@n@9In64&search_mode=GeneralSearch) in which only papers published during the last five years were selected. The topic selected were "bioenergy", "review", "biotechnology" and "biofuels".

Studies from the literature which dealt either with neutral-carbon, negative-carbon, sustainability or environmental impacts, in relation to biofuels or bioenergy were selected. Each manuscript was read in detail and recorded in our database along with its topic, objective and conclusion. Compilations of the results from the different studies were made and the main sections of this manuscript were written.

DISCUSSION

Air, greenhouse gas emissions and bioenergy production

Biofuel is the fuel derived from organic matter either directly from plants or indirectly from agricultural, commercial, domestic and industrial wastes. However, biofuels will be a viable alternative only if they provide a net energy gain, have environmental benefits, be economically competitive, and be producible in large quantities without reducing food supplies (Hill et al., 2006).

Biomass encompasses vegetation, energy crops, as well as biosolids, animal, forestry and agricultural residues, the organic fraction of municipal waste and certain types of industrial wastes. Biomass can be obtained in two ways, either from the residues or from the dedicated energy crops. Biomass residues and wastes are materials of biological origin arising from the by-products and wastes from the agriculture, forestry, forest or agricultural industries, and households. Dedicated crops are grown for energy and an ideal energy crop has efficient solar energy conversion resulting in high yields, needs low agrochemical inputs, has a low water requirement and has low moisture levels at harvest. It is generally considered as a carbon neutral source of energy, as during conversion and combustion roughly the same amount of CO_2 is emitted as was absorbed during the feedstock growth. Its appeal is due to its potential worldwide availability, its conversion efficiency and its ability to be produced and consumed on a CO_2-neutral basis (Cebrucean et al., 2010). Such waste-to-energy plants offer both generation of clean electric power and environmentally safe waste management and disposal (Iakovou et al., 2010). Many research efforts document the current and potential role of biomass in the future global energy supply (Parikka, 2004; Yamamoto et al., 2001). Theoretically, the total bio-energy contribution (combined in descending order of theoretical potential by agricultural, forest, animal residues and organic wastes) could be as high as 1100 EJ, exceeding the current global energy use of 410 EJ (Hoogwijk et al., 2003). Berndes et al. (2003) further reinforce this potential of biomass in the future global energy supply by analyzing earlier studies on the subject.

Recent awareness of CO_2 emissions has resulted in a shift from less environmental friendly fossil fuels to renewable and sustainable energy alternatives (Gil et al., 2010). Among these, biomass is considered to be one of the few viable replacement options (Munir et al., 2009). Biomass can be grown in a sustainable way through a cyclical process of fixation and release of CO_2, thereby mitigating global warming problems (McKendry, 2002). Biomass fixes CO_2 in the form of lignocellulosics during photosynthesis, and the CO_2 emitted from the combustion of these materials makes no net contribution to the accumulation of CO_2 in the atmosphere or to the greenhouse effect.

Converting rainforests, peatlands, savannas, or grasslands to produce food crop–based biofuels in Brazil, Southeast Asia, and the United States creates a "biofuel carbon debt" by releasing 17 to 420 times more CO_2 than the annual greenhouse gas (GHG) reductions that these biofuels would provide by displacing fossil fuels (Fargione et al., 2008). In contrast, biofuels made from waste biomass or from biomass grown on degraded and abandoned agricultural lands planted with perennials incur little or no carbon debt and can offer immediate and sustained GHG advantages (Fargione et al., 2008). However, it is well known that some crops cultivated with organic amendments or organic wastes increases the CO_2 and N_2O concentrations in the atmosphere (Lopez-Valdez et al., 2011; Fernandez-Luqueno et al., 2010), while it has been reported that the use of biodiesel in engines decrease significantly the emission of unburned hydrocarbons, polyaromatic hydrocarbons and soot, particulate matters, carbon monoxide, carbon dioxide and sulfur dioxide but the $NO_{(x)}$ emissions is more with biodiesel (Palit et al., 2011).

It has been reported that assuming the direct substitution and that the electricity generation from energy crops releases zero emissions; the avoided emissions from the investment under analysis may be computed as 17981 ton CO_2 equivalent/year (Carneiro and Ferreira, 2012). However, if the CO_2 emissions are accounting during the whole agriculture system, there will be a CO_2 net emission, that is, after an integrated assessment of sustainability of agricultural systems and land use, the bioenergy may come at the expense of greenhouse gases emissions and environmental health.

