

LAND USES: BIOMASS FOR FOOD AND FUEL IN BRAZIL – THE NEXT 20 YEARS¹

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1. INTRODUCTION

Table 1 displays the technical potential for the production of renewable energy for the most important alternatives (IPCC-SYR, 2001). As noted solar, wind and biomass energy are the ones that can make the major contribution to the forecasted energy demand in the year 2100. According with the assessment (IPCC, 2001) total energy demand by the year 2100 should be between 515 and 2737EJ/yr depending of the evolving economic global and social scenarios. Even assuming the most energy-intensive scenarios renewables will be able to supply all the demand as far as technology is concerned. For the evaluation of Table 1 the following assumptions were assumed: a) 1% of global land area will be used for the installation of solar collectors and for windmills; b) all potential crop land area not been required for food crop would be used for biomass energy plantation, which means 1280 million ha by 2050, essentially 42% more land used for food production worldwide in 1990 (Moomaw and Moreira., 2001). Wind energy potential assumes that 10% off all land area with an average wind speed above 5.1 m/s at 10 m above ground (which adds to 27% of all earth land area – 3000 million ha) could be used. Thus total area covered by windmills would be 300 million ha, which exceeds the value of 4% availability found by a detailed survey carried out for USA and the Netherlands. For solar energy potential it is assumed that 10% of the land classified as “other land” category by the FAO (1999) would be used, which is 393 million ha. Obviously, land areas ranging from 1300 to 300 million ha occupation are huge and their uses would face severe difficulties. Furthermore, these estimates did not consider economic feasibility, and institutional and social barriers, Figure 1 presents a general behavior of potentials other than the technological one and how they evolve with time. It is clear from the Figure that market potential is usually much smaller than the technological potential and many policies must be successfully designed and implemented in order to increase the market potential. This issue will be retaken in section 5 of this paper

2. FORESTS IN THE FUTURE - ENERGY FOR HOUSEHOLDS –SCENARIO 1

Globally forests cover one-fourth to one-third of the earth land surface (3400-4100 million ha (FAO 1993; Dixon et al 1994). Although the great majority of these forests can be considered as managed to some degree, only 4% (135 million ha) consist of intensively managed plantations (Kanowski et al 1990; Dixon et al 1994). From this total only 25 million ha are dedicated to fast growing trees being 6 million ha used for hardwood, the trees most suitable for fuelwood (Bazett 1993). About 30% of industrial timber production (industrial roundwood, i. e., non - fuelwood raw logs) in Latin America, for example, may have originated on plantations (McGaughey and Gregerson 1982).

Current and future global need for forest products can be forecasted based on regional population projection (Alcamo et al 1994) and regional forest product consumption (FAO 1993). Figures are presented on Table 2, showing that total wood demand will increase, but fuelwood and charcoal will increase faster than industrial roundwood, more than double present demand in the year 2050. The amount of fuelwood (including charcoal) consumed at global level showed a steady decline up to 1950 when its absolute value started to increase again, being presently responsible by 18 EJ or 6% of global primary energy (Nakicenovic et al 1996; Woods and Hall 1994).

Presently, annual global need is approximately 1% of potential global growing stocks (Solomon et al 1996). Need is projected to reach nearly 3% of global productive standing stocks by the year 2050, since not only demand increases but global growing stocks is expected to decline by one-fourth or one-fifth. In tropical

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regions, where as much as 90% of forest production is consumed as fuelwood (FAO 1993) need for fuelwood reaches nearly 5% of growing stocks (Solomon et al 1996). This figure is above the current level of annual growth in tropical forests, which is 2% of standing stocks (DeBacker and Openshaw, 1972). This means that, at least in tropical countries a wood product availability shortfall of some 3% of total standing stocks occurs by 2050. This evaluation includes large areas of long established natural vegetation that are in equilibrium and consequently present small growth rates

Using well designed scientific methodology, satellite imagery, field measurements and destructive sampling it is possible to evaluate with good accuracy the standing wood stock, as well as the growth rate, allowing another way to verify the above paragraph conclusion. Application of this approach for Pakistan has been recently carried out yielding an average value of 18.7 ± 3.6 tonnes/ha and a growth rate of 10% of this figure for woody biomass (Haider 1997). Assuming this result holds for all developing countries the demand in the year 2050, as shown in Table 2 could only be accomplished with collection of fuelwood over an area of 13 million km² (3.41×10^9 m³/0.7/1.87t/ha). This extension is enormous but still within the boundaries of the tropical countries. Assuming an average standing stock 2 times higher (what make sense since vegetation for Pakistan is considered very low due the large pressure caused by the large population the area would be halved supporting even better the conclusion that fuelwood demand could be satisfied in 2050. Nevertheless, the conclusion is valid for the average area and not for neighborhoods with large population concentration. Actually the conclusion is that scenario 1 is dangerously feasible.

On the other hand, it is very clear that increment in biomass demand to fulfill commercial non-fuel uses can easily be accomplished by better handling of natural forests or by the use of deforested areas not suitable for food or energy crops. This is understood considering the small amount of wood commercialized (see Table 2). Most of the volume of roundwood is produced from the exploitation of 135 million ha, which should grow by 1% per year reaching 200 million ha by 2050. Considering that all this product is presently obtained from the careful management of only 4% of the natural forest, future demand may easily be attended by the management of a larger area of forests (7%).

3. FORESTS AND BIOMASS CROPS IN THE FUTURE - ENERGY SUPPLY AND TRANSPORTATION – SCENARIO 2

Fuels derived from sustainable biomass have the merit, among others, of replacing fossil fuels without any net CO₂ emission, other than the energy consumed through the use of fossil fuels in the agricultural and industrial phases of the biomass fuel preparation. For many biomass fuels the amount of fossil fuel energy required in its processing is low (10 to 20%) compared with the energy built in the biomass fuel, resulting in an alternative to fulfill human demand for fuels while slowing down CO₂ emission (Turhollow and Perlack 1991).

The future situation of forests can be quite different of the scenario discussed in section 2) if forest management practices will be extensively used. Such practices which involves conservation, storage, and management for substitution of forests can be promoted by the necessity of reducing greenhouse gas emission while inducing good social, economic and ecological sense.

