RESOURCE POLICY

Wood Energy in America

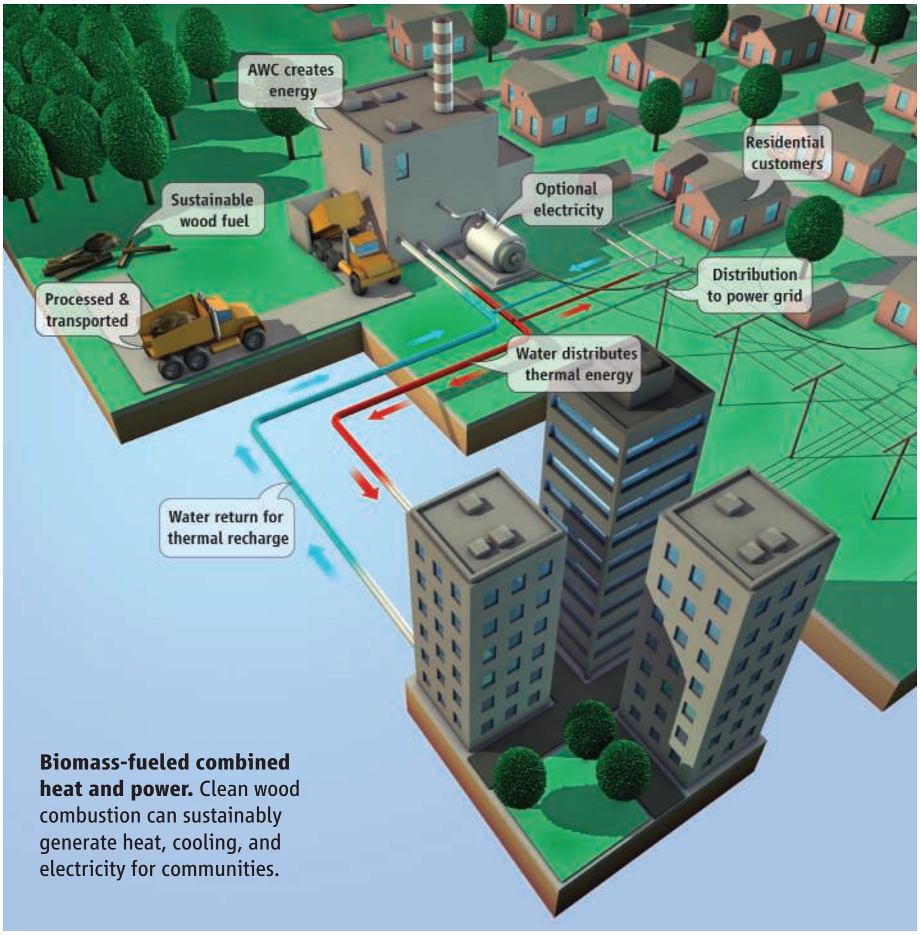
Sustainable wood energy offers recurring economic, social, and environmental benefits.

Daniel deB. Richter Jr.,[1]* Dylan H. Jenkins,[2] John T. Karakash,[3] Josiah Knight,[4] Lew R. McCreery,[5] Kasimir P. Nemestothy[6]

Consumers increasingly want energy that is renewable, clean, and affordable from solar, wind, hydroelectric, geothermal, and biomass sources (*1*). One of the simplest and oldest of renewables is direct combustion of wood (*2*, *3*). Wood supplied more energy than fossil fuels in the United States until the 1880s, when coal superseded wood. This transition occurred earlier in Europe, but today, thanks to regrowth of forests and improved technologies, advanced wood combustion (AWC) is being deployed throughout Europe, supplying heat, cooling, and power and reducing greenhouse-gas emissions (*4*). We argue that the European experience can guide successful implementation of community-based AWC in many regions of the United States.