The carbon sequestration options can be divided into two categories: the enhancement of the natural sinking rates of CO_2, and a direct discharge of anthropogenic CO_2 (Yamasaki, 2003). The relevant sequestration options in the first category include terrestrial sequestration by vegetation, ocean sequestration by fertilization, and an enhancement of the rock weathering process. In the direct discharge options, the CO_2 produced from large point sources, such as thermal power stations, would be captured and separated, then transported and injected either into the ocean or underground (Yamasaki, 2003). Although the sequestration options are less beneficial in terms of cost per unit CO_2, reduction compared to other options, technical developments in sequestration options are necessary for the following reasons: i) A huge potential capacity for carbon sequestration; ii) carbon sequestration enables a continuous use of fossil fuels, which is unavoidable at the moment, before switching to renewable energy sources.

From an environmental perspective there are several concerns that are innate to certain biofuel production systems depending on the biofuel being utilized and the production process itself, for example, in the absence of methanol reclamation equipment, methane is emitted into the atmosphere during the course of biodiesel production, while the net reduction in emissions resulting from the combustion of biodiesel in lieu of petroleum diesel will be less than optimal due to the offset caused by the emission of methane (Fore et al., 2011). Lapuerta et al. (2005) stated that methyl esters obtained from the most interesting Spanish oleaginous crops for energy use - sunflower and Cynaracardunculus- were both used as diesel fuels. The use of these vegetable esters provides a significant reduction on particulate emissions, mainly due to reduced soot and sulphate formation, while on the contrary, no increases in NO_x emissions or reductions on mean particle size were found.

According to the above information, there are not enough evidences about the bioenergy effects on the atmosphere. However, nowadays it is well known that the production, exploitation and waste disposal of bioenergy increases significantly the greenhouse gas emissions.

Bioenergy cropping systems also helps to balance the greenhouse gas emissions, and it depend on various aspects like plant life cycle, yield, feedstock conversion efficiencies, nutrient demand, soil carbon inputs, nitrogen losses, and other characteristics and management practices. Cropping systems with grain crops have higher feedstock conversion C than biomass crops because they lack the co product lignin, which is a source of energy during combustion (Paul et al., 2007). Cellulosic energy crops such as switchgrass and hybrid poplar provided the largest net greenhouse gas sinks, >200 g CO_2e-C $m^{-2}yr^{-1}$ for biomass conversion to ethanol, and >400 g CO_2e-C $m^{-2}yr^{-1}$ for biomass gasification for electricity generation. The life cycle analysis of gasoline and diesel compared with ethanol and biodiesel from corn rotations, reed canary grass and hybrid poplar show a reduced GHG emissions by ~40, ~85 and ~115%, respectively (Paul et al., 2007).

A substantial effort is required in order to get C-neutral biofuels to stimulate large-scale biofuel production. However, as already explained, it has to be remembered that, critics of the growing biofuels market have long environmental worried over its impact on land-use change throughout the world. Although biofuels are often presented as a contribution towards the solution of the problems related to our strong dependency on fossil fuels, additional research may be required in order to understand the true impact of biofuels. In order to offer enough biofuels without harming the environment some approaches linked to the biotechnologies cutting-edge might be studied. Likewise, research advances are needed along many fronts to efficiently and sustainably harness the potential of biofuels as an environmentally friendly source of energy.

The water footprint of bioenergy

Promotion of energy from biomass for reducing greenhouse gas emissions has led to increased usage of freshwater, especially during the cultivation of biomass (Gheewala et al., 2011). This has raised concerns about the increase in water stress, particularly in countries that are already facing water shortages. The current expansion of bioenergy with a view to both mitigate climate change and provide more sustainable energy solutions portends to have significant implications on land and water use. Increases in demand for freshwater may exacerbate the already existing water stress, which, in some regions, is further expected to be compounded due to the effects of climate change, but it has to be remembered that the effects of increased biomass production on water resources may be ameliorated through proper land, water, and agricultural management practices.