Conservation management can be obtained controlling deforestation and carrying out protection and conservation of forests. Presently 15.4 Mha/yr are deforested, mostly in tropical countries, and some countries (e. g. Brazil, India, Thailand are being able to reduce this figure (Solomon et al 1996). In recent years, there has been significant expansion of “protected areas” into areas of both mature and secondary forests for conservation of biodiversity, and sustainable timber and firewood production. (see Thiam 1997).

Storage management means increasing the amount of C stored in vegetation (living, above and belowground biomass), soil (litter, dead wood, mineral soil) and durable wood products. This can be achieved by protecting secondary forests and other degraded forests whose biomass and soil C densities are less than their maximum value and allowing them to sequester C by natural or artificial regeneration and soil enrichment. Other approaches are to establish plantations on non-forested lands: promote natural or assisted regeneration in secondary forests; or increase tree cover on agricultural or pasture land (agroforestry) for

environmental protection and local needs. In some eastern countries this is happening naturally due to surplus in agricultural land. Total area of abandoned agricultural land is estimated to be 200/300 thousand ha (Muiste et al 1997) and one possibility considered is utilize the existing forest of fast growing species (esp. alder) instead of establishing new plantations (Muiste et al 1997)

Under such C - sequestering projects, if biomass production is to be regarded as a sink, the total amount of carbon stored per hectare under the crop must be greater than the level of C stored in the vegetation previously on that land. The size of the carbon sink is dependent on the level of vegetation already present on the land and the time perspective of the newly planted vegetation (e.g. rotation length of a plantation and the length of time the land will be used for energy production (Marland and Marland 1992). Increasing both the length of rotation and the productivities will result in higher average levels of standing carbon (Wood and Hall 1994). However, for energy production purposes the optimum rotative length may be shorter since the rate of tree growth falls off after a certain age, so reducing the annual productivity and economic return.

Substitution management, view forests as renewable resources. It focuses on the rate of C sequestration or the transfer of biomass C into products that substitute for or lessen the use of fossil fuels, rather than on increasing the C pool itself (Grainger 1990; Mixon et al 1994). This approach involves extending the use of forest for wood products and fuels obtained either by establishing new forests or plantation or by increasing the growth of existing forests through silvicultural treatments. Figure 2, extracted from IPCC, 2001 shows the concept. Typically each ha of forest stores approximately 100t of C in all living biomass and another 100t of C in litter, dead wood and soil up to 1 m depth., at a total C accumulation ratio of 1 to 5t/ha/yr (Nabuurs and Mohren 1993). When forests are used to produce sawtimber, plywood, or other industrial wood products, C can be sequestered for long periods. Also the production of wood products is much less energy intensive than production of alternative products like steel, aluminum, and concrete, and there can be a large energy return on investments in wood products. Over long time periods the displacement of fossil fuels either directly or through production of low-energy-intensive wood products is likely to be more effective in reducing C emission than physical storage of C in forest or forest products.

The benefits of C-sequestration may thus have to be balanced against these C-substitution in the selection of the optimum rotation length. The most clear benefit, in C-sequestration terms, would be if the plantation was established in a desert with an existing standing stock of almost 0 tC/ha. Both the above and below ground levels of carbon would be raised compared to the existing level. However, if the standing stock of the previous vegetation was greater than that of the new plantation then a net reduction in the standing C levels would result. Only if the plantation biomass were to be used as fossil fuel substitute a net reduction to atmospheric CO₂ emission would occur after a given time period.

Some studies (Nilsson and Schopfhauser 1995; Trexler and Haugen 1994) evaluated the amount of land likely to be available, the feasible annual planting rates, growth rates and rotation lengths. As much as 215 Mha is available at high and mid latitudes countries and 130 Mha in tropical countries. This last figure is only 6% of the suitable land (2228 Mha) because of additional cultural, social and economic constraints add to the technological limit. The total available area is 345 Mha. A frequently quoted study (Johansson et al, 1993) presents results for present and potential cropland availability, as well as built a scenario for a Renewables-Intensive Global Energy Scenario (RIDGES) for the years 2025 and 2050 (see Table 3). The final conclusion is that 256 million ha will be committed to biomass plantations in the year 2025 and 271 million ha in the year 2050 for the production of 145EJ and 206EJ, respectively. These figures are lower than the technological potential quoted in section 1) since the model already includes the existence of economic and institutional barriers even after a set of policies are implemented. RIDGES also quotes developed and developing world shares as well as regional participation of biomass. Table 4 presents such results for different technologies for the Developing World and for Latin America for the years 2025 and 2050. Also is shown the total demand for commercial fuels as forecasted in the International Panel of Climate Change (Ishitani et. al, 1996) for an accelerated policies energy savings scenario and the remarkable result is that biomass production may be responsible for 56.5%(71.8%) of the energy otherwise produced from conventional fuels in 2025(2050) in the Developing World, while the results would be 95.6%(123.5%) in 2025(2050) for Latin America. Such high participation of biomass means that both the Developing World and mainly Latin America may be exporters of renewable fuels to the Developed World. Another study

(Winjum et al 1992) estimated an area of 375 to 750 Mha for the same forestry practices. Not only the land is available but also the plantation rate of approx. 10 Mha/year, which will be necessary to cover the area with the calculated rotation length, are not realistic. For South America a plantation rate of 0.18 Mha/yr which is assumed (Nilsson and Schopfhauser 1995) is much below annual forestation carried out only in Brazil during 1970-1980 when financial incentives were available. For mild altitudes countries the plantation rate is also modest compared with present planned activities in some countries. In Turkey, government plan considers the forestation and afforestation of approximately 0.06 Mha/yr for energy forests up to the year 2000 (Turker and Kaygusuz 1997). Such level of energy forest activity has been already achieved during the 80's (Saraçoglu and Durkaya 1997).

Through the 345 Mha of plantation and agroforestry, plus 138 Mha for slowed tropical deforestation and 217 Mha for natural and assisted regeneration of tropical forest, 700 Mha of land might be available globally for C conservation and sequestration, abating 60 to 87 GtC by the year 2050. Which is 12 to 15% of the total fossil fuel emission over the some period.

4. CROP VERSUS FOREST PLANTATION

Other study (Ishitani et al 1996), mostly interested in evaluating future energy supply, is also very optimistic about the possibility of using vast quantity of biomass as an energy source, due its positive social and environmental impact, mainly low C emission. The study confirms the future availability of 50-100 Mha of agricultural land in Europe, 52 Mha in USA, by the year 2030, and the feasibility of recovering more than 600 Mha of degraded land in tropical countries, while supplying all the food requirements if agriculture can be modernized in the developing world. Expectation of better yields for wood energy plantation is justified based in the shortage of laboratory and field research. Many common tree species are still being analyzed regarding the potential and optimization as an energy source (Chow et al 1997). Biomass other than wood is also considered under the argument that expected improved yields from new technology is possible, mostly because little biomass has been grown on plantation for energy. These estimates of prospective yields are based on experience with crops grown for food and fiber, involving limited commercial experience. Even so some high yields have been achieved over large areas in Zambia as is the case of sugarcane with 70 dry tonnes per hectare per year (dt/ha/yr) (compared with the world average of 33 tonnes dt/ha/yr (Hall et al 1993), larger than the best yield obtained for eucalyptus in Brazil, which is 47 dt/ha/yr (and an average commercial yield of 21 dt/ha/yr). Considering all these factors the study built an energy scenario for the years 2025, 2050, 2075 and 2100 where up to 325 EJ per year from a total requirement of 700 EJ would be derived from biomass at the year 2100.(see Figure 1) As much as 550 Mha of land would be used, most of it for energy crop (70%) and the remaining from fuelwood plantation(165 Mha). Such scenario not only fulfill a significant fraction of the global energy demand but reduces CO₂ emission from its present value of 6 Gtonnes of C to 2 Gtonnes of C in the year 2100. It is worthwhile to note that this biomass scenario uses modest biomass yields, very efficient energy conversion technologies and efficient end-use to limit energy supply to 700 EJ.

If we believe that by the next 50 years, commercial, average yield of sugarcane would reach the Zambia record of 1300 GJ/ha/year, as much as 122 tonnes/ha (70/33 x 63.3) of harvested cane stems wet weight could be produced. Assuming 122 tonnes/ha/yr and 87 l/tonne, as much as 10614 l/ha/yr as well as 61 MWh/ha (assuming generation of 500 kWh/tonne of crushed cane) of electricity would become available (Williams and Larson 1993). Including in this scenario economic and institutional barriers which shall be minimized through policies but never fully removed we assume the use of half of the 550 Mha for this plantation, which would produce:

$(550 \times 10^6 / 2) \times 10614 \text{ l/ha} = 2.92 \times 10^{12} \text{ l/yr}$ or 16.0 billion barrels of oil equivalent
that is only 30% below present level of world oil consumption, and

$$(550 \times 10^6 / 2) \text{ ha} \times 122 \text{ tonnes/ha} \times 0.5 \text{ MWh/tonne} = 16775 \times 10^6 \text{ MWh/yr}$$

or 16,775 TWh/yr that is equivalent to half the theoretical world hydroelectric potential and 10% above the amount of electricity generated in the world in 1990 (Moreira and Poole 1993).

The achievement of such yields are not far from reality. Sugarcane has been explored as a source of liquid fuels in Brazil, since 1975 and in 20 years with typical R&D investment of US\$ 20 million/year it has been possible to rise the average yield from 3900 to 5100l/ha in the Center/South region. Assuming such development will continue at the same rate, in the next 50 years, an average productions of 7140 l/ha will be achieved with the modest investment of US\$ 1 billion in R&D (or US\$ 20 million/yr which is being invested today). This increase in yield is quite small when compared with productivity increase in wheat, where in UK have increased 3 folds in 42 years (Buringh 1987). Thus, a significant larger effort will be required but the 10,000 l/ha record is not unreal.

It is worthwhile to analyze the ProAlcool Program in Brazil as a case study to quantify CO₂ atmospheric abatement capacity by biomass fuel replacement of fossil fuel versus the alternative of C-sequestering by biomass long standing plantation, since now we are interested in the evaluation of the economic potential.

The extension of sugarcane planted areas are stagnated since 1986 when it reached 4.3 million ha from which 2/3 is used for fuel ethanol production. From 1987 up to 2001 168.7 x 10⁶m³ of ethanol (Datagro, 1997; Unica, 2001) has been produced, displacing 135.0x10⁶m³ of gasoline. This amount of gasoline, if burned would emit 115.7 x 10⁶ tonnes of C. That amount of ethanol was obtained with the use of 2.87 million ha of land (Datagro 1997), which means 40.31 tonnes of C/ha, neglecting that some fossil fuel has been used in the production of the ethanol. Considering an energy balance of 8.2 to 1 (Goldemberg et al 1993) and 10% energy surplus in the bagasse, which is used to replace fossil fuels in other agroindustrial activities (BEN 1996), the final figure would be 39.52 tonnes of C/ha in the 14 years period.

To sequester this amount of C with planted trees, it would be necessary to record yields of 74.15 (39.52/0.533³) oven dry tones/ha in 14 years, which is easily achievable with many varieties of trees in tropical countries. Nevertheless, the evaluation is not complete, since we must consider the increment in the total carbon stock (above and below ground, live and dead biomass C and soil C) due the planted forest (see Figure 2) against the earlier land vegetation. In tropical countries, even deforested landscapes have an average of 21tonnes C/ha of total C stock while tree plantations for sawlogs (rotation length period of 12 years) have a total C stock of 64.6 tonnes of C/ha (including 7.9 tones C/ha stored in wood products⁴) yielding an increment of 43.3 tonesC/ha (Fearnside 1995).. For longer rotation length forest (90 years) the total C stock can reach 200 tonnes of C, yielding an increment of 180 tones C/ha (200-21). (Fearnside 1995). Even with this more complete accounting the result is still favorable to C sequestration as compared with renewable fuel production.

The difference in C emission avoidance between energy crop and planted forests for C sequestration (longer rotation length) will begin to show up after six decades or so, when it is expected to obtain the same or even more annual replacement of fossil fuel throughout the use of ethanol (28.2 tonnes C/ha/decade(evaluated from the above figure of 39.52tC in 14 years)) using the same area of land while the net amount of total C stored in trees will saturate at the level of roughly 180 tones/ha.

Considering a) that ethanol production uses one of the sugarcane residues (bagasse) in a very inefficient way and others residues which are burned or unused can become useful sources of energy with technology improvement; b) CO₂ emission reduction programs must be effective for at least a century since CO₂ half-life in the air is several decades, the advantage of biofuels over C-sequestration is not negligible.

But, major differences are in the financial aspect and in the amount of C abatement. Using energy crops or short rotation forest, which are suitable for fossil fuel displacement, it is possible to have short term revenue from the investment through sales of energy, while C-sequestration may requires around a decade to provide capital return through C certificate sales if it is valued around US\$10/tC. Regarding the C - sink potential the expected limit is 60 to 87GtC by the year 2050 (Kauppi and Sedjo, 2001).

³ Wood carbon content = 0.533 (Hall et al, 1995)

⁴ Which have an average life of 12.6 years (Fearnside, 1995)

Even so, the issue is controversial and many projects are being developed, under the AII/JI umbrella, with the purpose of C-sequestration. The major argument is the low investment cost in these projects. Excluding land costs and other transaction costs the cumulative cost to conserve and sequester C in the next 60 years in the quantity of 36 Gt, by means of forest regeneration and slowing deforestation has an unit cost of less than 3 US\$/tC. (Brown et al, 1996). These cost estimates generally represent only the cost of direct forest practices and could be increased by several times if land and opportunity cost and/or the costs of establishing infrastructure, protective fencing, training programs, and tree nurseries were included (Brown et al 1996). Programs, presently, under way are costing around US\$ 5/tC, which means that the needs stated above are not being implemented (Dixon et al 1993; Kinsman and Trexler 1993).

For expansion of C pools which must be more expensive than forest regeneration and slowing deforestation several studies conducted for developing countries evaluate the cost of sequestering C using options like agroforestry, long and short-rotation plantation (with C transfer to products), forest management, and silvicultural practices. Based on an estimate of the technically available land area in a given country, the tropical studies have developed cost curves that show increasing marginal costs (\$/tC) with higher sequestration. Most of the results indicate the unit cost for sequestering C on 80% of the technically available area would be less than \$ 10/tC (Brown et al 1996). All these estimates account for above and below-ground biomass C, but not all account for C in soil, fine and wood detritus, under story and wood products and as such over estimate the unit costs. On the other way the unit cost do not include the opportunity cost of land and growing stock, annual maintenance costs, and monitoring and evaluation costs which can increase such costs by several folds. Nowadays, localized shortage of fuelwood and stringent regulatory on its use for industrial purpose are awakening large industrial groups about the necessity of fuelwood plantations (see Miranda 1997).

Sugarcane plantation, for biofuel has a higher carbon cost. Anhydrous ethanol price in Brazil, sold at mills, excluding taxes, is US\$ 237/m³ (average price for July 2001, assuming 1US\$=R\$2.50) which is equivalent to 364 US\$/tonne of C avoided⁵. But ethanol is being used to replace gasoline which has an average price at the refinery gate, of US\$ 208/m³. Deducting 10% profit from the oil and ethanol costs the production costs are US\$213 and 187/m³ for ethanol and gasoline, respectively. This means that cost difference is 213 - 187x0.8⁶ = 213 - 150 = 63US\$/m³ of ethanol or 79 US\$/tonne of C avoided⁷, a high value when compared with C-sequestration figures discussed in Section 3. Other externalities could be accounted in the cost of ethanol, (creation of 700,000 rural jobs, decrease in the amount of hard-currency needs for oil importation, improvement in air quality in large cities) but they are not yet well quantified. Assuming CO₂ abatement as the only externality, Brazilians already paid (39.52 tonnes of C/ha x 2.87x10⁶ ha x 63 US\$/tonnes) US\$7.14 billion in C taxes in the last 14 years⁸.

5. BARRIERS AND POLICIES NEEDS

The second scenario has been explored up to now with considerations about technology and some aspects of economic feasibility, nevertheless the requirement for institutional and social policies have been mentioned but not included in the scenarios. Table 5 provides a taxonomy of barriers and opportunities for the implementation of scenario 2. It is very ample and general and presents in a concise way the barriers and what is needed to overcome them. Nevertheless, instead of discussing each cell of Table 5, we decided to

⁵ Ethanol has 23.80 GJ/m³ and is 15% more efficient than gasoline, when used in well designed Otto engines displacing 27,36 GJ of gasoline per m³ of ethanol. Gasoline emission is 22.5 kgC/GJ 20.5 kgC from Nakicenovic et al 1996, plus 10% of fossil fuels used in its processing. Thus 1m³ of ethanol avoids 628 kgC less C emission from fossil fuels used in the ethanol processing. Making this correction the figure is 554 kgC. Assuming 15% profit, ethanol cost is US\$ 237/m³ x 0.85 (=201). Cost per tonne of C avoided is US\$ 201/554 kgC or US\$ 364/tonne of C.

⁶ 1 liter of ethanol displaces 0.8l of gasoline in Otto engines.

⁷ 1m³ of ethanol avoids 554 kgC (see note above). Thus 63US\$/554 kgC=114US\$/tC. Considering taxes which are equivalent at the final user but different at the sugarmill and gas pump, a correction must be applied yielding US\$ 79/tC.

⁸ This result is probably a lower limit. Alcohol costs were much higher a decade ago compared with gasoline. A correct evaluation can be performed comparing year by year gas and alcohol costs and the annual production amount of alcohol. Data are available but this calculation is out of the scope of this paper.

discuss more specific barriers and opportunities related with our problem in order to be more pragmatical but paying the cost of examining only a few issues. This section deals with these missing aspects.

Since one of our scenario deals with biomass for transportation and energy supply, the discussion about barriers and policies is presented for these two end-sector and then for the agriculture and forestry sector since forests and fuel biomass cropping are important contributors to the scenario. Finally, we discuss barriers and policies under the Developing Countries context.

5.1 Transport

5.1.1 Barriers to Mitigation

SAR II 21 (1996) noted many reasons why GHG mitigation in the transport sector has proved difficult. Transport activity is closely interwoven with infrastructure, lifestyles, economic development, and patterns of industrial production.. Climate change and energy saving is usually a minor factor in decisions and policy in the sector may not be implemented if they seem to reduce the benefits provided by the transport system to individuals and firms. Appropriate mixes of policies need to be designed for local situations.

Car technology is good example of “lock-in”. A century of development has put the gasoline engine, and the infrastructure to maintain it and supply its fuel, in a virtually unassailable position. Technologies based on alternative fuels, batteries, or fuel cells will have to compete with gasoline engine performance and cost levels that continue to improve.

While information on the fuel efficiency of vehicles is widely available, it may not be easy to find or assimilate for the average purchaser. Labeling laws and information programmes have been introduced in many countries to overcome this information gap (ECMT, 1997). Nevertheless, the fuel economy information on labels is usually obtained in standard test cycles, the information from which may be inaccurate (IPCC, 1996).

Even considering that ethanol powered cars require few different parts than a gasoline car vehicle manufacturers have no incentive to promote its use since globalized production and hard price competition yields severe concern with any cost increase which shall be a natural consequence of producing two slightly different models of the same car.

5.1.2 Opportunities for renewable fuels

The phenomenon of lock-in can also be seen to apply to road transport more generally. Cars are preferred over other transport modes partly because of their intrinsic advantages in flexibility, convenience, comfort, and privacy. A car makes it possible to live in a suburban or rural area poorly served by public transport, taking advantage of low house prices and pleasant surroundings. However, there are also many sources of “positive returns to scale”, strengthening the incentives for using cars as their prevalence grows.

As car fleets have grown, modern western societies, cultures, and economies are increasingly built around motorized road transport. Car-oriented culture has charged cars with significance as a means of freedom, mobility and safety, a symbol of personal status and identity, and as one of the most important products in the industrial economy. Car-oriented infrastructure and settlement planning makes it hard to use any alternative transport mode. Many attempts to encourage a shift in planning provision away from cars, toward public and non-motorized transport also fail because of the strength of links among transport planners, construction firms and the financing institutions (e.g., Stenstadvold, 1995).

A second aspect of the lock-in to car transport is the result of economies of scale, and a century of R&D and learning from experience in car production. The real cost of owning and operating a car has declined over the last half century while public transport costs have risen (Sathaye and Bouille, 2001).

Because of the social and economic importance of transport, most governments provide budgetary subsidies for construction and maintenance of transport infrastructure, and for transport services including many linked to car use (de Moor and Calamai, 1996; OECD, 1997b).

Under this very favorable conditions it is easy to understand the significant increase in the number of cars running in all countries. The amount of CO₂ emission in the transport sector has shown a continuous and constant increase of 2.4% / yr for the last 40 years, independent of all efficiency improvements obtained (Moomaw and Moreira, 2001). At this rate the transport sector will be the leading CO₂ emitter by the year 2020, surpassing industries. To curb overall C emissions it is necessary to minimize cars emission. Since it seems very difficult to avoid fleet growth an intelligent solution would be switch to a less C intensive fuel, like ethanol from sugarcane. Our major conclusion is that all existing favorable conditions for increasing cars use are essentially an opportunity for the enlargement of environmentally sound renewable liquid fuels

5.2 Energy Supply

5.2.1 Barriers

There are two primary types of options available for reducing emissions. One is to increase the efficiency of energy supply, and the other is to switch from carbon intensive fuels to low or no carbon content fuels. The two options face different categories of barriers and the most relevant are described in this section.

Energy prices

Low prices are, in part, a consequence of direct and indirect subsidies to producers, and the non-inclusion of external costs in their production and use (Watson *et al.*, 1996; Harou *et al.*, 1998). It is common in the energy supply sector to find price policies (public or private) which do not reflect the “full costs”. These full costs include environmental externalities, which, for example, are not included in any coal transaction or gasoline prices in the United States. Producers and users of new energy technologies are not usually rewarded for the associated environmental benefits (World Bank, 1999).

Lack of adequate financial support

There are substantial opportunities in developing countries for expansion of electricity supply. While the capacity being installed is improving in efficiency, this process is slowed by difficulties in accessing the necessary capital. Many environmentally sustainable technologies require large up-front investments. In effect, the cost of pollution abatement is paid in advance. This is a serious obstacle for some technologies, particularly nuclear power generation and large hydropower schemes.

Multilateral development banks, public banks, and private banks generally do not offer soft credit, or programmes aimed specifically at energy technologies. This acts as a further barrier to capital-intensive energy projects. The absence, up until now, of specific programmes and an administrative process adapted to this type of project has resulted in high transaction costs and a lack of discussion of this key issue as a solution in the climate change problem.

Institutional transformation and reforms

The liberalization of the power industry, which introduces competition within the generation segment, could have a significant impact on the viability of renewable sources. Some observers may argue that subsidies of any sort are antithetical to the concept of a deregulated market, and that the purpose of liberalization is precisely to eliminate such subsidies and market distortion. In competitive markets where the process is replaced by the market-driven decisions of generation companies subsidies to renewable sources may become less acceptable (Bouille, 1998).

Along with the institutional difficulties of technology transfer projects, high transaction and implementation costs act as barriers as well. Often, cost estimations of new technologies do not include items related to

transaction costs or items associated with technology penetration (policy implementation costs). Both transaction costs and policy implementation costs are additional expenses to technology transfer, limiting competitiveness and market potential.

Legal and regulatory framework

Many energy supply sources are subject to a lack of regulation other than for safety, inadequate tariffs for transport and distribution, and no incentives to increase efficiency and preserve the global environment. For example, there is often no penalty for natural gas flaring. This reduces the motivation for improving the efficiency of the supply chain of such sources and for the use of renewable fuels.

