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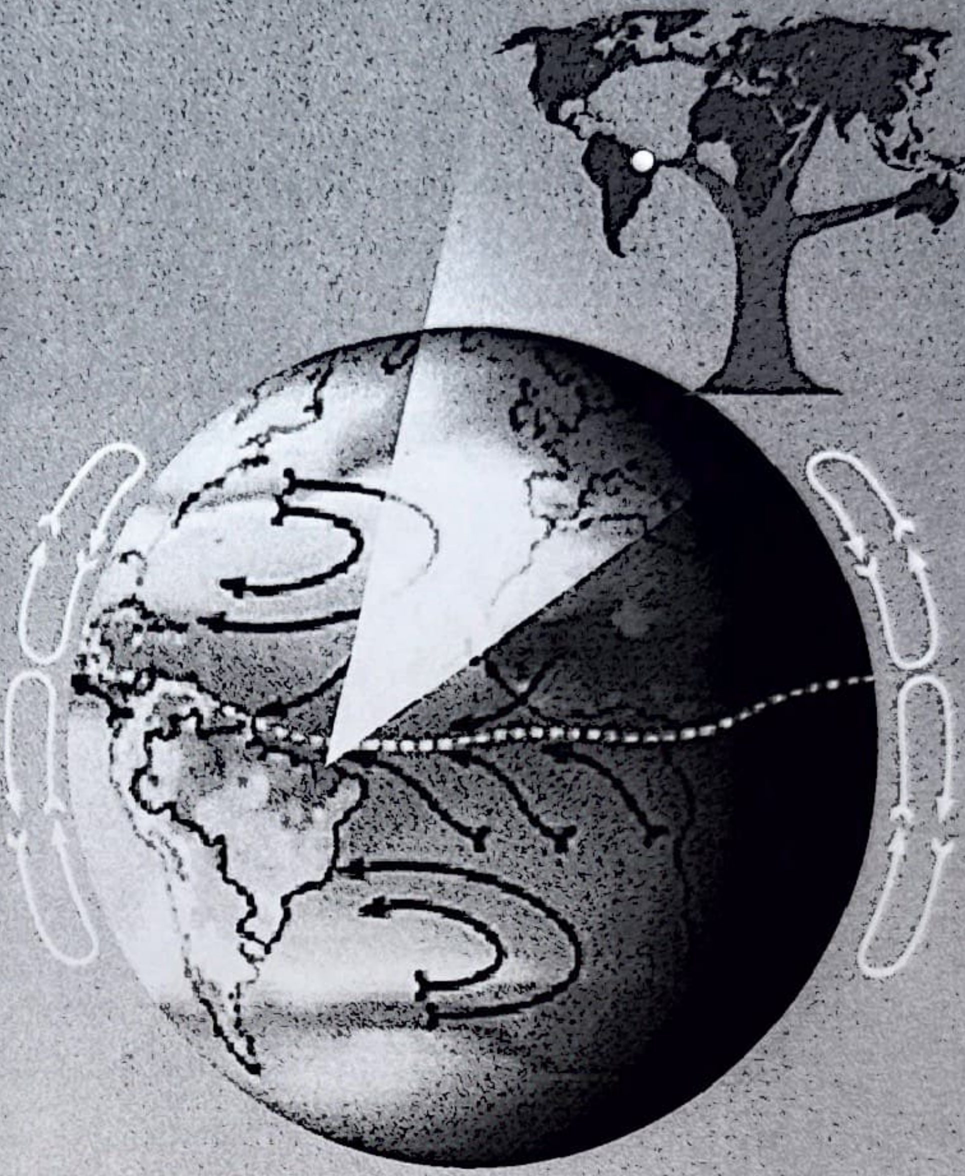

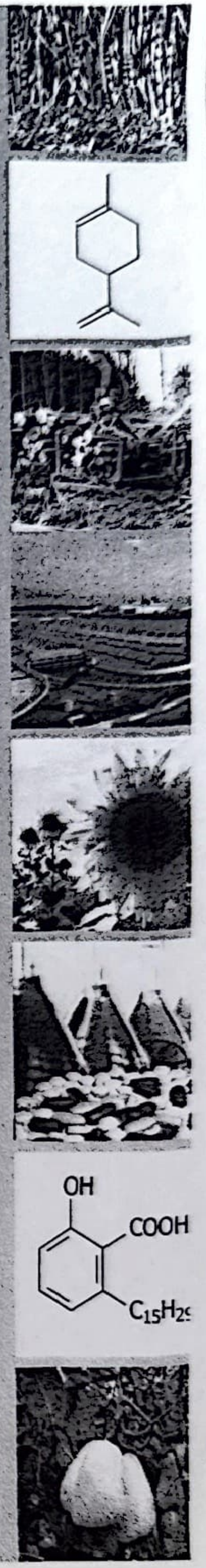

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BIOMASS FUTURE BASED SUPPLY

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ABSTRACT

Biomass is a way found by Nature to store solar energy in the form of chemical energy. As a primary energy source used worldwide it amounts to 1,200 MToe (10.6% of the world Total Energy Supply – TES) but unfortunately close to 80% of this is used very inefficiently and unsustainably, mostly as fuel wood for cooking and house heating. The main characteristics of biomass is that it is produced in a decentralized way, covering most regions in the globe, can be used for secondary energy production in a continuous way, offers a wide option of feedstock and has a considerable local impact.