Water footprint of bioenergy crops is related to the energy yield of a crop to its actual water use under actual field conditions during the growing season, and depends on crop type, agricultural production system and climate. It shows large variations for similar crop types, depending on the agricultural production systems and climate conditions (Abdullah, 2010). Large-scale bioenergy crop plantations create both opportunities and challenges to the water sector, and much depends on the choice of species, genotypes, location of production, prevailing management practices, and water management options. Many crops (e.g., corn, sugar cane, oil palm) have high water requirements at commercial yield levels and are best suited to high-rainfall tropical areas, unless they can be irrigated (Fraiture et al., 2008). Water requirements of different types of bioenergy crops per unit of energy produced varies largely due to several plant, environmental and management factors.

Evaluation of impacts on water resources will be an important component of any assessment of energy from biomass in the future. It is known that nearly 80% of the world-population is exposed to high levels of threat to water security (Vorosmarty et al., 2010). The rapid expansion of biofuel crops can significantly affect regional hydrological patterns (Subhadra, 2010), while the water footprint of the growing biofuel sector should be factored into discussions about water security (Vorosmarty et al., 2010).

In India, jatropha plants, a biofuel feedstock with a large water footprint (Gerbens-Leenes et al., 2009), are increasingly being cultivated in rural areas so that biomass crops are competing with agricultural crops. Future studies on bioenergy will need to take into consideration the water aspect so that the trade-offs between climate change mitigation and water stress must to be addressed.

Bioenergy and sustainability: A growing challenge

It has been stated that bioenergy could substitute and hence diminish the impact of fossil fuel combustion. However, the significant growth of bioenergy sources might present sustainability challenges because it may jeopardize the yield traits of bioenergy crops. The production of these crops could lead to competition for land with food crops and land use change resulting in environmental and social impacts. Furthermore, the type of the biomass resource and its management will have its own positive and negative impacts on society. Avoiding or mitigating such risk is crucial to the sustainable future of the bioenergy industry. It is very much necessary to understand such risks, innovation of bioenergy systems, and regulatory and industry measures. The harvest of corn stover and production of herbaceous crops as cellulosic feedstocks for alternative biomass purposes have been shown to have significant energy benefits and their conversion to alternative energy sources can help to reduce the dependence on crude oil and net emissions of greenhouse gases (Powers et al., 2011). However, the removal of stover from fields for use as a bioenergy crop can potentially have multiple environmental impacts, with the largest concerns related to soil quality. Without the stover on the fields, there is concern that the soil organic matter cannot be replenished. In addition, the stover also acts as a physical barrier to reduce erosion.

The use of a continuous corn cropping system has significant advantages for maximizing the removal of stover as the cellulosic bioenergy crop is essentially doubled compared to a corn-soybean rotation (Powers et al., 2011). However, the added N required with stover removal relative to the conventional tillage baseline scenario could result in even greater amounts of N discharged and would require more fossil fuel consumption for energy intensive N fertilizer production and application (Lavigne and Powers, 2007). Additionally, continuous crop grown on soils may increase N leaching or N volatilization, soil C loss and soil losses. The efficient growth strategies of the perennial biomass grasses and trees rely on a pattern of partitioning of newly assimilated and recycled C and N between leaves, shoots and roots, resulting from a continually shifting balance between sources and sink throughout the year.

This balance is affected by biotic (pests and diseases) and abiotic stresses, especially water limitation (Karp and Shield, 2008). Achieving a sustainable approach to the production of crops for bioenergy should include aspects of total yield, water quality, soil quality, pollution, greenhouse gas emission, net energy balance, and crop productivity among other parameters.

Bioenergy is a part of complex interlinked system whose sustainability can be evaluated through life cycle analysis (LCA). It is one of the best methodologies to access bioenergy sustainability, by identifying energy and materials used as well as waste and emissions released to the environment; moreover it also allows the identification of opportunities for environmental improvement. The study highlighted on dedicated crops (maize, sorghum, triticale and miscanthus) and manure through anaerobic digestion (AD), and combined heat and power (CHP) generation shows that when addressing environmental sustainability of bioenergy chains, all life cycle phases and subsystems must be carefully considered, as there is no single dominating item, but rather several of them play an important role in the overall sustainability (Blengini et al., 2011). According to them LCA results will be helpful in order to assist public decision makers during the evaluation of new bioenergy projects, and also to improve the overall environmental performance and boost eco-efficiency.

The LCA of ethanol from corn grain and biodiesel from soybeans shows ethanol yields 25% more energy than the energy invested in its production, whereas biodiesel yields 93% more. Compared with ethanol, biodiesel releases just 1.0, 8.3 and 13% of the agricultural nitrogen, phosphorus, and pesticide pollutants, respectively, per net energy gain (Hill et al., 2006). The greenhouse gas emissions are reduced to 12% by the production and combustion of ethanol and 41% by biodiesel. Biodiesel also releases less air pollutants per net energy gain than ethanol. These advantages of biodiesel over ethanol come from lower agricultural inputs and more efficient conversion of feedstocks to fuel (Hill et al., 2006).

Neither biofuel can replace much petroleum without impacting food supplies. Even dedicating all U.S. corn and soybean production to biofuels would meet only 12% of gasoline demand and 6% of diesel demand. Overall, LCA indicate that biomass energy systems can be energy efficient, significantly reduce green house gas emissions relative to fossil energy and provide other environmental benefits.

Russi (2008) evaluated all the consequences implied by meeting the Directive's target in Italy, using both imported and domestically produced biodiesel. Her studies revealed that the advantages in terms of reduction of greenhouse gas emissions, energy dependency and urban pollution would be very modest.

Additionally, she stated that the small benefits would not be enough to offset the huge costs in terms of land requirement.

There are a lot of information about some myths linked to bioenergy (Khan et al., 2007; Wetzstein and Wetzstein, 2011). For example, bioenergy is considered a type of renewable energy because its source, that is, biomass is a replenishable resource. However, Khan et al. (2007) stated that current fertilizer N management practices, if combined with corn stover removal for bioenergy production, the soil C loss is exacerbated. An excellent discussion about myths surrounding biofuels is analyzed by Wetzstein and Wetzstein (2011).

Bioenergy seeks to contribute to a sustainable environment in order to achieve global prosperity. However, additional hard work is necessary to conduct basic and applied research and development to create scientific knowledge and technological solutions to the challenges linked with the quality and bioenergy availability. Furthermore, each bioenergy development projects have to include side effects elsewhere in order to shape a sustainable future.

Biotechnology and bioenergy: developing together to generate opportunities

Applications of biotechnology play an increasingly important role in solving industrial, food and energy crisis. Biotechnology can be applied to the microbes involved in processing biomass to biofuels. Recent genetic modifications and breeding efforts of bioenergy crops aim at improving biomass yield, quality, and conversion efficiency. Improvements in composition and structure of bio-chemicals in bioenergy crops will enable the production of more energy per ton of biomass and will improve its calorific value, green house gas profile, and global climate change potential (Abdullah, 2010). Conversion of lignocellulosic biomass to fermentable sugars represents a major challenge in global efforts to utilize renewable resources in place of fossil fuels to meet rising energy demands (Lynd et al., 2008). Current corn hybrids have been bred to maximize food and feed production, first through millennia of crop selection by early farmers, then through modern plant breeding and most recently via biotechnology (Heaton et al., 2008). Additionally, lignin removal is an important technical issue for paper manufacturing and is the key challenge for the conversion of lignocellulosic feedstock into liquid transportation fuels such as ethanol (Gutiérrez et al., 2012). The economic viability of tree biomass for biofuel production requires improved processing technologies to meet this challenge. Nowadays, recent research advances are improving plantation trees for bioenergy and bioindustry adapted woody feedstock production through improved breeding, biotechnology and establishment of tree plantations (Seguin, 2011), which also offer potential for carbon sequestration and natural forest preservation. There has been a surging interest in optimizing the ability to extract fermentable sugars from plant-derived cellulose, earth's most abundant energy-rich polymer, for the production of bioenergy (Miller and Keller, 2009). The challenges inherent in this process involve complex biological and chemical problems that must be addressed to develop feasible infrastructure and efficient processes for energy production from biomass (Moon et al., 2010).

Regulatory costs and concerns are important considerations that must be made when transgenic plants are released into the environment, especially for commercialization. Both process and product of transgenic plants is regulated by most governments throughout the world. It will be important to assess the activity of the released genetically engineered crops, how they affect the native soil, and how they spread and survive in the environment. Additionally, the loss of genes from the genetically engineered crops and the possible transfer of genes to other crops will have to be investigated. However, a strategy called transgenic mitigation could be effective for some bioenergy crops (Di Fazio et al., 2012; Moon et al., 2010). Linked to a primary gene of interest, a mitigating gene, which is positive or neutral for crops, but negative or deleterious for potential non-transgenic hosts is introduced into the crop (Al-Ahmad et al., 2004). Finally, the most common way of controlling transgene spread is through management practices, including harvesting on short rotations before flowering begins, and ⁄ or the use of buffer zones where pollination and seed establishment are prevented, thereby mitigating spread outside the confines of plantations (Di Fazio et al., 2012).

Biofuels derived from microalgae are considered to be a viable alternative energy resource (Dragone et al., 2012). Microalgae are able to produce 15 to 300 times more oil for biodiesel production than traditional crops on an area basis. Furthermore microalgae have a very short harvesting cycle (1 to 10 days) depending on the process, allowing multiple or continuous harvest with significantly increased yields (Dragone et al., 2012). However, algae, being eukaryotic, can be improved by genetic manipulation much less readily than photosynthetic bacteria. Notwithstanding, the genetic manipulation of organisms such as plants, animals, and microorganisms is an available and well-studied technology which could enhance the yield of metabolites and biomass, in order to increase the biofuels availability throughout the world.

There are several important challenges that needs to be addressed successfully, in order to spur the biomass production without introducing environmental, social or economic disbenefits, such as producing enough biomass without incurring serious damage to the environment and to the food-supply system. Likewise, the development of cutting-edge tools in molecular and synthetic biology, process engineering, and in genetic engineering is desirable in order to produce high-quality biomass at high rates without compromising environmental health, food availability and social welfare.

Environmental, economic, and energetic costs of bioenergy

Global demand for food would require raising overall food production by some 70% between 2005 and 2050 (FAO, 2009). However, the advent of biofuels has the potential to change some of the projected trends and cause world demand to be higher, depending mainly on energy prices and government policies (FAO, 2009), while global demand for transportation fuels is expected to increase even more rapidly (USDE, 2006). There is a great need for renewable energy supplies that do not cause significant environmental harm and do not compete with food supply. Food-based biofuels can meet but a small portion of transportation energy needs. Among current food-based biofuels, soybean biodiesel has major advantages over grain ethanol. The analyses of ethanol and biodiesel (Hill et al., 2006) suggest that in general biofuels would provide greater benefits if their biomass feeding stocks were producible with low agricultural input, or were producible on land with low agricultural value and required low-input energy to convert feedstocks to biofuel. Soybean diesel needs only less energy to convert to biodiesel than corn grain ethanol, because soybeans create long-chain triglycerides that are easily expressed from the seed, whereas in ethanol production, corn starches must undergo enzymatic conversion into sugars, yeast fermentation to alcohol, and distillation. Energy conservation and biofuels that are not food-based are likely to be of far greater importance over the longer term. Biofuels such as synfuel hydrocarbons - synthetic fuels or cellulosic ethanol that can be produced on agriculturally marginal lands with minimal fertilizer, pesticide, and fossil energy inputs, or produced with agricultural residues (Perlack et al., 2005), have potential to provide fuel supplies with greater environmental benefits than either petroleum or current foodbased biofuels.

Ulgiati (2001) presented a comprehensive, system-based case study of biofuel production from maize or corn (*Zea mays* L.), as an example of the comprehensive approach that he suggested for any energy crop. He concluded that the biofuel option on a large scale is not a viable alternative based on economic, energy and eMergy (amount of available energy [exergy] of one form [usually solar] that is directly or indirectly required to provide a given flow or storage of exergy or matter) analyses of the case study data and estimated possible improvement of yield and efficiency. This is true for developed countries due to their huge energy demand compared with what biofuel options are able to supply as well as for developing countries due to the low yield of their agriculture and competition for land and water for food production. However, biofuels may contribute to optimizing the energy and resource balance of agricultural, livestock, or industrial production systems at an appropriate scale. Russi (2008) found that producing energy at large-scale has small benefits, while energy farming could be carried out on a large scale with industrialized agricultural techniques, which imply an intensive use of fertilizers and pesticides.

Bioenergy production gives rise to additional pressure on land and freshwater resources. The productivity of food and biomass feedstocks needs to be increased by improving agricultural practices. If bioenergy could be produced from low-input biomass grown on agriculturally marginal land or from waste biomass, it could provide much greater supplies and environmental benefits than food-based biofuels.

