World Resource Review Vol. 2 No. 1

Proceedings of
Global Warming - A Call for international Coordination
International Conference on the Scientific and Policy Issues Facing All Governments
April 9-12, 1990 Chicago USA

Biomass Energy and Global Warming

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SUMMARY

The proposal to use biomass energy to reduce fossil fuel consumption is almost as controversial as the effects of global warming. Nevertheless, forest and industrial wood residues can undoubtedly be used advantageously for energy from both economical and environmental standpoints. Biomass energy has the potential to meet 10 to 90 percent of futurt global and U.S. energy requirements. Biomass fuel could be its efficient as fossil fuel in applications where solid fuel is most commonly burned but would be less efficient where gaseous and liquid fuels are commonly used. At present, producing wood for energy is usually secondary to producing wood for consumer products. However, tree plantations dedicaled to energy production are becoming popular and will become more common in the future. Wood

for energy will also become a more significant part of forest production as improved harvesting and processing methods are developed for this purpose. Some side-benefits of producing and using more wood are conservation of energy and sequestration of carbon in wood products.

INTRODUCTION

The threat from global warming is certainly not without controversy. Probably the most valid reason for trying to mitigate this phenomenon is that procrastination could result in severe problems in the next century. By that time, the damage will be irreversible. The situation has been likened to waiting until a ship headed for the beach plows into the sand and then turning the ship around. Another reason for taking steps to mitigate global warming is that such steps are beneficial regardless of the end-result of global warming. I believe that global warming is a serious threat. At the same time, I believe that greater use of biomass for energy would be beneficial, whether or not we are threatened with global climate change.

Records show that the average global surface air temperature has become steadily warmer during the 20th century. Since 1959, when detailed recordkeeping was begun, the increase in atmospheric carbon dioxide has been significant. Although the use of biomass energy to combat carbon dioxide buildup is itself controversial, I believe this is a good approach to the problem of global warming.

Anticipated climale changes of the Earth's ecosystem are likely to have a significant impact on our forests. Conversely, the forests can serve as a remedy to the problem if appropriate action is taken now. Forests can reduce the amount of atmospheric carbon dioxide in four ways:

1. Forests are a natural carbon sink and can absorb carbon dioxide from the atmosphere.

2. Utilization of forests for wood products can sequester carbon for long periods.

3. Use of timber in lieu of steel, concrete, aluminum, plastics, and other-intensive materials can reduce energy requirements and carbon dioxide production during the extraction (such as timber harvesting and metal ore mining), processing, and use of these materials.

4. Forests can provide heating fuel.

In this paper, I will discuss carbon sequestration in forests and wood products, the use of wood for fuel, energy conservation through use of wood products, and reduction of atmospheric carbon through new technology. I will also describe different scenarios for managing the carbon cycle and thus mitigating global warming.

CARBON SEQUESTRATION IN FORESTS AND WOOD PRODUCTS

Efforts to increase timberland growth and to reforest marginal timberland will result in a higher rate of carbon sequestration. The more extensive the forests, the more vigorous in growth, the more effective the carbon sequestration. Assuming that carbon accounts for one-half the mass of dry wood, the amount of carbon C that can be sequestered per hectare in the steady-state carbon inventory of a forest stand that produces biomass at a constant rate of Y tonnes per hectare per year, with a rotation length of R years, is given by

$$C = (1/2)*(1/2)*Y*(R-1) \text{ t/ha (Williams 1989)}$$

Plantations with comparatively short rotations of 15 years or less will perform in accord with this equation, but old-growth trees are often overmature and grow at a slower rate than young trees. Standing large, old-growth trees do sequestcr large amounts of carbon, which are accumulated over long lifetimes. However, trees ultimately die and recycle carbon back into the atmosphere.

Research can determine the appropriate harvest cycle so that trees can be harvested at maturity when growth has slowed, and a new forest can be started. Plantations of fast-growing species could be used to produce recyclable fiber products to displace nondisposable plastics made from petroleum. Such changes in forest management could increase species diversity as we1l as forest productivity. At least some of this productivity would provide wood for use as fuel.

Extending the service life of wood also results in longer sequestration of carbon. To be as durable as materials that are not susceptible to decay and insect attack, wood must be treated or otherwise protected in exposed locations. Increased emphasis on environmental safety has resulted in decreased use of broad-spectrum pesticides for treating wood products. Research is needed on alternative ways to protect wood from decay and insect attack. Approaches include processing schedules for raw wood that provide less opportunity for biological deterioration; biocontrol through antagonists, antibiotics, or ecosystem manipulation; and treatments that modify the chemical structure of wood cell walls and thus prevent microbial degradation.

USE OF WOOD FOR FUEL

The use of wood fuel for mitigating global warming is controversial. Some people regard wood combustion as part of the problem rather than part of the solution. The most efficient way to obtain energy from wood by direct combustion is to recover heat, steam, or electricity. Combustion of wood does return carbon to the atmosphere. However, if the wood burned is continually replaced through reforestation, the carbon is continually recycled (Fig. 1); thus, no additional carbon enters the atmosphere and carbon sinks. To the extent that wood is used to replace fossil fuels, the addition of carbon into the atmosphere from fossil fuel combustion is reduced. It is therefore advantageous to use wood residues for fuel, including logging and manufacturing residues, insect-infested and diseased trees, and residues from land clearing.

Although the substitution of wood for fossil fuels directly reduces the amount of atmospheric carbon dioxide, much additional forest growth and harvesting would be needed to replace significant amounts of fossil fuels. The enormity of this task could be reduced by extending existing supplies of wood through recycling and more efficient utilization of the raw material.

Sources of Atmospheric Carbon

According to Rogers and Fiering (1989), human contributions to excess atmospheric carbon are minimal; conversely, contributions to atmospheric carbon dioxide through biomass in nature are significant. The authors base their reasoning on the net primary productivity of terrestrial ecosystems of 60 x 10^9 t of carbon per year. This anthropogenic excess of carbon is a result of fossil fuel combustion (58 percent), biomass fuel combustion (12 percent), crop residue burning (1 percent), grassland burning (20 percent). shifting agriculture (4.2 percent), cement production (1.4 percent), and solid-waste production (1.1 percent). Total excess carbon is estimated at 6.5 + or - 1.5 x 10^9 t of carbon per year. This annual flux is viewed against an estimated stock of 560 + or - 100 x 10^9 t of carbon in living biomass systems. Viewed from this perspective, human contributions to excess atmospheric carbon from the burning of biomass are in the same category as that from the burning of fossil fuels. Moreover, the human contributions to excess atmospheric carbon from the burning of biomass are in the same category as that from the burning of fossil fuels. More over, the human contribution to atmospheric carbon is small in comparison to nature's contribution.

Houghton (1989) views the anthropogenic contribution to atmospheric carbon from a different perspective. According to this author, the atmospheric carbon dioxide balance hinges on the annual anthropogenic emissions of this gas; about 70 percent of emissions come from fossil fuels and the remainder from forest abandonment resulting from shifting agriculture. The burning of biomass from forests that are managed on a sustained-yield basis is part of the solution to excess carbon dioxide; the carbon dioxide released from burning and otherwise consuming wood is constantly recycled over a short period (see Fig. 1). I believe this scenario is more realistic than that proposed by Rogers and Fiering.

Regardless of the source, carbon has been increasing in the atmosphere at a rate of about 3 x 10^9 t annually

(Houghton, 1989). If the carbon dioxide flux into the atmosphere could be reduced by this amount annually, the carbon level would stabilize around the present level. The release of carbon into the atmosphere can be controlled in three ways: (1) by reducing the level of fossil fuel combustion, which releases 5.6 x 10^9 t of carbon into the atmosphere annually, (2) by halting deforestation, which releases 2.5 x 10^9 t of carbon, and (3) by implementing reforestation, which could sequester 2.5 x 10^9 t of carbon (Houghton, 1989).

Efficient use of Wood for Fuel

Modern combustion equipment can burn wood fuel efficiently in almost any form with a high rate of heat recovery. Industrial burning of wood is usually much more efficient and nonpolluting than the burning of wood in stoves or furnaces for residential heating.

One problem with wood combustion is the formation of particulates and entrainment of the particulates in the combustion gases. Research is needed on the formation of ash and particulates during combustion. Primary and secondary wood-manufacturing plants produce wood residue byproducts that contain materials other than wood, such as resins, paints, and plastics. Research is needed on the combustion conditions required for safely burning byproduct residues for energy.

Liquid Fuels From Wood

Liquid fuels can be produced from wood by such processes as gasification, pyrolysis, and fermentation following hydrolysis. The fuels most often considered are ethanol and methanol because they can be used as motor fuels.

Ethanol can be produced from the carbohydrate in wood by acid or enzyme hydrolysis to form monosaccharides that ferment to ethanol. Through acid hydrolysis, about 20 percent of the energy potential of wood can be recovered in ethanol. While applicable to a wide variety of forest residues, acid hydrolysis destroys all fiber properties and creates significant waste products that must be disposed of. The kinetics of acid hydrolysis are well understood, and sufficient data exist to design pilot processing equipment. Pyrolysis and methanol are more efficient than ethanol for recovering energy from wood. However, neither acid hydrolysis for ethanol production nor wood pyrolysis for methanol production are currently economical. Further research is needed to make liquid fuels from wood more competitive with petroleum-based gasoline and diesel fuels.

Enzyme hydrolysis of wood can result in high ethanol yields in small-scale processes. Economic studies of cellulose hydrolysis have indicated that this method is not competitive in the wood processing industry. However, enzyme hydrolysis and fermentation of hemicellulose, especially hemicellulose from recycled fibers, may hold better prospects. In such a process, ethanol would be produced from the readily hydrolyzed hemicellulosic fraction of recycled fiber, and the cellulosic and lignin fractions would be recovered for their fiber and polymeric properties. Additional research is needed on enzyme hydrolysis to develop enzyme production rnethods and to demonstrate the hydrolysis process on a pilot scale.

The next step for methanol production is the demonstration of a large-scale wood gasifier for producing syngas that can be converted to methanol.

ENERGY CONSERVATION THROUGH USE OF WOOD PRODUCTS

Wood for Construction

Forestry and forest products is the fourth most important sector of the U.S. economy. The construction industry, particularly housing, makes up the largest segment of the forest products market. Developing wood construction materials can provide an economic boost to the construction industry as well as an opportunity to conserve energy through using wood, which is renewable and uses less energy than other materials. Moreover, increases substitution of wood for concrete prevents the release of carbon dioxide during concrete manufacture.

Residential frame construction provides an excellent opportunity for conserving energy through the use of wood. Research in the construction of tight, but well-ventilated, 11 OuseS, application of passive solar healing principles, healing with wood fuel, shade tree plantings for reducing cooling loads, and urban or community forest plantings could pay off handsomely in establishing technology for reducing the use of fossil fuel.

Recycling of Paper and Paperboard

Over half the wood cut in the United Stales is eventually used for paper and paperboard. Doubling the current U.S. recycling rate from 25 percent to 50 percent, the rate achieved in Europe and Japan, is technically possible, but not economically practicable. The United States has an abundance of low-cost trees. However, improved wastepaper recycling technology can make recycling more economical. If the U.S. recycling rate were doubled by improved recycling technology, the amount of wood cut from U.S. forests would be reduced by about 17 percent; landfill, 40 percent (by weight) of which consists of paper and paperboard, would be reduced by about 13 percent by weight overall. Thus, global warming would be reduced by increasing U.S. forest stands and by reducing the amount of atmospheric methane produced by landfills,

To increase the quality and thus the quantity of papermaking pulps derived from recycling wastepaper, recycling technology needs to overcome or greatly reduce barriers associated with three technical processes: (1) wet and dry deinking, (2) removal of synthetic adhesive contaminants, and (3) restoration or enhancement of fiber bonding.

Problems with wet deinking occur in the deinking of flexographic inks, which are increasingly used in newspaper printing, and the deinking of noncontact inks, which are increasingly printed on office papers. Research is needed to establish the effect of the interaction of controllable ink compounds and unit operations on ink removal. Dry deinking processes are needed to remove coating pigments in coated papers; the pigments constitute about one-third the weight of the paper. Although, coating pigments can be removed by typical wet deinking processes, disposing of the resultant sludge is costly.

Removal of synthetic adhesive contaminants requires a better understanding of the fundamental aspects of separation processes. Both wet deinking and contaminant removal processes depend at least in part on water-release (water-solid-air interface) properties. Techniques and instruments are needed for measuring carbon dioxide release under controlled conditions. Fundamental knowledge about separation processes in conjunction with new technology can lead to the development of highly selective chemical agents for improved separations and improved separation processes.

In the area of fiber bonding, economically viable and environmentally benign chemical processes are needed for restoring or enhancing bonding strength and for bleaching once-dried pulp fibers,

Recycling of Fiber

The largest use of fiber for paper products is in the manufacture of corrugated fiberboard, in 1988, 16.3 x 10^6 t of kraft linerboard and 5.2 x 10^6 t of semichemical linerboard were produced in the United States, resulting in the production of 21.5 x 10^6 t of corrugated board (excluding board from recycled fiber). The forest Products Laboratory has been developing a process concept for producing a new structual fiberboard called FPL Spaceboard. Spaceboard can be made from recycled fiber, and it could partially or fully replace corrugated fiberboard. Even though the United States consumes 11.8 x 10^6 t of newsprint per year, all the newsprint that is availilble as recycled fiber would not be sufficient to support the substitution of FPL Spaceboard for corrugated fiberboard. However, to whatever extent waste newsprint is recycled and used to make Spaceboard, energy will be saved.

REDUCTION OF ATMOSPHERIC CARBON THlROUGH NEW TECHNOLOGY

High-Yield Mechanical Pulping

Over 53.5 x $l0^6$ t of virgin pulp were produced in the United States in 1987. Over 46 x 10^6 t consisted of low-yield kraft pulps, which yield pulps in the range of 42 to 55 percent. The wood substance removed during kraft pulping is burned in the chemical recovery process. At an average pulp yield of 50 percent, the equivalent of over 41.7 x 10^6 t of wood is burned. Because sulfur-containing pulping agents are used, both sulfur dioxide and carbon dioxide are produced in large quanlities, By contrast, high-yield mechanical pulps are presently produced at a rate of about 6 x 10^6 t per year. Yields range from 80 to 95 percent pulp, and waste liquors are generally not burned. However, the usefulness of high-yield mechanical pulps is generally limited to a few select softwood species and certain printing grades.

Research is needed to (1) improve the strength properties of high-yield pulps so that they can be substituted for low-yield kraft pulps, (2) overcome the problem of color reversion, and (3) improve the properties of high-yield pulps produced from hardwoods.

Press Drying

The Forest Products Laboratory has conceived and developed a unique processing means for producing superior paperboard from low-value furnishes, at high yield and with reduced use of energy. in an analysis of process economics, Ince (1983) showed that the total amount of energy required for press drying high-yield linerboard would be less than 61 percent of that required for conventional processing. Estimated fuel costs of the press-dry process would be 38 percent the costs of the conventional process--although electrical costs would be 11 percent greater. Total energy required for linerboard production would be reduced from 24.6 to 14.9 x 10^{12} per tonne. However, press drying requires the development of new drying machinery. Despite the significant advantages cited for the press-dry process, it has not been put into commercial practice.

The benefits of press drying have been demonstrated in the laboratory. The next logical step is demonstration of the press-dry process in a small-scale production machine.

SCENARIOS FOR MANAGING THE CARBON CYCLE

The opportunities for reducing carbon dioxide emissions and atmospheric carbon accumulations can be broadened through further research. The extent to which managing the carbon cycle can reduce global warming and the accompanying side-effects, such as rising scalevel, has been subject to different interpretations. As discussed previously in this report, Rogers and Fiering (1989) conclude that the human contribution to the atmospheric carbon burden is small in comparison to the natural accumulation of carbon. This implies that humans can do little to alter long-term trends. Houghton (1989), on the other hand, maintains that stabilizing greenhouse gases in the atmosphere is not out of the question.