The wisest way to use biomass is to extract the high value products first and use the residues for energy. This is the case of sugarcane where sugar is extracted and the residues, bagasse and leaves, are use for electricity and process heat generation.

A very sensitive issue with respect to biomass for other uses is the competition with food and fiber production, but it can be handled properly. The resources use, land and water, and energy balance are very important issues in the selection of the alternative. In this respect, the photosynthesis efficiency is a main point.

The broad spectrum of products from biomass makes it a very important candidate to substitute for petroleum derived products, such as: biofuels, lubricants, oils, esters, ethers, ethanol and ethanol derived products.

The main routes for lignocellulosic biomass conversion into valuable products can be divided in two major groups:

- Biochemical conversion: fermentation, biodigestion and hydrolysis.
- Thermochemical conversion: pyrolysis, gasification/synthesis.

This work will discuss the feedstock alternatives and the conversion routes having in mind the sustainability and the potential of end products, especially for energy applications.

1. INTRODUCTION

Biomass is a way found by Nature to store solar energy in the form of chemical energy. It can have several uses ranging from the extraction of high value added nutraceutical products to food/feed/fiber and to energy production; these uses can be organized into two main groups: non-energy use and energy use. The main reason for this classification is that biomass for energy use requires very low cost of production, good energy efficiency and high greenhouse gas (GHG) abatement potential to be able to compete with the conventional energy alternatives as well as with other renewable energy sources. The other group of biomass uses has other priorities to gain market access and can tolerate higher production costs; energy efficiency is not a major issue and economics is the main factor. Table 1 shows a comparison for the vegetable oil case.

Table 1: Vegetable oil products, markets and prices

Products	Potential Market m^3/yr	Prices US$/t
Nutraceutical	$< 1 \times 10^5$	> 2,000
Chemicals	$< 8 \times 10^6$	> 1,000
Food	$< 1 \times 10^7$	> 600
Biofuels	$> 5 \times 10^8$	< 600

Source: [1]

The world photosynthetic production of new biomass is around 3,000 EJ (over 200 billion tonnes, dry basis) per year [2], that is more than six times the world total primary energy consumption. However, as we will see below, less than 2% of that is used for energy.

There are several other primary sources of renewable energy in use, such as wind, hydro power, solar, geothermal, ocean waves and tide, but biomass is the only one that can be converted to liquid transportation fuels. Besides, several other forms of useful energy (secondary energy) can be obtained from biomass: electricity, biogas, process heat, household heating and cooking, combined heat and power generation, making it the most flexible and versatile alternative. Other important characteristics of biomass is the possibility of continuous energy production, worldwide distribution, adequacy for decentralized production and high importance for the local economy.

But, there are several problems associated with biomass use for energy: natural resources use (mainly land and water), pollution from fertilizer and herbicide application, soil erosion, impacts on biodiversity and landscape, impacts on food production and prices, unsustainable exploitation of forests, social impacts on small growers. It is important to point out that these problems are also present in the production of food, feed and fiber, which represent 99 % of the arable land use in the world; therefore it is not fair to pretend that they only exist for energy biomass production, which accounts for 1 % of total world land use or 14 Mha [3].

Although biomass is produced worldwide, the tropical countries have productivities of 2 to 3 times the ones of temperate countries [2] and, therefore, the former have better conditions to produce this form of renewable energy, with less impact on the natural resources and better energy balance. On the other hand, the temperate developed countries have usually better technologies for cultivating, harvesting and processing agricultural crops. This paradox could be solved by bringing the high technology to the tropical developing countries, in the forms of agricultural machines, high yield varieties (including genetically modified species), breeding programs, minimum tillage practices, precision agriculture and others.

2. BIOMASS HISTORY

Biomass was the first source of primary energy to be used by mankind, initially for cooking and heating, and for many years it was absolute in supplying the energy needs, with some little help from wind, hydro and animal power, until the beginning of the industrial revolution. Coal surpassed biomass as a global primary energy source only at the end of the XIX Century [4]; in Brazil biomass was surpassed by oil in 1973 [5]. The increase in the coal participation continued until the World War I when oil consumption increase became faster; but oil passed coal as number 1 primary energy source only in the mid 1960's.

