# THE LIMITS AND POTENTIAL OF PLANT-BASED ENERGY[1,2]

**Lester R. Brown©**

As oil and natural gas reserves are being depleted, the world's attention is increasingly turning to plant-based energy sources. These include food crops, forest industry byproducts, sugar industry byproducts, plantations of fast-growing trees, crop residues, and urban tree and yard wastes—all of which can be used for electrical generation, heating, or the production of automotive fuels. The potential use of plant-based sources of energy is limited because even corn—the most efficient of the grain crops—can convert just 0.5 percent of solar energy into a usable form. In contrast, solar PV or solar thermal power plants convert roughly 15 percent of sunlight into a usable form, namely electricity. In a land-scarce world, energy crops cannot compete with solar electricity, much less with the far more land-efficient wind power.

In the forest products industry, including both sawmills and paper mills, waste has long been used to generate electricity. U.S. companies burn forest wastes both to produce process heat for their own use and to generate electricity for sale to local utilities. The 11,000 megawatts in U.S. plant-based electrical generation comes primarily from burning forest waste. Wood waste is also widely used in urban areas for combined heat and power production, with the heat typically used in district heating systems. In Sweden, nearly half of all residential and commercial buildings are served with district heating systems. As recently as 1980, imported oil supplied over 90 percent of the heat for these systems, but by 2007 oil had been largely replaced by wood chips and urban waste.

In the United States, St. Paul, Minnesota—a city of 275,000 people—began to develop district heating more than 20 years ago. It built a combined heat and power plant to use tree waste from the city's parks, industrial wood waste, and wood from other sources. The plant, using 250,000 tons or more of waste wood per year, now supplies district heating to some 80 percent of the downtown area. This shift to wood waste largely replaced coal, thus simultaneously cutting carbon emissions by 76,000 tons per year and providing a sustainable source of heat and electricity.

The sugar industry recently has begun to burn cane waste to cogenerate heat and power. This received a big boost in Brazil, when companies with cane-based ethanol distilleries realized that burning bagasse, the fibrous material left after the sugar syrup is extracted, could simultaneously produce heat for their fermentation process and generate electricity that they could sell to the local utility. This system, now well established, is spreading to sugar mills in other countries.

Within cities, garbage is also burned to produce heat and power after, it is hoped, any recyclable materials have been removed. In Europe, waste-to-energy plants supply 20 million consumers with heat. France, with 128 plants, and Germany, with 67 plants, are the European leaders. In the United States, some 89 waste-to-energy plants convert 20 million tons of waste into power

1 Earth Policy Release, Book Byte, Earth Policy Institute, September 15, 2010

2 Adapted from Chapter 5, "Stabilizing Climate: Shifting to Renewable Energy," in Lester R. Brown, Plan B 4.0: Mobilizing to Save Civilization (New York: W.W. Norton & Company, 2009), available on-line at www.earthpolicy.org/index.php?/books/pb4

for 6 million consumers. It would, however, be preferable to work toward a zero-garbage economy where the energy invested in combustible materials could largely be recovered by recycling. Until we get zero waste, the methane (natural gas) produced in existing landfills as organic materials in buried garbage decompose can also be tapped to produce industrial process heat or to generate electricity in combined heat and power plants. The 35-megawatt landfill-gas power plant planned by Puget Sound Energy and slated to draw methane from Seattle's landfill will join more than 100 other such power plants in operation in the United States.

Near Atlanta, Interface—the world's largest manufacturer of industrial carpet—convinced the city to invest $3 million in capturing methane from the municipal landfill and to build a nine-mile pipeline to an Interface factory. The natural gas in this pipeline, priced 30 percent below the world market price, meets 20 percent of the factory's needs. The landfill is projected to supply methane for 40 years, earning the city $35 million on its original investment while reducing costs for Interface.

Crops are also used to produce automotive fuels. In 2009 the world produced 19 billion gallons of fuel ethanol and 4 billion gallons of biodiesel. Half of the ethanol came from the United States, a third from Brazil, and the remainder from a dozen or so other countries, led by China, Canada, and France. Germany and France are responsible for a combined 30 percent of the world's biodiesel output; the other major producers are the United States, Argentina, Brazil, Spain, and Italy. Once widely heralded as the alternative to oil, crop-based fuels have come under closer scrutiny in recent years, raising serious doubts about their feasibility. In the United States, which surged ahead of Brazil in ethanol production in 2005, the near doubling of output during 2007 and 2008 helped to drive world food prices to all-time highs. In Europe, with its high goals for biodiesel use and low potential for expanding oilseed production, biodiesel refiners are turning to palm oil from Malaysia and Indonesia, driving the clearing of rainforests for palm plantations.

In a world that no longer has excess cropland capacity, every acre planted in corn for ethanol means another acre must be cleared somewhere for crop production. An early 2008 study led by Tim Searchinger of Princeton University that was published in *Science* showed that when including the land clearing in the tropics, expanding U.S. biofuel production increased annual greenhouse gas emissions dramatically instead of reducing them, as more narrowly based studies claimed.

Another study published in *Science*, this one by a team from the University of Minnesota, reached a similar conclusion. Focusing on the carbon emissions associated with tropical deforestation, it showed that converting rainforests or grasslands to corn, soybean, or palm oil biofuel production led to a carbon emissions increase—a "biofuel carbon debt"—that was at least 37 times greater than the annual reduction in greenhouse gases resulting from the shift from fossil fuels to biofuels. The case for crop-based biofuels was further undermined when a team led by Paul Crutzen, a Nobel Prize–winning chemist at the Max Planck Institute for Chemistry in Germany, concluded that emissions of nitrous oxide, a potent greenhouse gas, from the synthetic nitrogen fertilizer used to grow crops such as corn and rapeseed for biofuel production can negate any net reductions of $CO_2$ emissions from replacing fossil fuels with biofuels, thus making biofuels a threat to climate stability. Although the U.S. ethanol industry rejected these findings, the results were confirmed in a 2009 report from the International Council for Science, a worldwide federation of scientific associations.

The more research is done on liquid biofuels, the less attractive they become. Fuel ethanol production today relies almost entirely on sugar and starch feedstocks, but work is now under way to develop efficient technologies to convert cellulosic materials into ethanol. Several studies indicate that switchgrass and hybrid poplars could produce relatively high ethanol yields on marginal lands, but there is no low-cost technology for converting cellulose into ethanol today or in immediate prospect.

A third report published in *Science* indicates that burning cellulosic crops directly to generate electricity to power electric cars yields 81 percent more transport miles than converting the crops into liquid fuel. The question is how much could plant materials contribute to the world's energy supply. Based on a study from the U.S. Departments of Energy and Agriculture, we estimate that using forest and urban wood waste, as well as some perennial crops such as switchgrass and fast-growing trees on nonagricultural land, the United States could develop more than 40 gigawatts of electrical generating capacity by 2020 (1 gigawatt = 1,000 megawatts). For the global Plan B, we estimate that worldwide, biomass could quadruple to contribute 200 gigawatts of capacity by 2020, playing a relatively small yet important role in the new energy economy.