Long important in Scandinavia, over the last two decades, AWC has grown in its contribution to energy use of France, Germany, and central and eastern Europe. More than 1000 AWC facilities have been constructed in Austria (*5*), nearly all local community–based; more than 100 combine heat and electric power. Most serve towns, portions of cities, industrial complexes, and public institutions, and nearly all are 0.1 to 10 MW (thermal). The facilities emit remarkably low quantities of air pollutants, including greenhouse gases, and have thermal efficiencies across the system approaching 90% (*6*). A high-efficiency wood-burning plant was recently opened in Simmering-Vienna with total thermal capacity of 65 MW, delivering electricity to the grid and heat to the city's district energy system (7).

Whether a plant of this size can be sustainably fueled is an open question. However, Europe's thousands of new community-scale AWC facilities clearly demonstrate that, with public backing, AWC can be rapidly implemented, can reduce oil imports and greenhouse gas emissions, and can increase energy security



Biomass-fueled combined heat and power. Clean wood combustion can sustainably generate heat, cooling, and electricity for communities.

with wood drawn from local woodsheds. AWC can also help communities transition to other renewable energies.

Rakos (*8*) argues that the major barriers to AWC implementation are social, and not economic or technical, and that communities with successful AWC systems adopt systematic approaches to wood-energy policy and practice (*2*, *5*–*8*). To gain public support, decision-makers must increase community appreciation for AWC system reliability, air pollution control, and sustainable forest management, as well as for how wood-energy dollars add jobs and profits to local businesses. Community leadership and public education are critical.

Considerations in Adopting Wood Energy

American forests were recently estimated to be able to sustainably produce 368 million dry tons of wood for energy generation per year (*9*, *10*). This yield is likely an underestimate, as it does not account for wood used for pulp and paper or low-value solid products, or wood from fast-growing trees on nonagricultural lands (*11*). Wood energy can add financial value to the forest and can support restoration and improvement in the form of timber-stand thinnings. The sustainability of local woodsheds will need careful monitoring to assure that forest-energy outputs enhance rather than deplete ecosystems (*12*, *13*). Forest bioenergy planning can include detailed inventories and management plans; education for foresters, loggers, and the public; forest-management certification; and thoughtful consideration within U.S. renewable fuel and energy standards.

Carbon policies need to distinguish renewable sources of energy (such as wood) that recirculate CO_2 already in the biosphere's carbon cycle from fossil fuels that add more CO_2 to that in active circulation.

European technical advances in wood-

[1]University Program in Ecology, Southern Center for Sustainable Forests, Nicholas School of the Environment, Duke University, Durham, NC 27708, USA. [2]The Nature Conservancy, Pennsylvania Forest Conservation Program, Williamsport, PA 17701, USA. [3]Resource Professionals Group, Durham, NC 27707, USA. [4]Pratt School of Engineering, Duke University, Durham, NC 27708, USA. [5]State and Private Forestry, USDA Forest Service, Morgantown, WV 26505, USA. [6]Austrian Chamber of Agriculture, Department of Forestry and Energy, A-1014 Vienna, Austria.

*Author for correspondence. E-mail: drichter@duke.edu

energy development include automated control over combustion and air pollution. For example, Austria's 1000 AWC facilities emit minimal amounts of sulfur oxides, mercury and other metals, particulates, and carbon monoxide (*5–7*, *14*). Minimal pollutant emissions result from high-quality combustion control (*15*, *16*) and from wood's low pollutant content compared with that of fossil fuels. Critical activities to facilitate adoption of reliable wood-based technologies include training of plumbers, steamfitters, and electricians (*8*) and adaptation of international standards for equipment specifications, operation, pollution-control, and safety.

Wood-energy economics are generally more favorable in North America than in Europe (*14*), and it is ironic that AWC was initiated in Europe (*17*, *18*). If American communities have sustainable wood supplies and AWC gains public support, acute financial pressure will spur wood-energy development because fossil fuel costs currently exceed those of wood by four times per unit of energy produced (*17*, *19*, *20*).