During all this time, biomass participation in the world energy matrix declined steadily from close to 90 % in 1850 to 10.6 % in 2006. Hydropower was the only renewable energy source to increase significantly its participation in a world matrix ever more dominated by fossil energy sources. The reasons for this decline of biomass importance are many but the main ones are the exhaustion, or near exhaustion, of the biomass resources in the developed countries, due to unsustainable use, and the great success achieved by the steam engine powered by coal; the higher power density of coal also facilitated its transportation, storage and final use in places far away from the coal source, making energy services more widespread and less site specific. The advent of oil increased even more this advantage for fossil fuels due to its higher energy density, liquid form for easy transportation, handling and use.

After the oil shocks in the 1970's (1973 and 1979) the interest in biomass, and other renewable energy forms, grew in intensity and several R&D and demonstration programs were established to develop what is called now as modern biomass technologies, meaning more efficient conversion processes than the traditional use for house cooking and heating. Gasification, biomass-to-liquid (BTL), co-firing, hydrolysis and other advanced technologies received considerable attention and funds for projects that ran in parallel with the development of similar technologies for coal (Coal-To-Liquid –CTL, gasification and other "clean coal" technologies), the use of biomass, or biomass derived products, to substitute for chemicals from petroleum also became important; by 1985 around 500 million liters of ethanol were consumed per year in the alcohol-chemistry sector in Brazil. But, by the mid 1980's, the oil prices came down and with it the interest in renewable energy sources. Only two programs survived and continued to grow: the ethanol programs of Brazil and USA that produce together around 40 billion liters per year today, both of them driven mostly by the reduction of imported oil dependence. It is interesting to point out that as early as 1912 there were some scientists already concerned with the increasing consumption of coal and the finiteness of this resource [6]; solar, tide, geothermal, hydropower, biomass and atomic energy sources have been suggested and disregarded as economic options to displace coal. But he made the point that the enormous amount of solar energy that reached the earth has a portion that is stored in the forms of hydropower and biomass, estimated in 70 billion and 18 billion tons of coal equivalent, respectively. Ciamician [6] also suggested that chemicals could be obtained from the plants to substitute for coal derived products and that energy plantation and more advanced methods for full utilization of the biomass resource could be developed.

This work will try to show the context in which biomass is inserted and the challenges that will need to be faced to displace fossil sources of energy and chemicals. The energy use of biomass will be the major focus since it is more demanding in term of natural resources and economic competitiveness.

3. BIOMASS TODAY

The main driving forces to the use of biomass as source of energy and chemicals have been changing thought out the times but today they can be summarized as:

- Volatility of the world oil prices: recently the international oil prices are staying above US$ 80 per barrel; the production costs are considerably lower than this level, less than US$ 10/barrel in many regions, but the prices are not expected to return to the old levels below US$ 40/barrel. Most of the oil market analysts consider that the days of cheap oil are over [7];
- Security of oil supply: most of the oil production today comes from politically unstable regions, especially from the Middle East; this condition poses a continuous threat to the economies of countries that rely heavily on oil imports to meet their demands;
- Growing awareness about global warming and the major role played by the fossil fuels in the phenomenon: while from 1750 to 1980 the CO_2 concentration in the atmosphere increased 25 % [2] and it has increased another 13 % in the last 20 years, indicating an acceleration of the process. The increase in frequency and strength of the natural events such as hurricanes, tornados, droughts, floods and extreme temperatures is helping to bring the public attention to the global warming impacts;
- New opportunities for agriculture: the continuous migration of rural population to the cities is considered today as a major social problem, mainly due to the impossibility of the cities to provide jobs for such a large group of people, normally with little or no skills, and to keep up with the growing demand of infrastructure and services (housing, treated water and sewage, transportation). Therefore, any new economic activity brought to the rural areas will help to reduce this migration, fixing more people in the country.

It can be added to that the inertial use of biomass as a primary energy source is still very strong in several developing countries, some of them having their energy needs supplied in more than 80 % by biomass. Table 2 shows the biomass participation in the world and Brazilian Total Primary Energy Supply (TPES).

Table 2: World and Brazil Total Primary Energy Supply (TPES) – 2004

Primary Energy Supply	World (%)	Brazil (%)
Non-renewable	86.8	56.1
Oil	35.2	39.1
Natural gas	20.6	8.9
Mineral coal	24.8	6.7
Nuclear	6.4	1.8
Renewable	13.2	43.9
Hydro	2.2	14.4
Biomass	10.5	26.7
Other renewable	0.5	2.7
Total (Mtoe)	11 204	213

Source: [3],[8]

The Table 2 above shows that biomass accounts for 10.5 % share of the world total primary energy supply (TPES), totaling 1,180 million tonnes of oil equivalent (Mtoe) or more than five times the total primary energy supply of Brazil. This is indeed a tremendous contribution to meet the world energy needs but it must be pointed out that around 80 % of this biomass is used very inefficiently, and frequently in an unsustainable way, mostly as fuel for cooking and heating the households in developing countries (see Table 3). The present use of biomass for energy is detailed in Table 3.

