

The Role of Bioenergy in Greenhouse Gas Mitigation

Summary

Biomass can play a dual role in greenhouse gas mitigation related to the objectives of the UNFCCC, i.e. as an energy source to substitute for fossil fuels and as a carbon store. However, compared to the maintenance and enhancement of carbon sinks and reservoirs, it appears that the use of bioenergy has so far received less attention as a means of mitigating climate change. Modern bioenergy options offer significant, cost-effective and perpetual opportunities toward meeting emission reduction targets while providing additional ancillary benefits. Moreover, via the sustainable use of the accumulated carbon, bioenergy has the potential for resolving some of the critical issues surrounding long-term maintenance of biotic carbon stocks. Finally, wood products can act as substitutes for more energy-intensive products, can constitute carbon sinks, and can be used as biofuels at the end of their lifetime.

Introduction

The importance of solar-based renewable energy sources for the reduction of greenhouse gas (GHG) emissions has been widely recognized. Since the signing of the UN Framework Convention on Climate Change (UNFCCC) in Rio de Janeiro in 1992, there has been an intensification of interest. Among these solar-based renewable sources, energy from biomass is considered to be one of the most promising to replace some of the fossil fuels—whose combustion is by far the main source of anthropogenic greenhouse gases, notably CO₂.

The inclusion of biological sources and sinks for the accounting of national GHG emissions (Articles 3.3 and 3.4 of the Kyoto Protocol) has pointed out another potential role of biomass in GHG mitigation—the long-term storage of carbon in forests, on other land, and in wood products. While many details of the accounting systems have yet to be specified, it has become clear that biomass can contribute substantially to GHG mitigation through both reduction of fossil carbon emissions and long-term storage of carbon in biomass (Figure 1).

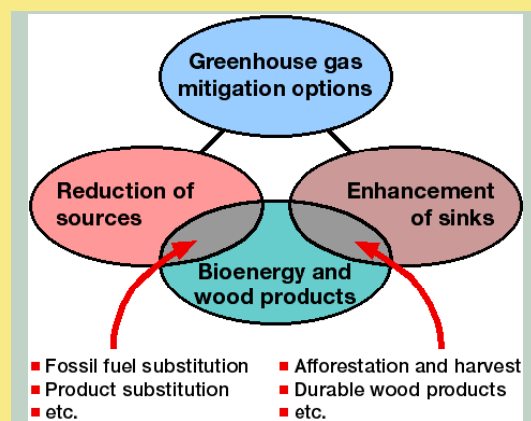


Fig. 1: The role of bioenergy and wood products in greenhouse gas mitigation

All forms of biomass utilization can be considered part of a closed carbon cycle. The mass of biospheric carbon involved in the global carbon cycle provides a scale for the potential of biomass mitigation options; whereas fossil fuel combustion accounts for some 6 Gigatons of carbon (GtC) release to the atmosphere annually, the net amount of carbon taken up from and released to the atmosphere by terrestrial plants is around 60 GtC annually (corresponding to a gross energy content of approximately 2100 EJ p.a., of which bioenergy is a part), and an estimated 600 GtC is stored in the terrestrial living biomass.

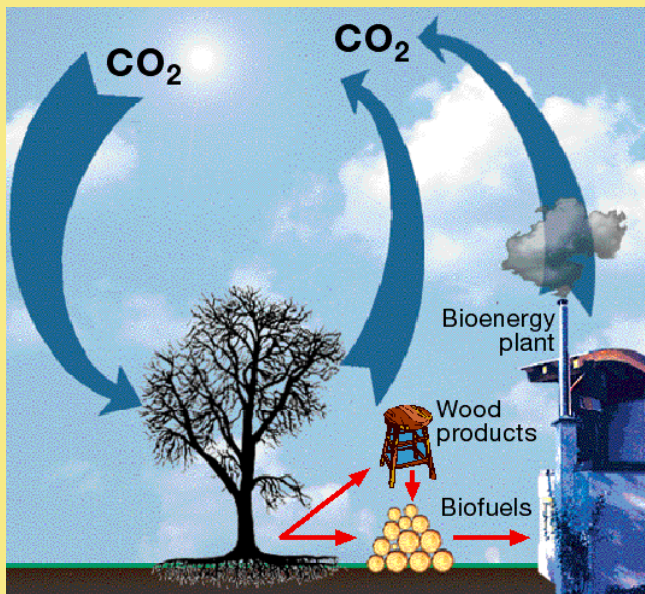


Fig. 2: Biomass utilization and the carbon cycle

The Kyoto Protocol, if and when ratified, would allow sources and sinks of GHGs in land-use change and forestry activities to be counted towards compliance with emission reduction commitments. However, these activities are limited to afforestation, deforestation and reforestation since 1990 (Article 3.3). The Kyoto Protocol also provides options to permit additional human-induced activities related to changes in GHG emissions by sources and removals by sinks in the agricultural soils and the land-use change and forestry categories to be added later in the negotiation process. Article 2, paragraph 1(a) of the Kyoto Protocol, stipulates that its goals include:

- promotion of sustainable forest management practices, afforestation and reforestation, as well as sustainable forms of agriculture in light of climate change considerations;
- research on, and promotion, development and increased use of, new and renewable forms of energy, of CO₂ sequestration technologies and of advanced and innovative environmentally sound technologies;
- limitation and/or reduction of methane emissions through recovery and use in waste management.