Thermally efficient conversion of wood fuel for heating and cooling of buildings or combined heat and power is a most important factor in sustainable siting and operation of AWC systems. Wood is too valuable to use inefficiently.

AWC Initiatives

To rekindle wood energy in America, we propose three energy initiatives that can have wide-ranging, positive effects in many kinds of communities over the coming few years. First, in localities with sustainable wood supplies, make AWC an energy system of choice for new construction and renovation. This initiative seems well targeted to the Northeast U.S.A., given the region's abundant forest land and dependence on heating oil (*21*), but AWC has great potential in the Southeast and West. Relatively rapid transitions to AWC heating and cooling are technically and economically achievable in schools, municipal offices, hospitals, prisons, and industrial facilities. A number of states promote renewable AWC in "Fuels for Schools" programs. In Vermont, for example, 20% of public school students now attend wood-heated schools (*22*).

Second, make better use of wood collected by municipalities from diseased and storm-damaged trees and from construction sites. The volume of safely combustible urban wood in the United States is nearly 30 million tons per year (*9*, *10*). Often, local communities dispose of this wood at some expense and miss energy benefits that could come from its clean combustion. Examples of successful operations include one in Minnesota where a refurbished coal-plant has been generating heat, cooling, and power by cleanly burning about 250,000 tons per year of urban wood waste and organic materials in downtown St. Paul (*23*).

Third, expand district-energy systems (in which heat is supplied from a central source to several sites) tied to AWC. District-energy AWC is used throughout Europe. It can be observed in downtown St. Paul, Minnesota; in hospitals and public buildings in Akron, Ohio; and on campuses such as Colgate University and the universities of Idaho and South Carolina. District energy is attractive for high-density communities and eco-friendly urban and suburban housing.

Wood Energy in Perspective

We use two wood-resource calculations to demonstrate the potential value of community-based AWC in America. The first considers a hypothetical program in a medium-sized U.S. state that develops community-based AWC on a scale similar to that in Austria (*24*). Consider if North Carolina were to install one community-scale AWC project per year (at 75 hp, 0.75 MW thermal) in each of 100 counties over a 5-year construction period. Although incremental investment might be \$100 million in each of the five construction years, fuel savings could grow to at least \$100 to \$180 million per year (*24*), and emissions of fossil CO_2 could decrease by 0.75 to 1.0 million ton per year (*24*). The fuel wood required by such a program would amount to about 20% of a recent estimate of the state's energy-wood supply (*25*).

The second calculation considers wood energy in relation to total U.S. energy consumption (*26*), currently about 100 quads [100×10^{15} British thermal units (BTUs) or 25.2×10^{15} kcal] per year. Today, wood supplies the nation with about 2 quads per year (*26*), and the national sustainable energy-wood supply (*9*, *10*) potentially contains about 5 quads per year (*24*). Although these rates may seem small, they are enormous quantities of energy, comparable to power production from hydroelectric sources (~3 quads per year) or the content of energy in the nation's Strategic Petroleum Reserve (~4 quads) (*27*). Considering the controversial plans to expand the nation's nuclear capacity, currently at 10 quads per year (*26*), how can we not ask about the future potential of wood energy, especially if the nation were to target its development not only in forests and woodlands, but on low-productivity agricultural lands and in cities?