If electric utility companies sell electricity within a regulatory system that allows them to recover all operating expenses, including taxes and a fair return for their investments, they will show no interest in increasing their efficiency. Within this system, utilities will be reimbursed the operational costs independent of the quality of the service offered (US DOE, 1996).

Distributed electricity generators often face a complex bureaucratic process for authorizing the construction and operation of co-generation facilities. Complicated terms of grid connection, technical, economic, and institutional rules limit access to the grid for distributed generators (Verbruggen, 1990; 1992; 1996).

Lack of information

While lack of information on energy technology performance, technical, and economic characteristics is not a very significant barrier in the energy supply sector, this market failure is related to market transparency. The inability of the private market to provide generic information (no transparency), and the possibility that “in the field” operation of a technology may differ from controlled environment operation by a technology producer, both increase uncertainty and risk in an investment⁹.

Decision-making process and behaviour

Many organizations are interested in using the most economically competitive technology, in terms of cost and availability of fuels, though not necessarily in terms of energy or carbon efficiency. The most competitive investments offer short payback periods, minimize overall investment, and receive an attractive rate of return. In such a framework, a relatively narrow range of technologies exists. Most of them are efficient in the economic sense but not necessarily in relation to GHG emissions reductions or avoidance. This represents a significant barrier to both developed and developing countries.

Uncertainty and risk aversion discourage long-term investments. Many forms of sustainable energy production require long-term investment. Most multilateral and international lending institutions are averse to technologically risky investments. As a result, both government and private entities may be reluctant to invest in high-tech projects that entail high capital costs (ECOSOC, 1994).

The lack of performance data for newer energy technologies often results in an unwillingness on the part of smaller firms to risk purchasing these more expensive technologies. While they may offer greater future savings than traditional technologies, the lack of test data prompts fears that reported energy savings may not materialize in practice.

The uncertainty inherent in new technologies leads investors to use high discount rates, which would make investments that are clearly cost-effective from a global perspective seem unattractive to private actors (Bouille, 1999)

⁹ Any decision-making process is one where the decision maker “buys” information to reduce uncertainty and risk in order to make a “better” decision. Lack of information means, essentially, uncertainty. The lower the degree of information the higher the uncertainty and the barrier to adoption of a specific technology.

Cultural aspects related with decentralized systems in rural areas

There are cultural barriers that oppose the use of decentralized systems in rural areas. Renewable energy is often promoted in rural areas to reduce local environmental impacts, and accomplish social and welfare goals. While these technologies may be competitive, easy to operate, and adequate for the project needs, technology diffusion is often confronted with cultural barriers (Barnett, 1990).

5.3 Agriculture

5.3.1 Barriers to New Activities

Farm-level adoption constraints

Several generic constraints characterize the adoption of most new agricultural technology. These include small farm size, credit constraints, risk aversion, lack of access to information and human capital, inadequate rural infrastructure and tenurial arrangements, and unreliable supply of complementary inputs. Participatory arrangements that fully engage all the involved actors may help to overcome many of these barriers.

Government subsidies

Subsidies for critical inputs to agriculture, such as fertilizers, water supply, and electricity and fuels, and to outputs in order to maintain stable agricultural systems and an equitable distribution of wealth can distort markets for these products. These types of subsidies prevail in both developed and developing countries. Low electricity prices in India, for example, provide a disincentive for the use of efficient pump sets, and encourage increased use of ground water, which depletes the water reservoirs. In the OECD, for example, high levels of farm subsidies have also contributed to the intensification of farm practices and often provide incentives to increase fertilizer use, livestock density, etc. (Storey, 1997)

5.3.2 Policies

Several measures may be pursued to address the above barriers. These include:

- The expansion of internationally supported credit and savings schemes, and price support, to assist rural people to manage the increased variability in their environment (Izac, 1997);
- The development of institutional linkage between countries with high standards in certain technologies, for example flood control; and
- The rationalization of input and output prices of agricultural commodities taking development issues into consideration which would lead to more efficient use of input resources.

5.4 Forestry

5.4.1 Barriers

Lack of technical capability

Currently lack of funding and technical capabilities in most tropical countries limit generation of information required for planning and implementation of forestry mitigation projects. Apart from a few exceptions, developing countries do not have adequate capacity to participate in international research projects and to adapt and transfer results of the research to the local level. Research on forests has not been sufficiently interdisciplinary to provide an integrated view of forestry (FAO, 1997) and the majority of the forestry research institutions has the main focus on research and not technology development and dissemination. Unlike in the energy or transportation sectors, the technologies or even the management systems are going to be forest type or country specific.

Lack of capacity for monitoring carbon stocks

Forestry-sector GHG mitigation activities and joint implementation projects generally face a wide range of technical issues that challenge their credibility. The twin objectives of using forestry to mitigate climate change and managing forests sustainably do pose a challenge in monitoring and verifying benefits from carbon offset projects in the sector (Andrasko, 1997). While methods generally exist to monitor carbon stocks in vegetation, soils and products, operational systems that could be readily implemented for this purpose are lacking in all countries (IPCC, 2000a).

Furthermore, policies to promote technology transfer have been identified (e.g., regulations, financial incentives) and sometimes implemented (e.g., Mexico, Bolivia). Under the UNFCCC, each party is required to communicate a national inventory of GHG emissions by sources and sinks.

5.5 Developing Countries Context

As a group, the developing countries are undergoing rapid urbanization, which leads to increased industrialization and motorization that has altered the manner in which people relate to their environment (Rabinovitch, 1993). Much of their technology stock is derived from developed countries, and increased globalization tends to expose even remote populations to socio-cultural patterns observed in the developed countries. Yet, the majority of the population in these countries lives in rural areas, and often in absolute poverty. These underlying attributes and phenomena create or emphasize barriers and opportunities that are particular to this group of countries.

