Greater Potential for Renewable Biomass Energy

In “Renewable Energy: Potential and Current Issues” (BioScience 52: 1111–1119), Pimentel and colleagues conclude that a mix of renewable energy sources should be developed simultaneously with efforts to conserve energy and other natural resources. The authors suggest that half of the energy needs of the United States can be supplied from renewable energy sources “without interfering with required food and forest production.” Although we agree with the conclusions of the article, some of the information presented about biomass energy systems is inaccurate and detracts from the authors’ conclusions.

Life-cycle analysis studies indicate that energy input–output ratios for woody biomass to electricity systems are greater than the estimates presented by Pimentel and colleagues. The net energy ratio (ratio of fossil fuel energy consumed to electrical energy delivered to the grid) is 1:10.9 for woody biomass crops that are cofired with coal (Heller et al. 2003), 1:28.4 for direct-fired wood residues, and 1:15.6 for woody biomass crops that are gasified (Mann and Spatham 2001).

The land-use estimates Pimentel and colleagues use for biomass supplies are based on the assumption that all biomass comes from sustainably managed forests that yield 3 oven-dry metric tons (otd) per hectare (ha) per year. However, little biomass currently used in the United States comes from forests that are harvested for bioenergy. Out of the 2.9 quadrillion Btus (quads) of biomass energy in 2000, the industrial and utility sectors accounted for 83.8% of the biomass, 97% of which is black liquor and wood residues (EIA 2002). The residential sector uses 13.1%, which is reported as wood. The transportation sector accounts for 3.1% as ethanol blended into motor gasoline. If we assume that the majority of the residential and a small amount of the industrial biomass energy comes directly from forests, a high estimate of the forestland that is harvested for bioenergy is about 9.0 million ha. Pimentel and colleagues’ estimate of 75 million ha is thus higher than is supported by data from the Energy Information Administration (EIA 2002).

Estimates for future biomass energy indicate that it will come from multiple sources. In 2025, woody biomass and dedicated energy crops are projected to supply 4.8 quads, with agricultural residues supplying an additional 2.3 quads (EIA 2003). Of the 4.8 quads, 26% is from urban wood and mill residues, 31% from energy crops, and 43% from forest residues. Wood and mill residues are byproducts of other operations. Current energy crop yields are in the range of 6.7 to 11.3 odt per ha per year. However, breeding efforts have produced yields greater than 16 odt per ha per year (Lindegard et al. 2001, Riemenschneider et al. 2001), which should be realized commercially by 2025. Forest resources include logging residues, salvageable dead wood, and thinned pole-size trees that are collected during other forestry operations and do not require dedicated land. If we use Pimentel and colleagues’ yields of 3 odt per ha per year for forest resources and 16 odt per ha per year for energy crops, the land requirement for the 4.8 quads of biomass in 2025 is only 42.4 million ha of forestland and 5.9 million ha of open land for energy crops, half of the area projected by Pimentel and colleagues. This is 21% of the timberland in the United States (Smith et al. 2001) and 15% of the surplus or idle agricultural land in the United States available for short-rotation woody crops (Graham 1994).

Pimentel and colleagues’ health-related statistics are associated with burning biomass in inefficient systems such as open fires, fireplaces, and woodstoves. Large-scale, efficient biomass conversion systems will continue to be the mainstay of biomass energy in the United States. Current and new (i.e., gasification) biomass conversion systems have particulate emissions levels that are one to two orders of magnitude lower than coal systems.

These more accurate assessments of land requirements, net energy ratios, and environmental benefits strengthen Pimentel and colleagues’ conclusions and indicate that biomass energy will play a significant role in the nation’s future energy supplies, without interfering with required food and forest production.

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Response from Pimentel

Like Volk and colleagues, my coauthors and I are strong supporters of biomass energy technology. Only some of the many claims made about this technology are sound, however. We must be careful to ensure that the public and decisionmakers are not misled.

US biomass captures less than 0.2% of the solar energy reaching it (Pimentel and Pimentel 1996). This is in contrast to photovoltaics, which capture 10% to 20% of incident solar energy. To put this into perspective, the total amount of solar energy captured by all biomass in the United States, including crops, forests, and other vegetation, is about 54 quads (ERAB 1981). As the United States consumes 96 quads of fossil energy (USBC 2002), the nation is using 80% more fossil energy than the total solar energy captured by all US plant biomass.

Volk and colleagues suggest that crop residues be used as a source of biomass energy. We believe this would be a major agricultural, environmental, and energy disaster. Current soil erosion rates resulting from US crop production average more than 10 times the soil replacement rates (USDA 1994). Removing crop residues is estimated to increase soil erosion rates by a factor of at least 10 (Troeh et al. 1999). In addition, an estimated $20 billion in fertilizer nutrients are lost annually in the United States as a result of soil erosion. Removing crop residues intensifies this nutrient loss and requires additional expenditures of fossil energy to replace the lost fertilizer nutrients (Pimentel et al. 1995).

We agree that it is possible to produce more than 3 metric tons of wood biomass per hectare per year by culturing biomass in a way similar to that we use to produce agricultural crops. To do this would require fossil energy–based fertilizers (nitrogen, phosphorus, potassium, and calcium), herbicides, insecticides, and irrigation water. This production technology would require large fossil energy inputs (Pimentel and Pimentel 1996). If the objective is to produce renewable energy, therefore, it is more logical to investigate a sustainable forest system that would not require large external fossil energy inputs.

Our investigation of electricity production used sound biomass data, including the electricity generation data that we obtained from a functioning electrical power plant in Burlington, Vermont (Pimentel et al. 2002). This plant provided a return of 7 kilowatt-hours (kWh) of electricity per 1 kWh of fossil energy invested in harvesting wood biomass, at a cost of 6 cents per kWh, which is below US average electricity costs (USBC 2002).

Volk and colleagues claim that the particulate pollutants produced by biomass could be reduced by biomass gasification. Unfortunately, gasification releases several chemical pollutants that are more toxic than those produced by conventional burning (EPA 1995). It is therefore questionable whether gasification can provide an environmental benefit.

We continue to believe that biomass energy will play a significant role in the nation’s future energy supplies, and we stand by our data and assessment.

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