References and Notes

1. Renewable Energy Policy Network for the 21st Century (REN21), *Renewables 2007 Global Status Report* (Worldwatch Institute, Washington, DC, 2008).
2. J. Perlin, *A Forest Journey: The Role of Wood in the Development of Civilization* (Norton, New York, 1989).
3. R. A. Ristinen, J. J. Kraushaar, *Energy and the Environment* (Wiley, New York, 2005).
4. AWC is defined as an automated, high-efficiency wood-fired energy system with strict air pollution controls.
5. R. Hackstock, *Renewable Energy—The Way Forward for the Next Century* (Austrian Energy Agency, Vienna, 2008); www.energyagency.at/(en)/projekte/res_overview.htm.
6. B. Voglauer, J. Rathbauer, *Austrian Biomass Boiler Manufacturers Survey* (Austrian Bioenergy Center, BLT-Wieselburg, Austria, 2004).
7. R. Madlener, M. Bachhiesl, *Energy Policy* **35**, 1075 (2007).
8. C. Rakos, in *Bioenergy—Realizing the Potential* (Elsevier, Amsterdam, 2005), pp. 47–57.
9. R. D. Perlack *et al.*, *Biomass as a Feedstock for a Bioenergy and Bioproducts Industry* [U.S. Department of Agriculture/Department of Energy (DOE), ORNL TM-2005/66, Oak Ridge, TN, 2005].
10. This estimate of the sustainable energy-wood supply does not include wood from forests protected for social, environmental, or economic reasons.
11. G. A. Keoleian, T. A. Volk, *Crit. Rev. Plant Sci.* **24**, 385 (2005).
12. D. A. Perry, R. Oren, S. C. Hart, *Forest Ecosystems* (Johns Hopkins Univ. Press, Baltimore, MD, 2008).
13. National Commission on Science for Sustainable Forestry, *Conserving Biodiversity Through Sustainable Forestry* (National Council on Science and the Environment, Washington, DC, 2007).
14. D. Hagauer, B. Lang, K. P. Nemestothy, *Instruction Manual for the Calculation of Wood Fuel Parameters* (Austrian Energy Agency, Vienna, 2008); www.klimaaktiv.at/article/archive/12740/.
15. M. Wörgetter *et al.*, *Bioenergy in Austria: Potential, Strategies, Success Stories* (BLT Wieselburg, Wieselburg, Austria, 2002); www.blt.bmlf.gv.at/vero/veroeff/0783_Bioenergy_in_Austria_e.pdf.
16. N. Kippel, T. Nussbaumer, *Einfluss der Betriebsweise auf die Partikelemissionen von Holzöfen* (Bundesamt fuer Energie, Bern, Switzerland, 2007); www.verenum.ch/Publikationen/SBOfenmessun.pdf.
17. Timber Mart-South (University of Georgia, Athens, 2008); www.tmart-south.com/tmart/.
18. H. Serup, *Wood for Energy Production* (Center for Biomass Technology, Danish Energy Agency, Copenhagen, Denmark, 2002).
19. Energy Information Administration (EIA), *Heating Oil and Propane Update* (DOE, Washington, DC, 2008).
20. EIA, *Natural Gas Prices* (DOE, Washington, DC, 2008).
21. Energy Efficiency and Renewable Energy Office, *Buildings Energy Data Book* (DOE, Washington, DC, 2007).
22. Vermont Fuels for Schools, Montpelier, VT, 2008; www.biomasscenter.org/services/programs/vermont-fuels-for-schools-vffs.html.
23. S. R. Schill, *Biomass* **2008**, no. 1428 (February 2008); www.biomassmagazine.com/article.jsp?article_id=1428&q=schill.
24. Supplemental calculations are available as supporting material on *Science* Online.
25. LaCapra Associates Team, *Analysis of a Renewable Portfolio Standard for North Carolina* (LaCapra Associates, Boston, MA, 2006); www.lacapra.com/downloads/NC_RPS_Report.pdf.
26. EIA, *Annual Energy Review 2007* (DOE, Washington, DC, 2008).
27. About 706 million barrels of crude oil are being stored in the United States' Strategic Petroleum Reserve (SPR), according to (*28*).
28. D. G. Victor, S. Eskreis-Winkler, *Foreign Aff.* **87**, 70 (2008).

Supplementary Online Material

www.sciencemag.org/cgi/content/full/323/5920/1432/DC1

10.1126/science.1166214