Trade and environment

A larger external debt and balance-of-payments (BoP) deficit is a reality in many developing countries. If a GHG mitigation technology has to be imported, it is likely to add to this debt and BoP deficit. Another barrier to the technology transfer process is the requirement in technology transfer contracts of “intellectual property rights” (IPR), which guarantee that private firms are compensated for sharing their technology. If IPR laws are not effectively enforced, there is little incentive for private firms to share their technology. However, patents and licensing fees can be very expensive and in such situations, developing countries may prefer the lowest priced, albeit possibly less efficient technology alternatives (Srivastava and Dadhich, 1999).

Institutional framework

Deregulation and privatization offer an opportunity for improving energy efficiency and reducing GHG emissions in the energy sector. Studies and scenario analyses show, however, a consequent increase in emissions resulting from low fuel prices, displacement of hydro and nuclear plants by cheaper fossil-fired capacity, and a change in attitudes and behaviour of the energy suppliers (Bouille, 1999).

Distorted energy prices

Energy price subsidies have been in place in many developing countries in the name of reducing the financial burden on the poor. This has spawned a culture of dependency on energy subsidies that is gradually diminishing (Jochem, 1999).

Finance

Lack of available capital and lack of finance at low interest rates is pervasive in developing countries. Together with the absence of standards or energy labeling schemes, these barriers support the proliferation of inefficient equipment and first-cost-minimization philosophy. Additionally, low incomes and poverty constrain access to adequate finance, and oblige the purchase of inexpensive and often GHG-intensive equipment (Bouille, 1999). Provision of special funds targeted to the poor and government financing of the first cost of equipment are ways to increase the provision of energy services.

Barriers

Information gap hindering proper technology selection, lack of adaptation and absorption capability, lack of access to state of the art technology, and the small scale of many projects (Jochem, 1999) are specific and important barriers in low income developing countries to effectively exploit the full potential benefit of technology transfer. Lack of information also slows the decision-making processes in developing countries.

6. CONCLUSION

Wood fuels and biomass will be an important source of energy for the next century. Their use in households, mostly involving non-commercial operation will continue and at a larger scale than happens today. Shortage of supply which already is a concern for some users will increase. Their use in industrial, and transportation sector are quite promising, based in credible forecasts and in the present trend of use observed in several developed and in some developing countries. Pragmatically this means that both scenarios presented will complement themselves instead of complete advantage of one over the other. The demonstration of a more successful future for the scenario where biomass is used for energy supply and transport may be a conclusion for more economically advanced developing countries, while scenario where biomass for fuelwood should be used more intensively is more appropriate for the other developing countries. Nevertheless, in long term as economy develops we understand the scenario 2 will prevail.

The main motivation for industrial, and transportation use is C air emission caused by burning fossil fuels and its global consequences. As the consensus about this risky issue is growing a more professional approach for supply and use of biomass is occurring. Land area availability, better technologies for increasing yield and improving the efficiency of its use are gaining space and opening a new and large market. The amount of money involved in this new market can be above which is involved in agriculture today. Developing countries, mainly the tropical ones, can take advantage of this fact to improve gains allowing better life quality of the population.

Energy crop and forest plantation and management are the best alternative to curb C emission while simultaneously attracting large commercial interest.

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Table 1
Long term technical potential renewable and nuclear energy supply

	Long-term Technical Potential (EJ/yr)
Hydro	>50
Geothermal	>20
Wind	>630
Ocean	>20
Solar	>1600
Biomass	>440
Total Renewable	>2800

2100 Total energy demand for SRES scenario ranges 515-2737 EJ/yr

Table 2
Current and future need for forest products in 10⁹ m³, based on regional population projection (Alcamo et al, 1994) and regional forest product consumption (FAO, 1993).

	Years			
	1990	2000	2025	2050
Industrial Roundwood				
Tropical Regions	0.28	0.35	0.52	0.65
Temperate Regions	0.89	0.95	1.04	1.04
Boreal Regions	0.43	0.45	0.49	0.49
Total Global Volume	1.60	1.75	2.05	2.19
Fuelwood and Charcoal				
Tropical Regions	1.37	1.70	2.63	3.41
Temperate Regions	0.37	0.42	0.49	0.51
Boreal Regions	0.01	0.01	0.01	0.01
Total Global Volume	1.75	2.12	3.13	3.93
Total Volume	3.35	3.88	5.18	6.12

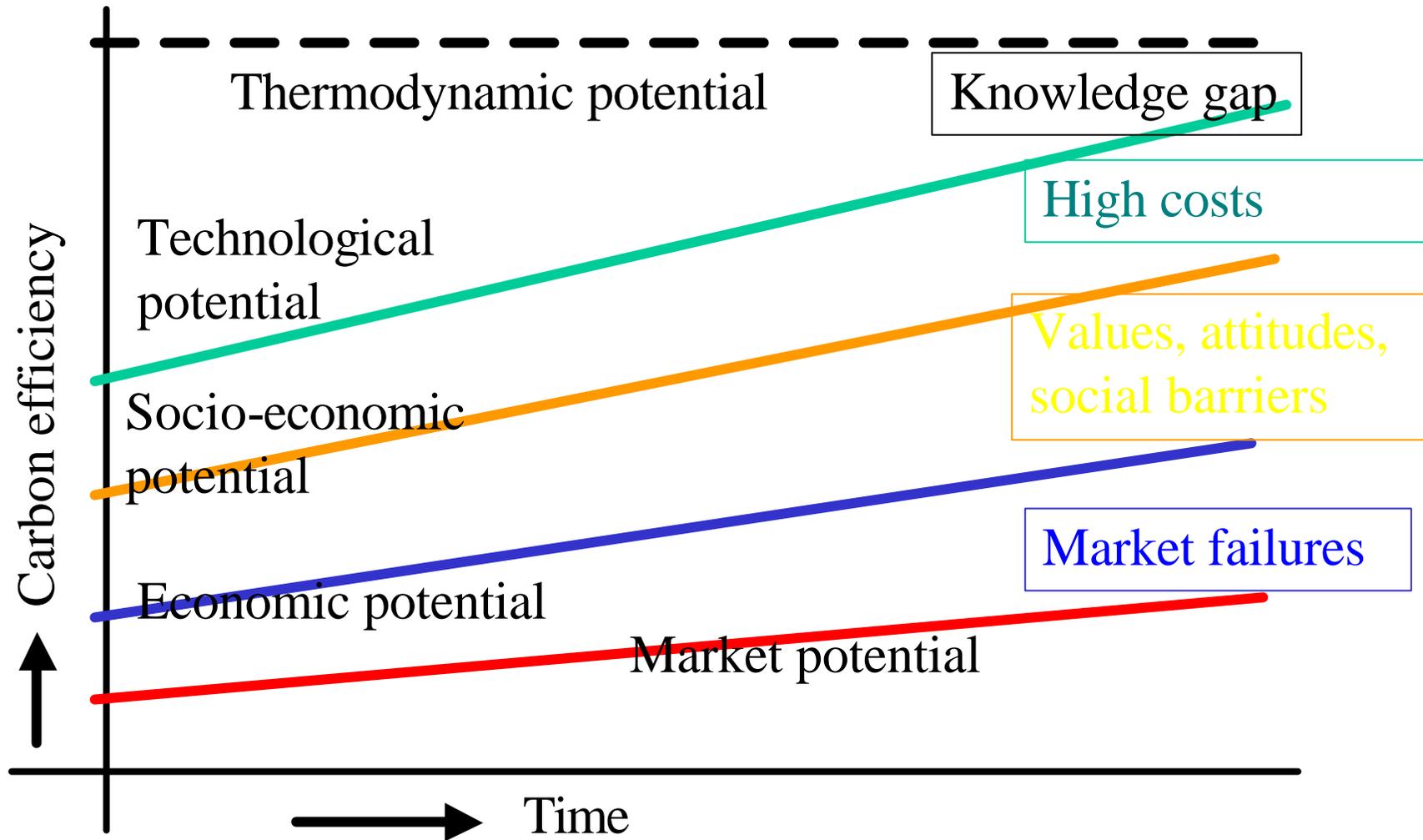
Table 3
Fuel Supply for Developing Countries (Latin America)

	2025		2050	
	Latin America	Developing World	Latin America	Developing World
1-Biomass and other	8.76	21.4	10.29	32.5
2-MeOH from biomass	17.36	32.3	22.30	46.8
3-Exported	5.21	-11.4	5.21	-9.1
4-EtOH sugarcane	0.44	0.9	0.50	1.0
5-H2 from biomass	3.32	8.5	10.61	16.5
6-Biogas (dung)	1.84	8.0	2.38	12.7
7-Biogas (distillers)	0.09	0.2	0.10	0.2
8-Exported H2	0	3.0	0	4.4
9-Subtotal	37.02	85.7	51.39	123.2
10-Total Commercial Fuels	35.40	151.6	41.60	171.6
Ratio 9/10	95.6%	56.5%	123.5%	71.8%

Table 4
Taxonomy of barriers and opportunities

Source of Barrier and/or Opportunity	Examples of Market and/or Institutional Imperfections and (Opportunities)^a	Examples of Social & Cultural Barriers and (Opportunities)
Prices	Missing markets (market creation) Distorted prices (rationalization of prices)	
Financing	Financial market imperfections (sector reform or restructuring of economy) Constraints of official development assistance (ODA) (removing tied aid and/or better targeting of ODA)	Long time and high transaction costs for small projects (pooling of projects)
Trade and environment	Tariffs on imported equipment and restrictive regulations (rationalization of customs tariffs)	
Market structure and functioning		Circumstances requiring rapid payback (fuel subsidies) Weaknesses of suppliers in market research (form associations to support market research)
Institutional frameworks	Transactions costs Inadequate property rights (improve land tenure) Misplaced incentives Distorted incentives	Institutional structure and design (restructuring of firms) National policy styles (shifting balance of authority) Lack of effective regulatory agencies (informal regulation)
Information provision	Public goods nature of information (increase public associations) Adoption externality (build demonstration projects)	
Social, cultural, and behavioural norms and aspirations		Inadequate consideration of human motivations and goals in climate mitigation (modify social behaviour) Individual habits (targeted advertising)

a: Remarks in parenthesis indicate opportunities, e.g., missing markets denote an opportunity for the creation of markets.



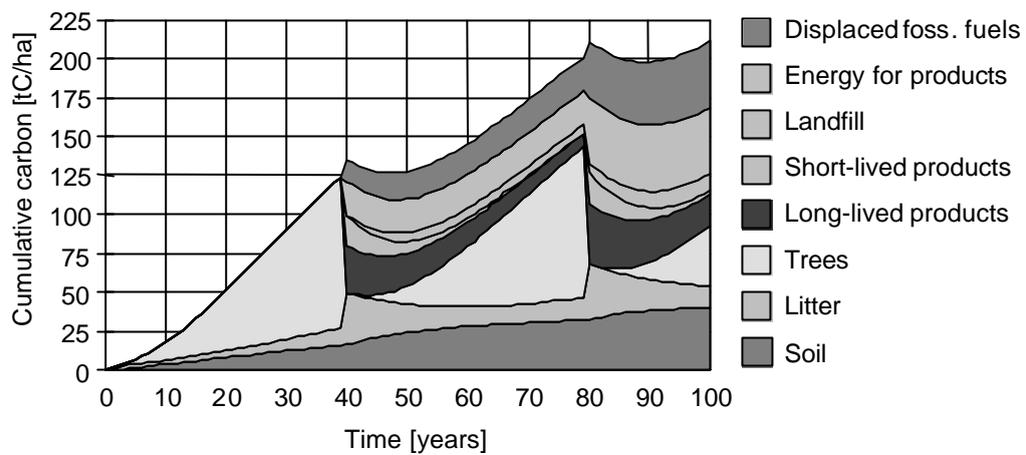


Figure 2. Cumulative carbon-stock changes for a scenario involving afforestation and harvest. These are net changes in that, for example, the diagram shows savings in fossil fuel emissions with respect to an alternate scenario that uses fossil fuels and alternative, more energy-intensive products to provide the same services. (adapted from Marland and Schlamadinger, 1999).