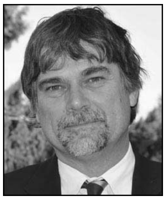
DISCUSSION

More Energy from Wood: What Are the Prospects?

Abigail R. Kimbell, Thomas Maness, and Hutch Brown



The United States has a long history of using wood for energy. As late as 1880, the nation generated more energy from wood than from coal. In the late 19th and early 20th centuries, fossil fuels (coal, oil, and natural gas) largely supplanted wood, helping to stabilize America's forest estate, which had declined, in part, because of the nation's voracious appetite for fuelwood. Biomass now accounts for less than 4% of US energy consumption, with fossil fuels making up some 85% (Table 1). About one-quarter of the fossil fuels used are imported, including about 70% of the oil.

The national reliance on fossil fuels is unsustainable, especially for oil. Global supplies of fossil fuels will one day run out; under one scenario, oil production will peak as early as 2025, and then rapidly decline (Wood et al. 2004). Moreover, the United States now depends on oil suppliers in politically volatile regions, where the costs of securing vital energy supplies are high.

Since the 1970s, the United States has been promoting alternatives to fossil fuels, but little progress has been made (Table 1). After peaking at almost 94% of US energy consumption in 1970, fossil fuel use declined to about 85% in 1990 and then remained at roughly the same level for the next 17 years. Although nuclear power use rose in the 1980s, renewable energy use has hovered at 6–7% of total energy consumption. In 2007, the President set a national goal of producing 35 billion gal of renewable transportation fuels by 2017, replacing 15% of projected fuel consumption. Congress subsequently passed the Energy Independence and Security Act, providing financial incentives to produce 36 billion gal of renewable biofuels by 2022.

Among renewable energy sources, wood seems to hold promise. Much of today's renewable energy (53%) comes from farm and forest biomass, and the United States has enormous biomass reserves, including the world's fourth largest forest estate. Net growing stock on timberland nationwide increased by 39% from 1953 to 2002, mostly in the smaller-diameter classes (Smith et al. 2004). Overstocked forest stands tend to be susceptible to drought, wildfires, insects, and disease, particularly in an era of climate change. Restoring such forests to health calls for removing excess vegetation, some of which has little commercial value. Other low-value woody materials include invasive species such as saltcedar and junipers, residues from forestry operations, and wood waste going into landfills.

Could the nation use such materials to generate more energy? Do cellulosic biofuels and other forms of wood energy offer hope for restoring forest health, mitigating climate change, and reducing the nation's dependence on fossil fuels?

The Promise of Ethanol

Since 2000, ethanol production has soared in the United States, but doubts about it are growing, because most of it comes from corn starch. Hill et al. (2006), in a life cycle analysis, found that the amount of energy generated from corn ethanol is not much more (25%) than the amount of fossil fuel energy that goes into making it. Nevertheless, federal subsidies, along with the use of ethanol in gasoline, invigorated the corn ethanol industry, almost doubling production from 2004 to 2007 (Renewable Fuels Association 2008). Over the same 3-year period, the percentage of the US corn crop going toward ethanol production more than doubled (Yacobucci and Schnepf 2007). Corn prices rose accordingly, from $2.15/bushel in the 10-year period from 1997 to 2006 to $4.00/bushel in November 2007, despite that year's record corn crop. The number of acres planted in corn rose by 20% in 2007, partly at the expense of soybean production, which fell by 19%, doubling soybean prices (USDA 2008).