According to Houghton (1989), the difference between total carbon dioxide emissions and carbon accumulation in the atmosphere is absorbed by either the oceans or, perhaps, by some terrestrial ecosystems. However, regardless of the total amount of carbon dioxide emissions, the buildup in the atmosphere is about 3×10^{12} t per year. Thus, if emissions were reduced by this amount annually, the concentration of carbon dioxide in the atmosphere would be temporarily stabilized; this would provide time to develop means for permanent stabilization of carbon accumulation. Emissions could be reduced annually by (1) increasing energy efficiency, (2) hailing deforestation, and (3) establishing reforestation. Reforestation could reduce carbon dioxide accumulation as long as trees were gaining mass, or it could reduce accumulation indefinitely if fossil fuels were replaced with wood fuel. Biomass could conceivably be used to completely mitigate an atmospheric increase in carbon dioxide worldwide.

Perhaps a more realistic scenario would be the partial mitigation of carbon dioxide accumulation through biomass production and use. The pollution equation of Holden and Ehrlich, as cited by Schneider (1989), postulates

$$\text{Total } CO_2 \text{ emission} = \frac{CO_2 \text{ emission}}{\text{Technology}} \times \frac{\text{Technology}}{\text{Capita}} \times \text{Total Population size}$$

Thus, carbon dioxide emission may be regulated through the control of technology. Fox and Moir (1989) conclude the severity of global warming can be mitigated to some extent by improving the efficiency of energy-using processes, reducing per capita demand for energy and commodities, and increasing the supply of assimilative ecosystems such as forests, estuaries, coral reefs, and riparian areas. The authors also conclude that failure to act contributes to global warming as well as to other unwanted environmental consequences. I agree with these conclusions. I also believe that, depending on how intensively we conserve energy and utilize assimilative ecosystems, we can reduce atmospheric carbon buildup from 10 to 90 percent.

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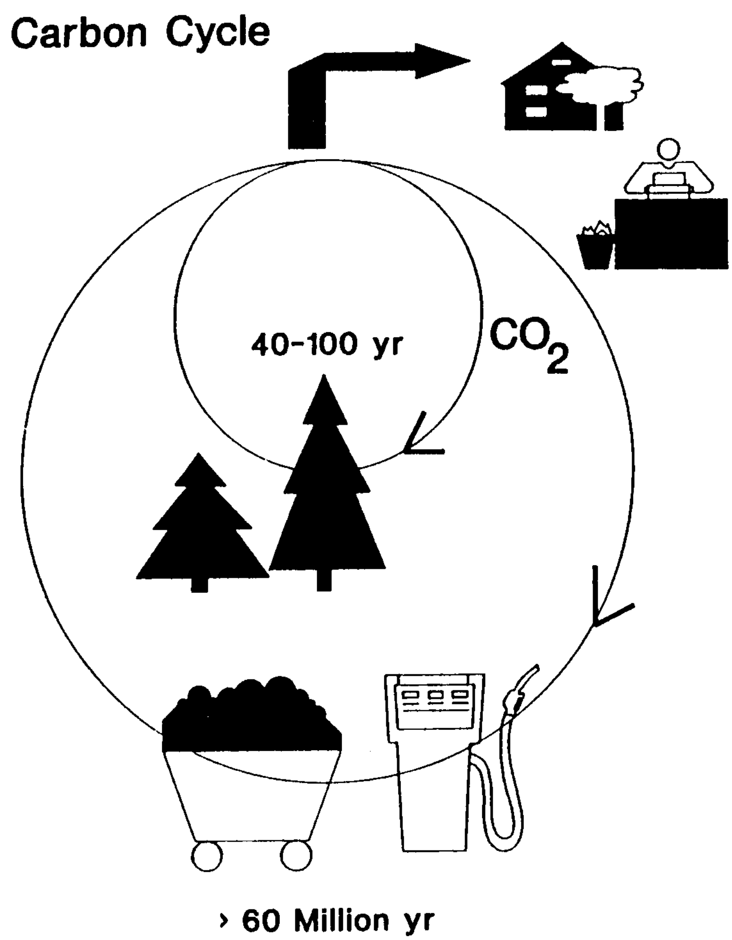

Figure 1--Carbon cycle in sequestration and recycling of carbon in trees and wood products compared to use of fossil fuels.