Sustainable bioenergy feedstocks from Southern forests

A Consortium to address purpose-grown wood for bioenergy and bio-based products

Technical Relevance and Merit

The US is establishing ambitious goals for biofuels and biobased products in the Renewable Fuel Standard, potential Renewable Energy Standard, and other legislative initiatives like the 2008 Farm Bill. These targets support multiple policy goals including greenhouse gas mitigation, strengthening rural economies and communities, and enhancing national energy security by reducing dependence on imported petroleum.

The *Roadmap for Bioenergy in the US* highlights key challenges to rapid escalation of the bio-based economy including increasing feedstock supplies and developing value chains that are socially, ecologically, and economically sustainable. The Billion Ton report and other studies have highlighted important constraints on biomass feedstock supplies. Concerns about sustainability are evident in contentious discussions of "food vs. fuel" and the "carbon neutrality" of biomass. Additional feedstock sources need to be developed to meet objectives such as the Twenty in Ten goal.

The southern United States has the potential to produce large amounts of woody biomass feedstock. It already leads the nation in production of cellulosic biomass for energy and renewable materials, harvesting over 8 billion ft^3 of wood in 2007 (~150M bdt). This is just over half of the total wood production for the entire country. This level of supply comes from a portion of the region's 220M acres of forestland, generated by land managers and owners making management decisions and implementing practices that produce wood to support the forest products industry. Each year, southern landowners plant about 1 billion seedlings and regenerate over 3 million acres after harvest to sustain productive forests on the landscape. Current woody biomass assessments are considering how the wastes from the existing landscape might be used—the hypothesis of this proposal is that southern forests can also be intentionally managed to produce a biomass feedstock product (purpose-grown wood or PGW) while maintaining or enhancing other values.

Research described in this proposal will address three critical barriers to expanding and diversifying the sustainable production of biomass energy and new biomaterials in the southern US: (1) Constraints on the capacity of wood feedstock production systems; (2) Constraints on the conversion of woody biomass into energy and bio-products for new and traditional products; and (3) Concerns about the sustainability of forest-based value chains.

Research will be designed to test selected aspects of four overarching hypotheses:

1. Biomass feedstock supplies from southern forests can be increased substantially while enhancing wildlife habitat, protecting water quality, and conserving other important functions and values of southern forest ecosystems.

2. The diversity of southern forests, southern forest landowners, and the South's rural economies and communities means that there is no single woody biomass solution for new feedstock supply. Factors constraining feedstock supplies generally include economic returns to biomass producers, logistics costs, interactions with existing forest products markets, impacts on the many dimensions of forest ecosystems, and social acceptability of biomass production. The relative importance of these factors varies substantially across the South. A range of feedstock systems will be needed.

3. In some parts of the South, the economic sustainability of managed forests and forest-based value chains can be enhanced substantially through investments in "purpose-grown wood" (PGW).

"Purpose-grown wood results from active, intentional, management of forests to generate woody feedstock as a sole product or in conjunction with other forest outputs. PGW can range from intensively managed short-rotation hardwoods to feedstock production as part of management of planted or natural forest stands."

4. Pulp and paper mills in the South will be key parts of the bio-economy, producing substantial quantities of thermal and electrical energy from biomass. These mills have potential to facilitate the development of biorefineries producing biofuels, new biomaterials, and traditional products.

The complexity of these hypotheses and their implicit interactions demands an integrated research approach that can engage a range of scientific disciplines and management perspectives. Specifically this proposal will create a consortium from two leading forest research organizations in the South—the US Forest Service Southern Research Station (SRS) and the National Council for Air and Stream Improvement (NCASI) to leverage existing resources and organization. The Consortium and its research partners will develop a coordinated plan of work to address key barriers and technology gaps in feedstock development, conversion processes, and life cycle analysis to support sustainable forest-based development. The Consortium will deliver research products to landowners, forest products companies, bioenergy developers, policy makers, and other stakeholders.

Technical Approach/Work Plan

Both SRS and NCASI have recently organized biomass/bioenergy research initiatives that are region-wide. Each group has conducted scoping and gap analysis to prioritize their work on woody feedstock. The initial task will be to coordinate these efforts by developing a Consortium structure and technical strategy that brings together researchers from both organizations. The Strategy will be developed from the perspective of the southern forest landscape—analysis of existing ownerships, demographics, forest condition and extent, infrastructure, industry, existing uses of forests, areas of ecological concern, potential development of bioenergy facilities, and other related factors. The outcome of this task will be to identify where and how southern forest management may change in response to demand for feedstock. Existing industrial ownership, for example, may have a profit-maximization objective that would be associated with certain types of feedstock production systems. Private landowners, on the other hand, may seek to maintain a range of forest outputs like wildlife habitat using feedstock production as a management tool or incremental income source. Given the principal set of management options for PGW, study sites will be established across the Region where appropriate replicates of the management treatments can be located. These field sites will serve as a core woody feedstock research network. In addition, the Consortium will identify key challenges to processing and conversion of southern woody biomass and develop a research plan to address gaps. Conversion studies will be conducted at labs and partner facilities across the region.