Table 3: Present use of biomass for energy

	Mtoe	EJ
Traditional biomass	950	40
Modern biomass	216	9.01
Bioethanol	16	0.67
Biodiesel	1.6	0.07
Electricity	32	1.33
Heat	166	6.94

Source: [9]

Traditional biomass refers to the low technology and low efficiency use of biomass normally collected in nature (fuel wood and animal dung) and used for home cooking and heating, in very primitive stoves. It is the only form of energy accessible to more than two billion people [10] and represents more than 8 % of the world TPES. This is the main primary energy source for many developing countries, especially in Sub-Saharan Africa and South East Asia, not because the people do not have access to modern forms of energy but because they do not have money to buy them. It is a great challenge for government, policy makers, technology developers, NGO's and financial institutions to find ways to convert, at least a significant part of, traditional biomass to modern biomass; this represents a potential of close to 1,000 Mtoe per year, that could find a better and more efficient use. A significant portion of this biomass is collected in unsustainable ways, causing devastation to natural forests and savannahs; in this case, women and children spend a lot of time in the collection of this fuel and suffer the consequences of heavy air pollution caused by the burning of this material indoors in open fires or very primitive stoves. It is estimated that 58 % of all human exposure to particulate air pollution to take place indoors in rural areas of developing countries [10].

On the other side, 20 % of the biomass energy is used in modern and efficient systems, converted to process and house heat, electricity and biofuels (see **Table 3**). Cogeneration schemes are often used in sugarcane sugar/ethanol mills (India, Brazil, Mauritius, Reunion, Guadeloupe, Guatemala, and others), pulp and paper mills and district heating installations.

Although biomass is mostly used in developing countries, representing around one third of their TPES, some developed countries (Denmark, Sweden, Austria and Finland) have reached biomass participation in the TPES above 15 %. But, as a whole, the developed countries average only around 4 % of biomass participation in their energy matrix.

Some successful experiences of modern biomass exist in developing countries such as small scale gasifiers and biodigestors for wastes, both in India and China [11]. In Brazil, large scale production of charcoal, using planted forest wood, has achieved, in some cases, conversion efficiencies around 30 % in well designed and operated kilns, that recover the gas fraction to heat the process. New designs of home stoves have been successfully tested in Mexico and elsewhere, reducing considerably the fuel wood demand and air indoor pollution. One area with a high potential for improvement in efficiency and sustainability of biomass use is in the ceramic industry that, in Brazil, is dependent on wood from natural forests; the magnitude of fuel wood demand by this sector makes it an obvious target for improvement. Successful technologies could be replicated in other regions or even in other countries such as the cases of biogas in India and China.

4. BIOMASS IN THE FUTURE – THE CHALLENGES

It seems fair to assume that the driving forces that push bioenergy forward today will continue strong, or even stronger, in the medium and long term. Bearing in mind that biomass contributes today with more than 10 % of the world total primary energy supply (TPES), with modern biomass use amounting to close to 200 million tonnes of oil equivalent (TOE), and that the annual photosynthetic biomass production is estimated to be around 3,000 EJ (70,000 Mtoe), or more than six times the present world TPES, one would expect an easy and bright future for biomass energy and other applications. Unfortunately, several challenges wait around the corner especially when biomass starts to compete seriously with fossil fuels and chemicals and to demand a significant part of the world natural resources for its production, mainly land and water. The role biomass will play in the future as a renewable source of energy and chemicals will depend on several factors such as technology development, energy security polices in the developed countries, the international agreements for GHG emission reduction and competing renewable energy alternative development. Several scenarios from important institutions, such as IPCC, IIASA, International

Energy Agency – IEA, Energy Information Agency – EIA, Shell, BP, have shown different degrees of biomass participation in the world TPES, in the long term.

A study developed by the European Renewable Energy Council – EREC (EREC, 2006) analyzed two scenarios for renewable energy penetration in the world energy matrix up to 2040. One, called Advanced International Policy Scenario (AIP) that assumed that regions already active in the promotion of renewable energies will increase their efforts and other regions will follow the example; the other, called Dynamic Current Policy Scenario (DCP), considered less international cooperation than the AIP scenario but with intensive policy measures on national level, specially in the develop countries. **Table 4** below shows a summary of DCP scenario.

Table 4: Renewable Energy Scenario

	2001	2010	2030	2040
TPES (Mtoe)	10 038	11 258	15 347	17 690
Biomass	1 080	1 291	2 221	2 843
Conventional hydro	223	255	296	308
Small hydro	9.5	16	62	91
Wind	4.7	35	395	580
Solar PV	0.2	1	110	445
Solar thermal	4.1	11	127	274
Solar thermoelectric	0.1	0.4	9	29
Geothermal	43	73	194	261
Ocean	0.05	0.1	2	9
Total renewable	1 364.5	1 682.5	3 416	4 844
% Renewable	13.6	14.3	22.0	27.4

Source: [12]

It can be seen that in this scenario it results in a significant participation of the renewable energy alternatives in the world TPES, around 22 and 27 %, by 2030 and 2040, respectively. Biomass will contribute with almost 60 % of the total renewables and the main commercial renewable energy today, hydro, will have only 6 % participation, having grown only 38 % from the 2001 level. Wind and solar power will grow very fast from the low base today to play important roles by 2040. It should be remembered that biomass is, and probably will continue to be, the only source of liquid biofuels.

The Advanced International Policy (AIP) scenario leads to a 48% participation of renewable in the world TPES. The possibility of supplying these amounts of renewable energies is not analyzed by EREC.

The World Energy Outlook-WEO 2006 [8], foresees a more modest participation for biomass in 2030; in the Alternative Policy Scenario the biofuels share in the transportation fuels demand in 2030 would be around 7 % (147 Mtoe), demanding 3.8 % (53 Mha) of all arable land in the world. Although small in a worldwide context, this land demand may cause disruptive impacts on local level, if not properly addressed.

Examples of this assessment are:

- European Union (EU) already uses 22 % of the land planted with oilseeds crops for biofuels: to meet the EU biofuels target for 2012 will require 84 % of the area that is being used to produce oilseeds today, assuming current technology still being used in that date;
- USA today is using around 20 % of the corn produced in the country to ethanol, but the 20 billion liters represents only a little above 2 % of the gasoline consumption, on an energy basis;

This does not mean that biomass cannot play an important role in the world energy matrix but it rather means that the options in term of crop types and the location to grow the crops need to be carefully evaluated. Technology development, both for the feedstock production and processing, needs to continue at a faster pace, if the targets already set are to be met. The sustainability of each alternative has to be evaluated before embarking in a large, long term, bioenergy program. In this effort the following aspects should be considered [13].

Economic/energetic

Since the bioenergy alternative is intended to displace fossil fuels to reduce GHG emission and improve the country's energy security, the energy balance and the GHG life-cycle analysis (LCA) are the key issues, the go/no-go, in the bioenergy alternative selection process. The energy balance, to obtain the net energy ratio (NER = renewable energy output/fossil energy input) considering the whole production chain, will indicate how much fossil energy will be displaced and the GHG LCA will provide an estimate of the cost to reduce the GHG emission (US$/t of CO_2 equivalent).

Taking ethanol production as an example, the energy balances for three feedstock alternatives are presented in Table 5; the switch grass alternative is an estimate only, since the technology is not at the commercial stage yet but the results for corn and sugarcane are based on detailed analysis of the whole production chain [14,15].

Table 5: Energy balance for the ethanol production using different feedstocks

Process	Maize [1] (GJ/ha.yr)	Switchgrass [1] (GJ/ha.yr)	Cane [2] (GJ/ha.yr)
Energy consumption in agriculture	18.9	17.8	13.9
Biomass energy	149.53 [3]	220.2	297.14 [4]
Energy ratio in agriculture	7.9	12.3	21.3
Energy consumption in distillery	47.9	10.2	3.4
Ethanol energy content	67.15 [5]	104.4	132.56 [6]
Total energy ratio	1.21	4.43	8.32

[1]Source: ORNL; [2]Source: Copersucar/UNICAMP; [3]Corn Stover not included; [4]Tops and leaves not included; [5] Does not include credit for co-products; [6]Includes credit for 8% bagasse surplus.

It can be seen from the Table 6 that the NER for the biofuel, ethanol in this case, can vary considerably depending on the feedstock, from 1.21 for corn to 8.32 for sugarcane; two major differences are easily noticed – the much larger primary energy of the biomass and the lower energy requirement for processing the sugarcane. The final useful energy per unit of cultivated area is approximately twice for sugarcane compared with corn. So, sugarcane has a clear advantage over corn for the production of ethanol with respect to fossil energy displacement and land use requirement.

The variation of production costs with the feedstock and location of the crop is quite wide, as shown in Table 6.

Table 6: Production costs of ethanol for different feedstocks and countries

Country	Feedstock	Cost (US$/L)
Brazil	Sugarcane	0.20
Thailand	Sugarcane	0.29
Australia	Sugarcane	0.32
USA	Maize	0.47
EU	Cereals	0.97

Source: Datagro in [16]

There is a clear advantage for the sugarcane ethanol made in Brazil, even with the subsidies in USA. Only high import taxes keep the Brazilian ethanol from reaching, in large scale, the USA and EU markets.

Wheat ethanol has a NER very close to corn ethanol and beet sugar ethanol is only slightly better. Adding to this the higher production costs of these three alternatives, when compared to sugarcane ethanol, it is not reasonable to expect that they will survive in the long term, or even in the medium term.

The GHG life-cycle analysis is a more complicate process to compare because the procedures, system boundaries, by-product contribution and input parameters, are quite variable among the authors. Larson [17] presents a review of more than 40 life-cycle analysis of liquid biofuels. One important point is that almost all LCA's are referred to EU and North America, with only two cases dedicated to developing countries (sugarcane ethanol in Brazil and India). Important cases such as cassava ethanol, palmoil and Jatropha biodiesel have not been found in the literature. The LCA's for the same biofuel and feedstock have shown a considerable range for the results indicating the effects of the local conditions, the differences in input values and in methodology;; the emissions related to N_2O and land use change are not clearly treated. Surprisingly there is a lack of focus on land use efficiency and changing in yields for future crops. Soil carbon sequestration appears to be an area where a lot of efforts are required to clarify the effects of site specificity, agricultural practices (tillage, fertilizer use), climate and soil characteristics. In spite of the variation in the results and differences in approach Larson concluded that conventional grain and oilseed based biofuels can provide only modest reduction of GHG emission and displacement of fossil fuels in the long term, due to the poor energy balance (low NER's) and large land requirements; he also considers that land use efficiency in reducing GHG emissions may be the most important point to be considered.

Land Use

There have been lately hot discussions on the threat of biofuels occupying land needed to grow food, feed and fiber crops, causing an increase in food prices. There is more passion than wisdom in most of these discussions, but it is an issue that deserves careful attention when choosing bioenergy options.

The world land use today and some of the main crops are shown as indicated below [18].

	Mha
Total Land Area	13,400
Arable area	1,400
Perennial crops	136
Grassland	3,400
Forests	3,900
Main crops	
Wheat	208
Rice	153
Maize	145
Soybeans	92
Sugarcane	20

A considerable portion of the unused land is not suitable for cultivation (deserts, too cold, urban areas, mountains etc.), leaving some 3,300 Mha for rainfed cultivation [19]. These authors made a projection to 2050 which is shown in Table 7.

Table 7: Land available for energy biomass production in 2050 (Gha)

Region	Total Land	Rain-fed cultivation	Land under Forest	Arable land in use	Housing, food, infrastructure	Additional land available	Land for bioenergy
NA	2.1	0.4	0.1	0.2	0.0	0.00	0.00
S&CA	2.0	0.9	0.3	0.1	0.1	0.25	0.25
EU	2.3	0.5	0.1	0.2	0.0	0.08	0.04
Africa	3.0	0.9	0.1	0.2	0.1	0.44	0.18
Asia	3.1	0.5	0.0	0.6	0.1	-0.07	-0.07
Oceania	0.9	0.1	0.0	0.1	0.0	0.04	0.04
Total	13.4	3.3	0.8	1.5	0.3	0.74	0.44

Source: [19]

From that analysis it resulted that some 440 Mha would be available for growing energy crops in 2050, after deducting 300 Mha for additional food production and additional housing and infrastructure. It is important to notice that more than 80% of this available land is located in Africa and South and Central America and that sub-Saharan Africa has some serious problems to face before being able to really participate in a large biofuels market. That leaves Central and South America as the place to look at for long term sustainable bioenergy industry.

How much biofuels or bioenergy can be produced in this land is a question difficult to answer because it depends on the type of bioenergy, the feedstock and technology used. Considering today's technology parameters for both agriculture and processing if this 440 Mha were fully used to produce either ethanol or biodiesel from different feedstocks the results, from the energy point of view, would be as indicated in Table 8.

Table 8: Energy from biofuels production with different crops in 440 Mha

Biofuel	Feedstock	Yield (L/ha/yr)	Fuel production (10^9 L)	Energy production (EJ)
Ethanol	Sugarcane [1]	6,000	2,600	55
	Maize[2]	3,500	1,500	32
Biodiesel [1]	Soybeans	400	180	6
	Castor beans	500	220	8
	Oil palm	3,000	1,300	47

Notes: [1] Brazil productivity; [2] USA productivity

It is clear that the energetic result from the available land is highly dependent on the type of biofuel and feedstock; using the land to produce ethanol from sugarcane would result in nine times more energy than would be obtained from the same land producing biodiesel from soybeans.

When, and if, the second generation technologies for bioenergy production become commercial, the problem will continue for the results would be dependent on agricultural productivity (for energy crops) or residues collection parameters, as well as on the processing technology used. The second generation is normally divided in two main routes to convert the lignocellulosic feedstocks into biofuels and electricity:

- Biochemical routes: the cellulose and hemicellulose fractions of the feedstocks are broken into sugars, either by enzymes or acid, and the hydrolysate is purified and fermented to ethanol. The lignin fraction is normally used to help to meet the energy demand of the process;
- Thermochemical routes: the whole feedstock is gasified (gasification) or liquefied (fast pyrolysis) and than converted to biofuels and electricity. As an option, the biogas can be totally used, after proper cleaning, to generate only electricity in a very efficient combined cycle. Several types of biofuels can be obtained from the same feedstock depending on the biogas (syngas) processing technology.