Current bioenergy markets, growing as a result of attractive economics, which involve domestic heat supply, large scale industrial and community combined heat and power generation (particularly from low cost feed stocks from forest residues, bagasse, municipal solid waste, etc.) and co-firing in large coal based power plants. Many bioenergy routes can be used to convert a range of raw biomass feedstocks into a final energy product. Technologies for producing heat and power from biomass are already well-developed and fully commercialized, as are first generation routes to biofuels for transport. A wide range of additional conversion technologies are under development, offering prospects of improved efficiencies, lower costs and improved environmental performance. Transport biofuels are currently the fastest growing bioenergy sector, however today they represent only 1.5% of total road transport fuel consumption (IEA-Bioenergy, 2009). They are expected to play an increasing role with second generation biofuels, which is expected to increase in the next decades. Different technologies exist or being developed to produce electricity from biomass. In the transport sector, first generation biofuels (mainly bioethanol from starch and sugar crops and biodiesel from oil crops and residual oils and fats) are widely deployed, but its production costs depend on the feedstock used and on the scale of the plant. First generation biofuels face both social and environmental challenges because it may cause an increase in food price and possibly indirect land use change. These risks lead to the development in advancing next generation processes which depend on non-food biomass e.g. lignocellulosic feedstocks such as organic wastes, forestry residues, high yielding woody or grass energy crops and algae. The use of these feedstocks for second generation biofuel production would significantly decrease the potential pressure on land use; improve GHG emission reductions when compared to first generation biofuels and result in lower environmental and social risk. Further development of bioenergy technologies is needed mainly to improve the efficiency, reliability and sustainability of bioenergy chains. The bioenergy production may increasingly occur in biorefineries where transport biofuels, power, heat, chemicals and other marketable products could all be co-produced from a mix of biomass feedstocks.

Recently, significant breakthroughs have improved the production methods of 2,5-dimethylfuran (DMF). Such advances have attracted attention towards DMF as a potential gasoline alternative. DMF's physicochemical properties are competitive to ethanol. Firstly, its energy density (31.5 MJ/l) is 40% higher than ethanol (23 MJ/l) and much closer to gasoline (35 MJ/l). Secondly, it has a higher boiling point (92°C) than ethanol (78°C), which makes it less volatile and more practical as a liquid fuel for transportation (Binder and Raines, 2009).

Ahlgren et al. (2010) investigated the land use, environmental impact and fossil energy use when using biogas instead of natural gas in the production of nitrogen fertilizers. The biogas was produced from anaerobic digestion of grass and maize. Their calculations showed that 1 ha of agricultural land in south-west Sweden can produce 1.7 metric tons of nitrogen in the form of ammonium nitrate per year from ley grass, or 3.6 ton from maize. The impact on global warming, from cradle to gate, was calculated to be lower when producing nitrogen fertilizer from biomass compared with natural gas. Eutrophication and acidification potential was higher in the biomass scenarios while the greatest advantage of the biomass systems however lies in the potential to reduce agriculture's dependency on fossil fuels. In the biomass scenarios, only 2-4 MJ of primary fossil energy was required, while 35 MJ/kg N was required when utilizing natural gas.

Liao et al. (2011) found that the bioethanol techno-system is not only supported by commercial energy and materials products, but also substantially by solar radiation and the labor and services invested. The bioethanol techno-system contributed to the overall supply of energy/exergy resources, although in a less efficient way than the process by which the Earth system produces fossil fuels. Their results show that bioethanol cannot be simply regarded as a renewable energy resource. Biofuels are widely seen as substitutes for fossil fuels to offset the imminent decline of oil production and to mitigate the emergent increase in GHG emissions. This view is, however, based on too simple an analysis, focusing on only one piece in the whole mosaic of the complex biofuel techno-system, and such partial approaches may easily lead to ideological bias based on political preference.

One of the most important strengths of biomass is the promotion of the development of rural areas, reducing the rural exodus and reinforcement of local industry. Another very important aspect is the possibility of creating jobs predominantly in less favored regions throughout the world. As potential weaknesses the possible use of land that may be needed for food production is frequently referred (Carneiro and Ferreira, 2012). Additionally, it is well known that there is still also a lack of knowledge about energy crops. Therefore, integrated policies for energy, land use and water management are needed. The contribution of bioenergy to meet the global energy demand can be expanded very significantly in the future, providing GHG savings and other environmental benefits, as well as contributing to energy security, improving trade balances, providing opportunities for social and economic development in rural communities, and improving the management of resources and wastes.