All this helped raise food prices, given the presence of corn and soybeans in so many processed foods and corn's prevalence in poultry and livestock feeds.[1] However, the diversion of corn into ethanol barely dented oil imports; corn ethanol accounted for only about 4.6% of US gasoline consumption in 2007 (Renewable Fuels Association 2008). Moreover, increases in corn production have damaged the environment (Runge 2002, Hill et al. 2006). Corn causes more soil erosion and uses more herbicides, pesticides, and nitrogen fertilizer than any other crop in the United States. Runoff from cornfields pollutes rivers, degrading habitats and aquifers and contributing to hypoxia in the Gulf of Mexico at the mouth of the Mississippi River. Given the limits on expanded corn production, future US corn ethanol yields are not likely to exceed 16 billion gal, or about 11% of today's gasoline consumption (Yacobucci and Schnepf 2007). The Energy Independence and Security Act of 2007 set a renewable fuels standard of up to 15 billion gal of corn-based biofuels per year, with further increases in biofuels production coming from cellulosic—or, to be more precise, lignocellulosic (Winandy et al. 2008)—feedstocks ranging from corn stover, to straw, to switchgrass, to woody biomass. Hill et al. (2006) estimated that cellulosic ethanol has two to three times more "net energy value" (energy output minus energy inputs from fossil fuels) than corn ethanol. Not surprisingly, cellulosic ethanol also accounts for fewer greenhouse gas emissions per unit of energy output. What scientists call "advanced cellulosic biofuels" (including biodiesel and other fuels, in addition to ethanol) have several additional advantages over corn eth-

Table 1. Percentage of US energy consumption, by source and year.[a]

			Renewable energy					
Year	Fossil fuels	Nuclear power	Hydrological	Geothermal	Solar	Wind	Biomass	Total
1960	93.4	—	3.6	—	—	—	2.9	6.5
1970	93.6	0.4	3.9	—	—	—	2.1	6.0
1980	89.4	3.5	3.7	0.1	—	—	3.2	7.0
1990	85.4	7.2	3.6	0.4	0.1	—	3.2	7.3
2000	85.6	7.9	2.8	0.3	0.1	0.1	3.0	6.3
2007	84.8	8.3	2.4	0.3	0.1	0.3	3.6	6.7

[a] Totals do not all add to 100 because of rounding and/or net electricity imports.
Source: Energy Information Administration 2007.

anol, including fewer inputs, larger feedstocks, higher yields per acre, less competition with food crops, and fewer environmental impacts. Recognizing the potential, the federal government has provided tax breaks and other incentives to stimulate advanced biofuels production. The Energy Independence and Security Act called for using 16 billion gal/year of advanced biofuels in US vehicles by 2022.

Biofuels from Wood: How Viable?

US Forest Service scientists and others are working to make advanced biofuels production commercially viable. The US Department of Energy (2007) has identified two major hurdles: for all advanced biofuels, lowering feedstock costs from $60 to 30/tn; and, specifically for cellulosic ethanol, raising feedstock yields from 60 to 90 gal/dry tn. The hurdles seem to be lowest for short-rotation woody crops and for plantations, especially in the Southeast (Biomass Research and Development Board 2008a). However, the hurdles are high for the use of forest residues and small-diameter materials from natural forests, where biomass tends to be highly dispersed. For such locations, it would be difficult to bring collection and delivery costs below $30/dry tn. For example, the Biomass Research and Development Board (2008b) reported that enough woody materials from forests are available to produce up to 4 billion gal of ethanol per year, but the cost would be $40–46/tn at the roadside. Transportation and storage costs would add significantly to that cost.

Other uses often pay more for forest residues. In spring 2008, export prices for wood chips were about $151/oven-dry metric tn (Wood Resources International 2008). The demand for pellets made from wood residues has increased dramatically over the past 10 years, and prices commonly exceed $200/dry tn (Peksa-Blanchard et al. 2007). Moreover, logging residues and small-diameter materials are heavy in bark content, making them poor as an ethanol feedstock but ideal for wood pellet production. Technological advances could help make woody biomass more commercially viable as an energy source (Biomass Research and Development Board 2008a), but such changes would not necessarily favor biofuels production over other forms of wood energy.

Agricultural wastes and grassy energy crops compare favorably with woody biomass as bioenergy feedstocks. Switchgrass can be grown on marginal or eroded cropland unsuitable for food production; up to 52.6 million ac of such lands are available nationwide (McLaughlin et al. 2002). Kaylen et al. (2000), in a study comparing the feedstock potential of energy crops, crop residues, and woody biomass in Missouri, found that crop residues were the most cost-effective. They concluded that the optimal location for a bioenergy plant in Missouri was an agricultural part of the state, not a heavily wooded one. In 2008, five of the six biorefineries funded by the US Department of Energy to meet federal goals for cellulosic ethanol production were designed to process agricultural and landfill wastes. Only one, built by Range Fuels, Inc., in central Georgia, was designed to process forest biomass.