Task A—Feedstocks Development

A set of principal management options will be defined and critical barriers to feedstock production will be clarified in terms of research needs. As noted in the Roadmap, increasing feedstock supply means increasing the yield per acre and/or increasing the number of acres in production. In the context of the southern forest landscape this can be achieved by:

- Improved plant material (genetic improvements and/or species selection)
- Biomass recovery from non-productive forestland acres (mesquite, eastern redcedar)
- Increasing site productivity through more intensive management practices (fertilization, weed control)

- Shifting forest management to even-aged plantations (SRWC through multi-product pine)
- Dual-cropping energy crops with conventional forest production (i.e. switchgrass and pine)
- Afforestation of non-forest lands such as in the lower Mississippi alluvial valley (LMAV)
- Increasing efficiency of recovery through the logistics system (harvest, process, transport)
- Improving conversion processes to recover more product from the same feedstock

The Consortium will develop field study sites across the region to generate research data and provide demonstration sites for technology transfer. Management options will be replicated across the South and across physiographic regions and forest types. The objective would be to have representative installation of sites to permit regional comparisons similar to the Long-Term Soil Productivity study or the Fire and Fire Surrogates project.

While a PGW system that produces only bioenergy, like short-rotation willow, may be relatively simple to assess, forest systems that are managed for multiple products are very complex. Management systems for feedstocks have to consider interactions among objectives. How does maintaining wildlife habitat or biodiversity affect the yield per acre of biomass? When would an optimal biomass thinning occur during the course of a forest rotation? How does removal of forest biomass in intermediate stand entries affect a wide range of ecological functions and values? How do management choices affect feedstock properties? These types of research gaps can be more efficiently explored by the Consortium using common assessment methods, replicated plot designs, and integrated projects. For example, a study of nutrient cycling could also be used to evaluate harvesting economics and wildlife habitat effects by coordinating researchers.

As appropriate, key areas of expertise will be directed to the PGW program including: genomics, site productivity, short rotation systems, silviculture of pine and hardwood in natural stands, and forest operations. Feedstock types will include: short rotation woody crops such as poplar and sweetgum and pine, underutilized species such as mesquite and eastern red cedar, shrub/understory and invasive species like Chinese privet and ty-ty, genetically-modified material both native and non-native, limbs and tops of softwoods and pines, stemwood, stumps, and bark.

Task B—Biofuels and Biobased Products Development. The diversity of feedstock types described above makes conversion complex. Either conversion processes have to be developed that are robust enough to accept variation in feedstock properties, or feedstock pre-processing operations must be developed that can reduce material to a more uniform format. Thus, the work in biofuels and bio-products development is directly linked to the activities in feedstock development, drawing samples from the various management scenarios. Scale is a critical conversion parameter as it affects economic haul distance, competitive impacts with other forest uses, and process variables.

SRS has been evaluating thermal conversion through gasification and combustion in small-scale systems. This would be appropriate for distributed power systems or local production of advanced biofuels. Additional work will address other thermal conversion such as torrefaction and pyrolysis. The current proposal will build on this expertise in conversion to determine the impact of feedstock properties on the bioenergy and bioproducts produced.

At the same time, the South has a large existing biopower industry in pulp and paper. Pulp mills have high potential to serve as platforms for cost-effective development of biorefinery processes because the pulp mills have much of the necessary infrastructure already in place (wood procurement systems, utilities, environmental permits, etc.). In theory, pulp mills can increase their production of heat and power from biomass in order to reduce their use of fossil fuel and/or provide renewable energy needed to produce new products.

In practice, there are significant financial and technical barriers to using pulp mills as platforms for biorefinery processes. A key issue, for both large scale and small-scale bioenergy production are the emissions associated with conversion. In this proposal, we will focus on barriers associated with EPA's proposed regulations for industrial boilers known as Maximum Achievable Control Technology (MACT). In particular, we will conduct research needed to achieve major reductions in emissions of Hg, dioxins and furans, HCl, and CO from boilers that burn biomass alone or in combination with other fuels. The lack of crucial information about this single issue is impacting deployment of new bioenergy installations.

Task C—Biofuels Development Analysis

Sustainable development of new forest-based value chains requires integration of feedstock production, feedstock harvesting and transportation, conversion of biomass into energy and materials, and marketing / distribution of products. Metrics of sustainability include economic return on investment, environmental performance, and social responsibility. The Consortium will draw on expertise in the Economics and Policy Unit as well as the Integrating Human and Natural Systems team to assess social and economic impacts.