With the increase in global human population throughout the world, more land may be needed to produce food for human or animal consumption, which is a potential challenge for bioenergy, whereby bioenergy could be particularly useful in specific situations where lower pollution levels are important, such as mining, protected areas, coastal, marine environments, etc. According to the last statements, bioenergy could be used as a supplement to other energy form but not as a primary source.

Improvement in the areas of better machinery development for growing and harvesting dedicated bioenergy crops, good site preparation and weed elimination are highly influential on the performance of many energy crops (Clarke et al., 2009). There are also crop losses associated with inefficient harvesting/picking up of cut energy crops.

The production and provision of energy from biomass resources as an economically feasible technology, as a developing environmentally friendly, as a facilitator of develop in the rural areas, and at the same time as a provider of social welfare still presents some challenges. Recent trends in the laws and policy of renewable energies are promoting the technological development, the innovation, production, distribution and use of bioenergies. However, today many countries in the world do not have any socio-economic strategies to spur their bioenergetics development. Additionally, in each country, many different issues should be taken into account, not only the energy yield or the economic cost, but also social and environmental factors, prior to launch of a bioenergetics policy. Moreover, the biomass resources must be produced with high environmental standards. Each country in the world has to formulate and implement a number of innovative policies and programmes to promote bioenergy technologies prior to launch of renewable energy programmes.

Biomass: Challenges and opportunities

Biomass is the non-fossilized and biodegradable organic material originated from plants, animals and microorganisms (Carneiro and Ferreira, 2012). Biomass is a heterogeneous energy source which may be used to meet a variety of energy needs in houses or industries, including generating electricity, heating homes, fuelling vehicles and providing process heat for industrial facilities. Today, biomass supplies some 50 EJ globally, which represents 10% of global annual primary energy consumption (IEA-Bioenergy, 2009).

Biomass source that are already concentrated in one place, often as a sub-product of another process, tend to be cheaper since they require less intensive collecting and treatment procedures and have no production costs. The potential high efficiency of the biomass power plants along with the use of a fuel associated with renewed life cycles and their possible positive social impacts in particular at regional level, turn biomass into an interesting alternative for the bioenergy generation (Carneiro and Ferreira, 2010).

Biomass energy differs from other renewable energies, however, extensively its use is directly tied to the farms, forest and other ecosystems from which biomass feedstocks are obtained. The use of biomass has environmental and social impacts depending on what type of biomass is used, as well as how and where they are produced. In this sense, sustainability refers to choosing management practices that minimize adverse impacts and compliment land management objectives, such as farm preservation, forest stewardship, food production and wildlife management.

One problem associated with the biomass production in the land use issue is the conflict between food production and bioenergy. Many traditional food crops, such as corn, sugar and vegetable oils are also some of the most commonly used energy feedstocks. Furthermore, agricultural land may be shifted from producing food to the production of dedicated energy crops, contributing an increased price to these commodities. Another serious issue associated with biomass production is the greenhouse gas emissions from land management and land use change. These refer to emissions of greenhouse gases (especially CO_2, CH_4 and N_2O) resulting from agricultural inputs (such as fertilizers), management practices and land use changes (when forests, grasslands or other ecosystems are cleared to produce crops) associated with production of biomass. It is also important that biomass markets will add value to biomass products, residues and productive lands. So the development of biomass production also poses these challenges especially agricultural greenhouse gas emissions, the effect of land-use change, and ecosystem impact associated with biomass thinning in forests, and the indirect effects created by changes in markets for biomass feedstocks for food. Bioenergy must increasingly compete with other energy sources. Logistic and infrastructure issues must be addressed, and there is need for further technological innovation leading to more efficient and cleaner conversion of a more diverse range of feedstocks. Further work on these issues is essential so that policies can focus on encouraging sustainable routes and provide confidence to policy makers and the public at large.

The current frontier in the bioprocessing of organic lies in the biorefinery concept where organic waste is considered as a feedstock for the biological production of high value commodities. There is a particular interest in the production of metabolites as renewable, biodegradable substitutes for petrochemical products. According to Clarke and Alibardi (2010), these metabolites include:

1. Lactate, produced by fermenting carbohydrate rich waste using either fungal or bacterial cultures, for the production of polylactate, a plastic constituent;
2. Polyhydroxyalkanotes, particularly polyhydroxybutyrate, which are natural storage polymer of many bacterial species with properties similar to polyethylene and polypropylene and harvestable from mixed cultures fed with organic wastes;
3. Succinate, a valuable and flexible precusor for pharmaceutical, plastic and detergent production, fermentable from carbohydrate rich wastes by selected bacterial species.

The biorefinery concept is also being applied to produce fuels with a higher value than methane. Although methane is the easiest biofuel to produce, there is strong price incentive to consider H_2 and ethanol instead of methane. The ultimate yield of all of these products from an organic feedstock is proportional to the chemical oxygen demand (COD) of the feedstock. This includes H_2 where microbial electrolysis cells can be used to completely convert carbohydrate to H_2 on a COD basis with only minor power input to the cell. H_2 and ethanol have current market prices of approximately 0.6 and 0.3 $US kgCOD^{-1}, respectively, compared to methane with a price of only 0.07 $US kgCOD^{-1}. Meanwhile, it is known that today a hectare of sugarcane can produce about 6,000 L of ethanol with production costs ranging from US$0.25 to 0.30/L (Leite et al., 2009).

As previously said, bioenergy could be used as a supplement to other energy form or mixed with other technologies but not as a primary source. Kobylecki (2011) studied the possibility to cofire lignite with hard coal and biomass during the operation from large-scale circulating fluidized bed boilers (CFB). His experimental results indicated that the CFB technology was, indeed, 'fuel flexible' and the addition of up to 30 wt% of lignite to the hard coal and biomass mixture did not affect the boiler performance and bed hydrodynamics. Agriculture residues such as palm shell are one of the biomass categories that can be utilized for conversion to bio-oil by using pyrolysis process (Abnisa et al., 2011) which is a biotechnological possibility that has been studied during the last months. Additionally, the possibilities of biomass production in the farm sector have been extensively investigated throughout the world (Schindler, 2010; Jasiulewicz, 2010). Nijsen et al. (2012), made a first global, detailed attempt to estimate the bio-energy potential on degraded areas. Depending on crop type, the potential was estimated at 190 EJ year^{-1} worldwide, of which around 25 to 32 EJ year^{-1} on land not classified at the moment as crop or pasture land or as forests. Degraded areas throughout the world may be a promise for bioenergy production with little negative impacts on food production, biodiversity or GHG emissions. Additionally there are important biotechnological advances to improve the quality and increase the biomass production from crops, microorganisms, and forest, among other sources; however, there is still a question that has not been answered: how and how much biomass energy can be environmentally sustainable?

Although biomass-based renewable hydrocarbons are considered to be one of the sources with the highest potential to contribute to the energy needs for both developed and developing economies worldwide, and taking into account that efforts to make biofuels from renewable resources have escalated over the past few years, today the production of bioenergy from different biomass-derived feedstock have been developed. However, it is necessary take into account and facing up social, economic, environmental, and technological challenges involved in the production of bioenergy from biomass.

CONCLUSIONS

There has been a growing interest in the use of biofuels as a sustainable replacement for fossil fuels over recent years, but a holistic approach should be adopted to account for emissions occurring and the environmental impact. As pointed out by the above authors, biomass utilization is increasingly considered as a practical way for sustainable energy supply and long-term environment care around the world, notwithstanding that bioenergy is not as green as it seems. Biofuels may contribute to optimizing the energy and resource balance of agricultural, livestock, or industrial production systems at an appropriate scale. However, it has to be remembered that, although biofuels under certain conditions help to reduce greenhouse gas emissions, the global effects of an expansion of biofuel production will depend crucially on where and how feedstocks are produced. Finally, notwithstanding the benefits of bioenergy are being promoted, the environmental profile is not fully understood. Thus the holistic approaches to natural resource management should be considered because the bioenergy may come at the expense of greenhouse gases emissions and environmental health. Bioenergy could be used as a supplement to other energy form but not as a primary source. Furthermore, each bioenergy development projects have to include side effects elsewhere in order to shape a sustainable future.

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