Huge challenges in scaling up biofuels infrastructure

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Swithchgrass being stored for bioenergy generation.

(PhysOrg.com) -- Ramping up biofuels production to replace fossil fuels and provide a significant portion of the nation's energy will require nothing short of a transformation of the U.S. agricultural, transportation and energy sectors in the next few decades, according to a bioenergy expert in Penn State's College of Agricultural Sciences.

Major changes will be needed to grow, handle, transport and store the immense quantities of biomass -- mostly lignocellulosic feedstocks such as switchgrass, crop residues and forest wastes -- necessary to continually feed electric power generation stations and produce biofuels for transportation, noted Tom Richard, professor of agricultural and biological engineering, who is director of the University's Institutes of Energy and the Environment.

In an article, titled "Challenges in Scaling Up Biofuels Infrastructure," published in the Aug. 13 issue of the journal *Science*, Richard contends that converting to a system in which biomass provides much of the country's energy will require new ways of thinking about agriculture, energy infrastructure and rural economic development.

"It is estimated that bioenergy has the potential to provide up to 60 percent of the world's primary energy, and biomass seems poised to provide a major alternative to fossil fuels," he wrote. "The International Energy Agency estimates that a 50 percent reduction in greenhouse gas emissions by 2050 will require an exponential increase in bioenergy production, to 20 percent of our total energy supply in less than 40 years."

But the massive demand for lignocellulosic biomass will require major changes in supply chain infrastructure, Richard warned. "Even with densification and preprocessing, transport volumes by mid-century are likely to exceed the combined capacity of current agricultural and energy supply chains, including grain, petroleum and coal," he wrote. "To reach the International Energy Agency 2050 target for primary energy from biomass would require 15 billion metric tons of biomass annually."

To gain some perspective on the quantities involved, consider the volumes of related commodities currently being managed. For agricultural commodities, the sum of rice, wheat, soybeans, maize and other coarse grains and oilseeds will approach 2 billion metric tons in 2010. Current global volumes of energy commodities are somewhat larger, with 6.2 billion metric tons of coal and 5.7 billion metric tons of oil transported in 2008.

"Thus, the combination of expected growth in energy demand and the lower density of biomass imply that by 2050, biomass transport volumes will be greater than the current capacity of the entire energy and agricultural commodity infrastructure," Richard wrote.

If managed poorly, Richard noted, this additional traffic could degrade rural roadways and increase safety concerns. But increased demand for biomass could also provide a strong incentive to improve rural transportation infrastructure, facilitating agricultural and economic development in concert with renewable energy.

The size and efficiency of bioenergy-conversion facilities will determine how far these huge volumes of biomass and biofuel will need to travel, and thus influence transportation's contribution to the energy, economic and environmental impacts of biomass use. Decentralized systems have the potential to source feedstock locally with minimum infrastructure costs.

The delivery of finished biofuel also would stress transportation systems, Richard wrote. "For example, a large biofuel plant would require 16 to 20 tanker trucks or railcars per day to move the fuel to market, increasing both traffic and costs."

But regardless of the fuel product, massive investments in new pipe, rail and highway infrastructure are needed to move those fuels from a new biorefinery network dispersed across the landscape, Richard wrote. Densification strategies including baling systems for grasses, crop residues and forest trimmings, as well as higher-density pellets and cubes, will be key.

Biomass-production operations must occur year-round because it is difficult to amortize capital costs for facilities that are used for only a few months of the year. However, many biomass feedstocks have optimal harvest periods that may run for only a few weeks.

"There are likely other seasons during which harvesting should not occur due to weather or various ecosystem constraints," Richard wrote, adding that agricultural producers have demonstrated how to store biomass.

"Livestock farmers have been facing a similar problem supplying forages to their 24-hours-a-day, seven-days-a-week, 365-days-a-year milk- and meat-producing animals for over a thousand years, and have developed effective wet (silage) and dry (hay) storage systems for grasses and crop residues," he wrote.

The amount of nearby land dedicated to energy crops also will greatly affect the costs of feedstock supply, Richard suggested. Even short supply chains can significantly increase the cost of some biomass resources between the field and the biorefinery gate.

"The push-pull between economies of scale for conversion facilities and diseconomies of scale for feedstock supply chains suggest three distinct business models for biomass feedstock supply: independent local suppliers, large contiguous plantations and regional or global commodity markets," Richard wrote.

Independent local feedstock suppliers can work well for smaller biomass energy facilities, including combined heat and power plants that require a few truckloads of biomass each day or week. Such operations would have relatively short haul distances and little need for specialized equipment, and the extra expense required for densification would not be required.

"Local supply chains are currently common throughout the world, supplying everything from firewood for charcoal to waste oil for biodiesel," he wrote. "A second model of biomass supply chains is the plantation approach, where a single company controls a large contiguous land area. Plantations have long provided concentrated production of agricultural and forest products for high-volume processing and international markets."

This strategy is being used today for bioenergy crops in many regions of the world, including sugar cane and soybeans in South America, oil palm in Malaysia, and canola in Ukraine, according to Richard. "Most plantation systems have been structured so that the company needing the feedstock directly owns the land."

The third business model is the commodity biomass market, which would parallel the trading operations for other agricultural commodities (such as grains and livestock) as well as energy resources (such as petroleum and coal).

The transformation of American society to one in which biomass produces a major fraction of our energy is daunting but possible, Richard concluded. "It will require an innovative, informed and motivated citizenry -- entrepreneurs, farmers, foresters, neighbors and a host of new workers throughout the feedstock supply chain," he wrote.

Provided by Pennsylvania State University