Biomass Availability

How much forest biomass is actually available for biofuels production? Perlack et al. (2005), in an authoritative study for the US Department of Energy known as the "Billion Ton Report," identified up to 368 million dry tn of wood wastes and residues available each year on a sustainable basis. However, most of these materials are already being used for other purposes. Of the available 159 million dry tn of industrial wood wastes, 95% are being used for wood and paper products (38%) and energy (57%). The extra steps needed to transport the bulky materials from the mill, where they are currently being used, to a biorefinery and then through the supply chain to an automobile might sacrifice both economic and greenhouse gas efficiency. The same goes for another 35 million dry tn of fuelwood biomass said to be available—they are already being used to heat buildings and generate power.

Another 101 million tn, according to the Billion Ton Report, could come from fuels treatments on public land and from forestry operations on private land. However, small-diameter materials and forest residues contain high volumes of bark, not good for ethanol production. Moreover, recovery and transportation costs are likely to be high, and other uses (such as for wood pellets) might pay more. Production is likely to be cost-effective only on flat land close to biorefineries (within 50 mi). In addition, producing advanced biofuels takes up to 6 gal of water per gallon of yield (Aden 2007). In the arid Interior West, where fuels treatments tend to be needed most, water shortages compounded by climate change will likely limit opportunities.

Given the constraints, the Billion Ton Report's prediction seems overly optimistic. More recent assessments of the amount of forest biomass available each year for advanced biofuels production are on the order of 50 million tn (Biomass Research and Development Board 2008b, Skog 2008)—less than 14% what the Billion Ton Report predicted. In short, both corn and advanced biofuels can help reduce the US dependence on oil imports, but woody biomass from forests is not likely to play a major role in the production of cellulosic ethanol.

Alternative Approaches

The focus of the US Forest Service is on the health, resilience, and productivity of the nation's forests and grasslands. The agency

can restore many forests to health partly by removing small trees and other biomass. Even with subsidies and improvements in technology, however, advanced biofuels production alone is unlikely to increase the value of forest biomass enough to permit large-scale forest health treatments. A broader approach is needed.

US Forest Service researchers and their partners are pursuing several technology platforms to manufacture value-added products from biomass (Winandy et al. 2008): direct conversion, thermochemical, and biochemical. *Direct conversion* ranges from manufacturing wood pellets for heating buildings and generating electricity to using mill residues to cogenerate heat and electricity in relatively small local combustors. *Thermochemical conversion* yields pyrolysis oils, which can be used for either cogeneration or biodiesel production, and synthetic gas, which can be further processed into a natural gas substitute or converted into liquid transportation fuels. *Biochemical refineries*, in producing ethanol and other advanced liquid fuels, can generate byproducts that are further refined into energy sources for manufacturing forest products or feedstocks for producing chemicals, paper, and advanced wood composites—the technologies are still emerging. The optimal platform chosen will depend on the available supply of woody biomass, the cost of removal and delivery, the changing state of the technology, and market conditions for wood and energy products.

Biorefineries and some thermochemical processes can be readily integrated into wood-producing facilities, particularly pulp mills. The resulting "integrated forest product biorefineries" can take advantage of the existing supply chain, using wood residues while generating energy that replaces fossil fuels (Belin et al. 2008a, 2008b). Equipped with such biorefining technologies, pulp mills in North America might one day produce large quantities of biofuels (chiefly high-grade biodiesel). By generating a wider range of products, including biofuels and high-value chemicals in addition to conventional forest products, North American mills might boost their global competitiveness and reduce their dependence on fossil fuels.

However, Spelter and Zerbe (2008) and Balint (2008) found that wood pellet and torrefied wood pellet production, sometimes overlooked in the rush to develop cellulosic ethanol, might be a better wood-to-energy platform in the foreseeable future. As Roberts and Nilsson (2008) noted, direct conversion of wood to energy (heat and electricity) is more efficient than biofuels production: corresponding energy losses in the conversion process are 10–20% and 30–65%, respectively. The technology already exists for commercially viable wood pellet production; supplies are available, including forest biomass; and demand is high and growing, especially in Europe, where power plants and other facilities are increasingly using wood pellets mixed with coal to meet targets for reducing greenhouse gas emissions under the Kyoto Protocol. If the United States moves toward adopting a similar cap-and-trade system for carbon, the value of wood pellets and other wood-based bioenergy is likely to grow.