As example of the different results obtained with the same feedstock processed by some of these second generation technologies, can be obtained using the data published in California Energy Commission report [20]. The results for one tonne of dry biomass are shown in Table 9.

Table 9: Products and efficiencies of processing one dry tonne of biomass with second generation technologies

Product	BIG/GT [1]	Termochemical [2]	Biochemical [2]
Ethanol (L/t,DM)	-	333	246
Electricity (kWh/t,DM)	1750	606	226
Total efficiency (%) [3]	35	50	33

Notes: [1]The author (Biomass Integrated Gasification/Gas Turbine); [2]CEC – California Energy Commission [20]; [3]Energy consumed in the process comes from feedstock.

The thermochemical routes are not only more efficient in processing the biomass, but also much more flexible in terms of final products: ethanol, methanol, higher alcohols, diesel, gasoline, wax and other chemicals, as shown in Figure 1.

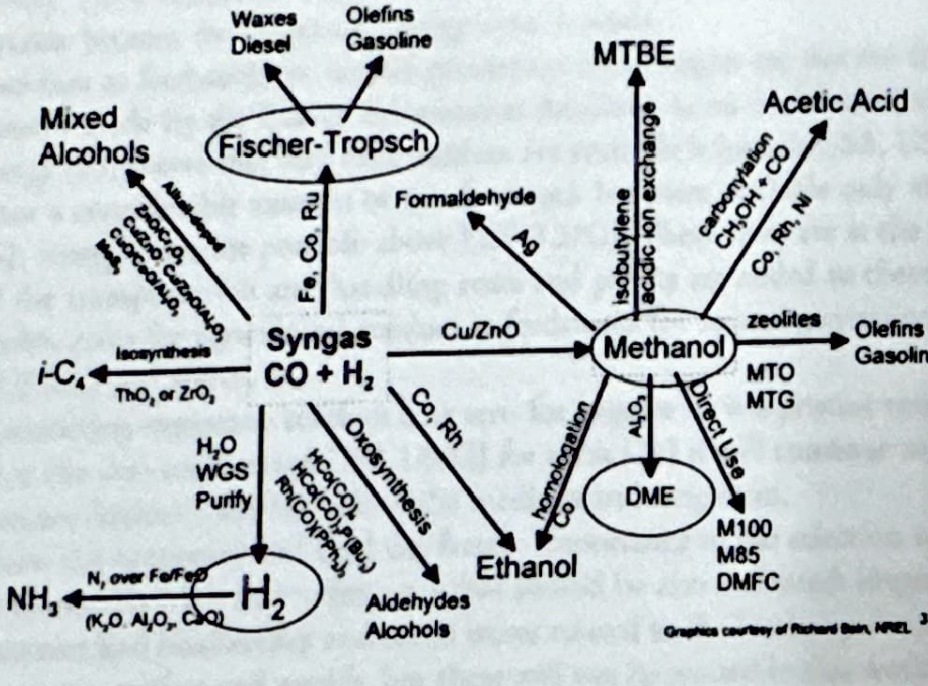

Figure 1: Syngas processing to final product

Leal [21] has demonstrated that excellent results can be obtained with the integration of the first and second generations with sugarcane as e feedstock, as suggested in Figure 2 (Courtesy of Dedini), to make the best use of the primary energy of the cane.

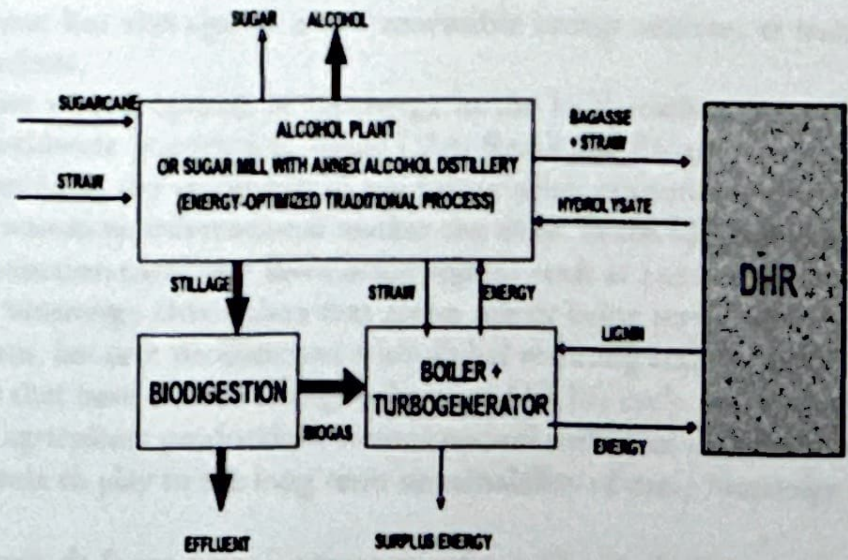

Figure 2: Integration of second generation technology with a conventional sugar/ethanol mill

Other possibility of increasing the land energy productivity is to develop better feedstocks for joint use of the two generations. Once again, sugarcane is proving to have an excellent potential for reaching very high levels of secondary useful energy forms per unit of cultivated land. Since the 80's, the concept of energy cane, with a high potential of primary energy production per hectare, is being developed and lately the West Indies Central Sugarcane Breeding Station has produced several varieties with very high primary energy production per cultivated area [22]. Table 10 shows a comparison between the average Brazilian sugarcane and one of the Barbados energy cane.

Table 10: Comparison between sugarcane and energy cane

	Sugarcane	Energy cane [1]
Yield (t/ha.yr)	70	100
Fiber % cane	13.5	26.0
Trash % cane	14.0	25.0
Pol % cane	14.5	12.0
Total fiber (t/ha.yr)	19.3	51
Primary energy: GJ/ha.yr MJ/tc	 520 7400	 1100 11200

Source: [1] [22]

The energy cane has a primary energy content, per hectare of cultivated land, that is around twice of that obtained with the conventional cane. Although the energy cane is more difficult to process by the conventional methods (first generation technology), due to its high fiber to sugar ratio, it seems well suited for the combined first/second generation processing. In Table 11, it is presented a simulation where today's technology is compared with the 2020 sugarcane and energy cane processed in this integrated system [21], considering that 50% of the cane residues, in both cases, are recovered and used as feedstock for the second generation process.

Table 11: Future performance of conventional sugarcane and energy cane

	Primary Energy	L/ha.yr	kWh/ha.yr	Effic. (%)
2005 [1]	7,400	6,000	4,200	30
2020 [2]				
Bioch.	7,600	10,400	7,200	45
Thermoch.	7,600	11,300	11,500	50
Energy Cane [2]				
Bioch.	11,200	13,000	12,000	31
Thermoch.	11,200	15,000	22,000	38

Notes: [1] First generation only; [2] Residues – 50% surplus bagasse+50% of trash

The results of this simulation are quite striking, since the production of primary and secondary useful energy per hectare/yr are approximately 1100GJ and 400GJ, respectively. These results are very much possible if the second generation technologies materialize because the feedstock, energy cane, is ready.

Residues as feedstock for second generation technologies are not for free. As an assessment made by the Energy Information Administration of the US Department of Energy [23] shows that very little residues are available below, in USA, US$ 1.4/GJ and that a considerable amount of this feedstock becomes available only above US$ 1.9/GJ; energy crops are possible above US$ 2.2/GJ. These costs are at the farm gate and if the transportation and handling costs and profits are added to these values, a reasonable price for agricultural residues as feedstocks for second generation plants is US$ 2.55/GJ and above.

Considering sugarcane residues cost zero for bagasse (it is a process residues produced at the site) and around US$ 1.0/GJ for trash [24] it will continue to be a very competitive feedstock for biofuels in the medium and long term.

Beside the economic and land use factors importance in the selection of the bio-energy alternatives there are other ones that should be also evaluated: impacts on the environment and biodiversity and social issues related to the local population such as land property, welfare and wealth, but these will not be treated in this work.

5. FINNAL COMMENTS

Biomass is an important primary source of energy today mainly in developing countries, and the scenarios developed by important institutions, such as the International Energy Agency (IEA), International Institute for Applied System Analysis (IIASA) and European Renewable Energy Council (EREC) indicate that it will continue so for many decades. But neither biomass nor any other form of renewable energy will replace totally the fossil energy sources. It can displace fossil sources as a feedstock for chemical products, but it is in the energy sector that this tasks is more challenging: the volume is larger and the prices are lower; technology development is therefore badly needed, both in the agricultural and processing sectors, to improve biomass competitiveness, specially in the case of biofuels, to be able penetrate the market with temporary subsidies only. The competition will be against not only fossil alternatives but also against other renewable energy sources, as means to reduce GHG emissions.

There are several options of bioenergy in the local markets but only a few have attained worldwide importance. Today USA, Brazil and EU produces 95% of all biofuels consumed in the world but in the future other countries must participate in a significant way so an international market can exist. In the future also, land availability and production costs may favor some regions such as Latin America and Africa.

Not all bioenergy alternatives that are in use or being tested today will survive in the long term, because the concerns with global warming and resources use will favor the options that have a better energy balance, GHG life cycle analysis and a high yield in terms of agriculture production; environmental and social impacts will have also an important role to play in the long term sustainability of every bioenergy type.

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