The use of bioenergy can play a crucial role in the achievement of all these goals. Today, many technologies and methods to realize bioenergy options are basically available. In many cases they only need some further optimization in order to become competitive by current standard economic criteria. Full cost calculations (i.e. including external costs) depict economic advantages of bioenergy against, say, fossil energy already today.

Current Role of Bioenergy

Today bioenergy is the second largest solar-derived commercial renewable energy source after hydropower. If non-commercial consumption is counted as well, it is probably the largest. Current total biomass use for energy is in the range of 50 EJ per annum (about 12% of world primary energy consumption of 406 EJ p.a., including biomass), mainly in traditional applications for cooking and heating in developing countries, but also in some industrial countries for heat and power production. Modern bioenergy technologies that feature high efficiencies, cleanliness, and convenience, are now becoming technically and (in many cases) commercially viable. Considering the renewable biomass potential still available and the need to reduce consumption of fossil fuels, bioenergy will be among the most important energy sources of the future.

Solid, liquid and gaseous biofuels can replace fossil fuels in almost every application. However, sustainable production and efficient conversion of biofuels have to be assured. Today's main sources for biofuels are residues from forestry and agriculture. In the future energy plantations could provide additional sources, opening up new opportunities for agriculture and forestry in the energy market.

Biofuels play a different role among countries regarding the extent and the way they are used. Whereas they only provide some 3% of total primary energy in the industrialized countries, they account for some 40% in developing countries. Countrywise, the contribution ranges from essentially zero in countries like Japan and The Netherlands to over 95% of total energy use in countries like Nepal and Tanzania. Among the industrialized countries, Sweden, Finland and Austria are examples with relatively high shares of bioenergy (in the order of 15%), in part due to the widespread use of district heating systems (Figure 3).

Opportunities for Bioenergy

Table 1 provides a range of estimates regarding the future role of biomass. The large potential of bioenergy to substitute for fossil fuels can also be illustrated for the case of the European Union. In the White Paper on Renewable Energy (COM(97)599: 26.11.1997) it was proposed that biomass energy in total in the EU could contribute an additional 3.8 EJ annually by 2010, as compared to the current contribution of about 1.9 EJ p.a. Of this additional amount, energy crops (trees, perennial grasses, etc.) are expected to pro-

vide 1.9 EJ, grown on just about 4% of the total EU land area. If these additional 1.9 EJ p.a. from energy crops replaced coal, they would reduce net CO₂ emissions by 50 MtC p.a. (or some 18% of the present EU total anthropogenic CO₂ emissions of 890 MtC p.a.).

Table 1: The role of biomass in future global energy use (in EJ)

Scenario	Year		
	2025	2050	2100
Shell (1996)	85	200–220	–
IPCC (1996)	72	280	320
Greenpeace (1993)	114	181	–
Johansson et al. (1993)	145	206	–
WEC (1993)	59	94–157	132–215
Dessus et al. (1992)	135	–	–
Lashof and Tirpak (1991)	130	215	–

Source: D. O. Hall and J. I. Scrase (1998), *Biomass & Bioenergy* 15(4/5), pp. 357–367

Even without additional land use for biomass there is a variety of possibilities for improved use of existing biomass resources for energy. Examples include the use of residues from forestry and agriculture, residues from the food and wood processing industry, and the biomass fraction of municipal solid waste (paper, landfill gas, disposed wood products). Thus a large fraction of the globally available biomass residues (representing a potential for about 40% of present energy use of 406 EJ p.a.) could be available for bioenergy.

The resource size of recoverable crop, forest and dung residues has been estimated to offer a yet untapped supply potential in the range of 40 EJ p.a., which could meet about 10% of the present global primary energy demand. Moreover, the difference between the annual growth increment and actual harvest from the world's forests is believed to be substantial.

New technologies for the production of biofuels in large quantities have been developed. Once demand exceeds the amount that can be supplied from residues, a change of land use and land-use practices may be required in some cases. The utilization of biofuels does not depend on the development of any fundamentally new technology. Only in some applications the properties of biofuels are such that modification of conventional fossil fuel technologies is required.

Over the last decade a great variety of bioenergy technologies have emerged (e.g. Biomass Integrated Gasification Cycle, fully automatic residential wood-pellet heating systems, etc.). Biomass combustion for heat production is based on technologies that are fully developed and economically competitive in many cases. The availability of efficient technologies for biofuel application in power

production, in contrast, is still rather limited—although modern technologies exist for the combined-heat-and-power production in district heating schemes and industry needs. For the transport sector various technologies are available as well, although these are often not cost-competitive yet under low fossil energy price regimes, and will have to be employed on a broader scale first in order to take more advantage of economies of scale.

Issues Associated with Bioenergy

Bioenergy supplies are more spatially dispersed than fossil fuel supplies. Whereas dispersion tends to increase harvest and transport costs, modern biomass options offer the potential for generating employment and thus additional income in rural areas. Moreover, the local availability of biomass for energy has the potential of reducing energy imports and hence of increasing a country's self-sufficiency.

Due to the limited availability of land, sometimes conflicts may arise between bioenergy and other options for land use, especially food production. Concerns about future food supplies for the world's population, which in many locations is still increasing, have sometimes been used to discount the potential for bioenergy. These concerns are associated with the (disputable) assumption that in some regions, particularly in developing countries, land may not be available in significant quantities for biomass production for energy—unless the agricultural systems are substantially modernized.



Fig. 3: Wood chips storage facility for biomass district heating plant, Bad Mitterndorf/Austria (Courtesy of LEV, Austria)



While providing residues for energy use, wood is also widely used for long-lived products, with a CO₂ mitigation benefit that is at least threefold. First, use as a substitute for more energy-intensive products (e.g. concrete, steel) leads to indirect replacement of fossil fuels. Therefore, the enhanced use of wood products can help in reducing CO₂ emissions to the atmosphere. Second, the stock of carbon in wood products can be increased considerably (a one time effect, though). Third, wood products can be used as biofuels at the end of their life cycle, thus additionally displacing the use of fossil fuel.

Possible Interaction with Sinks

Bioenergy, through the substitution of coal, oil or natural gas, will reduce CO₂ emissions from energy systems. A combination of bioenergy with sink options can result in a maximum benefit for GHG mitigation strategies. Afforestation of agricultural or pasture land can increase the carbon density of the land, while also yielding a perpetual source for biofuels and wood products. The use of the accumulated carbon in forests and wood products for biofuels alleviates the critical issue of maintaining the biotic carbon stocks over a long time. Enhanced use of perennial biomass crops, while providing a sustainable energy source, can also lead to increased levels of soil carbon storage.

Existing forests, if managed for a sustainable flow of forest products, are likely to contain less carbon than if protected to store carbon. However, the sustained displacement of fossil fuels repeatedly offers net carbon benefits over time, provided the productivity of the forest is high and the wood is harvested and used efficiently. Furthermore, the extraction of forest residues can result in a reduced carbon pool of decomposing residues and soil carbon, but this is a one-time effect and the carbon-pool size approaches a new equilibrium. Again, the displacement of fossil fuel through the repeated use of the biomass for energy will by far exceed this loss, especially in the long term.

Long-term and sustainable reductions of CO₂ emissions through land-based activities will to a large extent have to come from the use of wood for bioenergy and products. The provisions of the Kyoto Protocol with respect to sinks can be seen as a valuable incentive to protect and enhance carbon stocks now, while at the same time providing the biomass resources needed for the continued substitution of fossil fuels in the future.

Conclusion

Modern bioenergy options offer significant, cost-effective and perpetual opportunities for greenhouse gas emission reductions. Additional benefits offered are employment creation in rural areas, reduction of a country's dependency on imported energy carriers (and the related improvement of the balance of trade), better waste control, and potentially benign effects with regard to biodiversity, desertification, recreational value, etc.

In summary, bioenergy can significantly contribute to sustainable development both in developed and less developed countries, provided that all issues related to its practical exploitation are carefully considered.

IEA Bioenergy is an international collaborative agreement under the auspices of the International Energy Agency (IEA) aiming at the use of biomass as an environmentally sound and cost-competitive energy source to provide a substantial contribution to meeting future energy demands.

Currently 17 countries and the European Commission are participating in the agreement. Within its Task 25 on "Greenhouse Gas Balances of Bioenergy Systems" IEA Bioenergy is undertaking a comprehensive assessment of all processes involved in the use of biomass as an energy source with the goal of identifying strategies with a maximum greenhouse gas mitigation effect. This Position Paper was prepared by Task participants to illustrate the benefits of the use of biomass in view of the provisions of the Kyoto Protocol adopted at the Third Conference of the Parties to the United Nations Framework Convention on Climate Change in December 1997.

The Executive Committee of IEA Bioenergy endorses this Position Paper for dissemination at the Conference of the Parties to be held in Buenos Aires in November 1998 and thereafter.

Further information on IEA Bioenergy and Task 25 can be found at:

<http://www.forestresearch.cri.nz/ieabioenergy/home.htm>

<http://www.joanneum.ac.at/iea-bioenergy-task25>

November 1998