Whatever the technology platform, economies of scale are critically important. Typically, larger wood-to-energy facilities operate at lower cost because of better technology, reduced capital costs per unit output, and greater efficiency. However, the key to success remains matching operational capacity to available supply. Operating costs can be minimized by locating facilities appropriately, using technological improvements, and providing appropriate tax incentives.

To attract investors, biomass-based enterprises must have a steady and reliable supply of materials, and the US Forest Service is working with partners to secure sustainable supplies. In Oregon, e.g., a partnership of local businesses and community groups won a US Forest Service grant to apply a coordinated resource offering protocol (CROP), an instrument invented by Mater Engineering, Inc. (Livingston 2006). The partners used the CROP to calculate the biomass supplies available in central Oregon on a 5-, 10-, and 15-year basis. In 2005, they began coordinating delivery from public lands in a way that evened out the flow of small trees and other biomass, creating the basis for a range of businesses using small-diameter woody materials, including a 12-MW biomass power facility under development by the Confederated Tribes of Warm Springs.

Drawing on the experience in central Oregon, Mater Engineering, Inc., and the US Forest Service spearheaded a CROP program inventorying biomass supplies nationwide (Mater 2007). Investors can use the inventories to design and place wood-to-energy facilities near a range of suppliers and to scale their operations to available supplies. Other ways of securing supplies include using US Forest Service stewardship contracts and helping the US Forest Service effectively manage analysis requirements and public involvement under the National Environmental Policy Act.

A Needed Energy Source

The days when America could rely heavily on imported oil are numbered, and the world is already exploring alternatives. Congress has envisioned that biofuels will replace 30% of the nation's oil consumption by 2030 (Perlack et al. 2005), with about a third coming from forest biomass and the rest from agriculture. As technologies and markets develop, the long-term outlook appears promising, but it still is not cost-effective to produce that much energy from forest biomass. In replacing fossil fuels, wood will be needed, but as only one of several sources of renewable energy; others will include corn starch, grassy energy crops, farm residues, solar, wind, water, geothermal, and possibly wave action. Fuel efficiency, green building, and alternative modes of transportation will also play a role in reducing the nation's fossil fuel dependency, as will nuclear energy.

The US Forest Service is committed to developing the nation's wood-to-energy potential. In 2008, the agency published its Woody Biomass Utilization Strategy (Patton-Mallory 2008), a blueprint for removing excess biomass from overstocked forest stands and using it for energy, wood products, and other purposes. By finding optimal uses for small-diameter materials and other woody biomass, the US Forest Service can recover some of the costs of needed forest health treatments, reducing the burden on taxpayers while extending its capacity to care for the land. Future generations deserve nothing less.

Endnote

[1] Other factors contributing to the worldwide rise in food prices in 2008 included soaring oil prices and rising prosperity in China, India, and other developing countries, raising the demand for meat and other foods.

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Abigail R. Kimbell is chief, US Forest Service, Washington, DC. Thomas Maness is professor of forestry, University of British Columbia, Vancouver, Canada. Hutch Brown is policy analyst, US Forest Service, Washington, DC. *The authors acknowledge invaluable contributions by John Harrington, a Professor of Forestry at New Mexico State University, Las Cruces, NM; and the many improvements made by reviewers, including Marilyn Buford, National Program Leader, Silviculture Research, US Forest Service, Washington, DC; Ed Gee, Chair, Woody Biomass Utilization Group and Partnership Coordinator, US Forest Service, Washington, DC; Peter Ince, Research Forester, Forest Products Laboratory, US Forest Service, Madison, WI; Doug MacCleery, Assistant Director, Forest Management, US Forest Service, Washington, DC; World Nieh, National Program Leader, Forest Products and Utilization, US Forest Service, Washington, DC; Ken Skog, Supervisory Research Forester, Forest Products Laboratory, US Forest Service, Madison, WI; and Ted Wegner, Assistant Director of Wood, Fiber, and Composites Research, Forest Products Laboratory, US Forest Service, Madison, WI.*