We will use Life Cycle Analysis and other tools to characterize the carbon and water footprints of biofuels and biomaterials made from biomass produced in southern forests. Our analysis will build on prior research including studies conducted by the Consortium for Research on Renewable Industrial Materials (CORRIM) and Forest Industry Carbon Assessment Tool (FICAT) (developed by NCASI for the International Finance Corporation and available at www.ficatmodel.org

Our specific objectives are to estimate changes in the carbon and water footprints of model products (e.g., ethanol) that are attributable to:

- feedstock production system (e.g., short rotation wood crop vs. traditional plantation management)
- source of heat and power (fossil fuel vs. biomass) used to produce biofuel or biomaterials.

We will also conduct research on ecological and societal concerns associated with development and deployment of short rotation wood crops and other wood production systems in the South.

Energy Efficiency/Displacement, Rural Economic Development, Environmental Benefits

The Consortium will address the challenges of developing a large bioenergy industry in the South. Potential effects of successfully standing up such an industry are huge. Currently announced bioenergy projects in the South have a potential demand for about 40M bdt. As the market matures this could conceivably approach 100M bdt (about half of the DOE 2017 goal of 250M bdt). At an average site productivity of 5 bdt/ac/yr, feedstock production would be affecting at least 20M acres (10%) of the southern forest landscape. This level of production would provide feedstock for about 8B gallons of renewable liquid fuel, offsetting fossil fuel consumption. The CORRIM project estimates that forest operations to harvest and transport that amount of material will consume at least 180M gallons of diesel fuel per year, almost half in transportation. Fertilizer use for intensively managed stands is another significant fossil fuel input. Thus research and development through this Consortium to find efficiencies in operations and management practices will have a major impact on energy consumption and emissions. Identifying a 10% improvement in efficiency would have the effect of offsetting 18M gals of diesel use, for example. Reducing emissions associated with biomass conversion processes is also key to minimizing net total impact. The Consortium will evaluate LCA as it compares feedstock production from alternative management practices and conversion pathways.

The existing forestry sector in the South contributed almost 6 percent of total southern gross regional product in 1997 (~$104B). Forest sector jobs and wealth generation are concentrated in rural areas and

are critical to address the continuing challenges of poverty and poor public infrastructure. Woody feedstock production at large scale could conceivably generate a similar level of economic activity (relative to volume produced). However, it is also critical to understand how developing bioenergy markets may adversely impact employment and economic viability of existing forest industries. Feedstock production can be developed at various scales with a general sense that smaller-scale, more distributed systems would have better local economic effects than large-scale facilities depending on production processes and product distribution.

Forests are also a major component of the southern landscape (60%) with agriculture (30%) and urban (10%) trailing. Thus, the ecological condition of southern forests has a large effect on quality of life resulting from clean water and air, wildlife habitat, recreational use, and carbon and nutrient cycling. Biomass is a potential product that can add real value to forest management and help keep southern forests intact and healthy. However, at the same time active management imposes effects such as soil disturbance, roadbuilding, habitat alteration, emissions from operations, and removal of nutrient capital. The Consortium strategy will assess the types of impacts and work on developing science-based guidelines and methods to mitigate or avoid ecological problems.

Technical, Management and Facility Capabilities

The Southern Research Station of the US Forest Service (www.srs.fs.usda.gov) has developed a Bioenergy Team that integrates research programs across 14 different research work units. There are about 30 scientists in a wide range of disciplines currently engaged in various aspects of bioenergy studies with total annual program funding of approximately $4M. These scientists are supported by state-of-the-art research facilities and specialized equipment for areas including: genetics and genomics, plant physiology, short rotation woody crops, agroforestry, pine and hardwood silviculture, climate change, forest operations, wood chemistry and conversion, economics and policy. There are numerous long-term field plots and ongoing experiments. In addition, the SRS has an award-winning business operations structure that can efficiently support large-scale research efforts. Current overhead rate is 7.1% reflecting process efficiency. The SRS will serve as the lead organization with reporting and fiscal oversight.

The National Council for Air and Stream Improvement (NCASI) is the environmental research arm of the forest products industry in North America. NCASI (www.ncasi.org) is a leader in sustainable forestry research, life cycle analysis of forest-based value chains, and research on measurement and control of emissions from biomass combustion and other processes at manufacturing facilities in the forest products industry. NCASI has a technical staff of over 80 scientists and engineers with three regional research centers. NCASI is primarily supported by member dues and has a close relationship to industry.

Both NCASI and SRS work extensively through collaboration with university partners as needed to leverage additional resources and engage leading researchers. In this role, the Consortium will lead a large research effort by defining co-operative research topics and attracting external partners. The Consortium will develop a joint structure between the two organizations with key personnel (Director, Business Manager, etc) assigned for the duration. The project will have access to facilities and resources in both organizations.

Key personnel include: