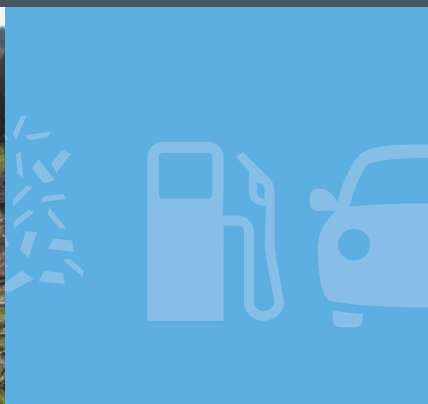


Integrating Sustainable Biofuels and Bioproducts into Forest Industry Supply Chains

A Project of the USDA-NIFA Biomass Research & Development Initiative (BRDI)

Accomplishments and Outcomes





Project Accomplishments and Outcomes

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Development Initiative (BRDI)**





Acknowledgements

This project was supported by the Biomass Research and Development Initiative, Competitive Grant no. 2010-05325, from the U.S. Department of Agriculture, National Institute of Food and Agriculture. We would also like to thank our many stakeholders and partners for their contributions to the project.

**2016 Rocky Mountain Research Station
U.S. Forest Service, USDA**

This book was produced by Reid Hensen, Research Assistant, with assistance from Maureen Essen, Nate Anderson, Larry Peters, April Kimmerly, and contributing principal investigators and partners.



Table of Contents

FROM THE DIRECTOR4

INTRODUCTION5

PROJECT MAP8

Improving systems of harvesting, processing, and transporting forest biomass feedstock from the forest to conversion facilities.

SECTION 2 | Conversion Technology.....17

Developing new technologies to convert biomass into valuable products.

SECTION 3 | Sustainability25

Working to evaluate the social, environmental, and economic impacts and potential costs and benefits of biomass systems.

NEXT STEPS36

From the Director

As with many large, integrated research projects, this NIFA-BRDI effort brought together an excellent team of professionals to address a complex research and development problem based primarily on their technical expertise and past accomplishments in relevant fields. As you will see, this spanned many disciplines and applied sciences and included a diverse group of talented people collaborating across industry, academia, and government. Many of us had never worked together, and others had never met before our first project meeting.



Some members of the project team gathered in front of the Tucker RNG system at ReVenture Park, Charlotte, North Carolina, 2014



Nate Anderson, Project Director

From the beginning, I expected a high level of accomplishment and outcomes from this group, and they delivered. What I didn't expect was to have the opportunity to work with such a consistently friendly and supportive group of colleagues, and to wrap up five years of work feeling so privileged to have worked with this team on such an important project.

Thanks to everyone for their contributions and to USDA-NIFA for supporting us.

Nate

Introduction



Biomass left behind after a timber harvest in Colorado.

Project Overview

Forest biomass is a promising feedstock for the production of bioenergy, biofuels, and bioproducts because it is renewable and widely available as a byproduct of forest management. Its harvest and use also has the potential to positively impact rural communities, especially those negatively impacted by upheaval in the forest sector.

However, many obstacles have prevented more widespread use of forest biomass. These include uncertainties related to feedstock cost, the performance of new technologies, competitiveness with fossil fuels and existing

products, and the environmental, social, and economic impacts of biomass use on forest ecosystems and local communities. The purpose of this project was to quantify, evaluate, and overcome many of these obstacles. Research, development, and outreach was organized into three technical areas.

Technical Area 1: Feedstocks Development

The team working in Feedstocks Development focused on improving systems of harvesting, processing, and transporting woody biomass





feedstock from the forest to biomass conversion facilities, with an emphasis on developing new systems and new equipment to minimize costs and improve productivity. They also worked to improve ways land managers and private companies evaluate biomass supply on the landscape. Specifically, they developed tools that help these stakeholders quantify and map biomass across complex landscapes and predict the sustainable biomass quantities that might be delivered to specific facilities under different logistics, management, and market conditions.



Varying types of processed forest biomass



Wood chips and biomass leaving Tricon Timber, LLC, in St. Regis, MT.

Technical Area 2: Conversion Technology and Products from Biomass

The Conversion Technology and Products Technical Area was focused on developing new technologies to convert biomass into valuable products. A major goal was to improve the performance of the modular Tucker Renewable Natural Gas (RNG) thermal conversion system (the “Tucker RNG system”), with an emphasis on bringing the system closer to widespread commercial use.

Scientists and engineers also worked closely with Tucker RNG to improve product value, including developing new catalysts to convert gas to liquid fuels and chemicals, using char co-products as a raw material for producing soil amendments and

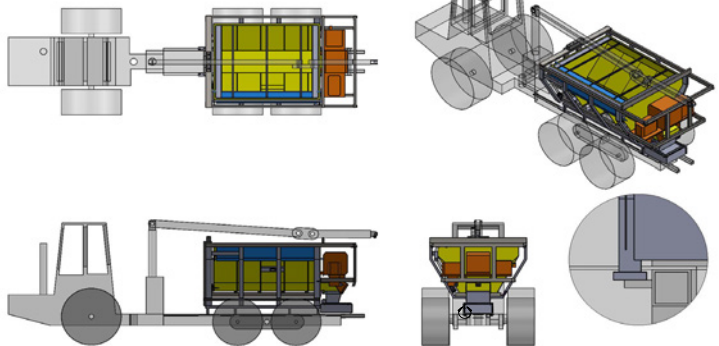
activated carbon, and pelletizing the char to facilitate handling and use. Another important advance in this area was the design, fabrication, and use of a pellet spreader that can efficiently and reliably distribute biochar pellets with minimal site impacts in difficult logging environments.

Technical Area 3: Sustainability

In order for these biomass technologies and products to be successful, they must be sustainable and offer significant improvements over fossil fuels and petrochemicals. The Sustainability Team worked to evaluate the social, environmental, and economic impacts and potential costs and benefits of biomass systems. With regards to the environment, researchers quantified the net greenhouse gas emissions of biomass products compared to alternatives, quantified soil and watershed impacts of biomass harvest with a focus on soil disturbance, site productivity, and erosion, and quantified long-term impacts on forest growth. Economists and social scientists on the team developed models for system financial performance, evaluated potential rural

economic development impacts, characterized social preferences for biomass energy, and conducted research to examine the attitudes and perceptions of various stakeholder groups, including National Forest managers.

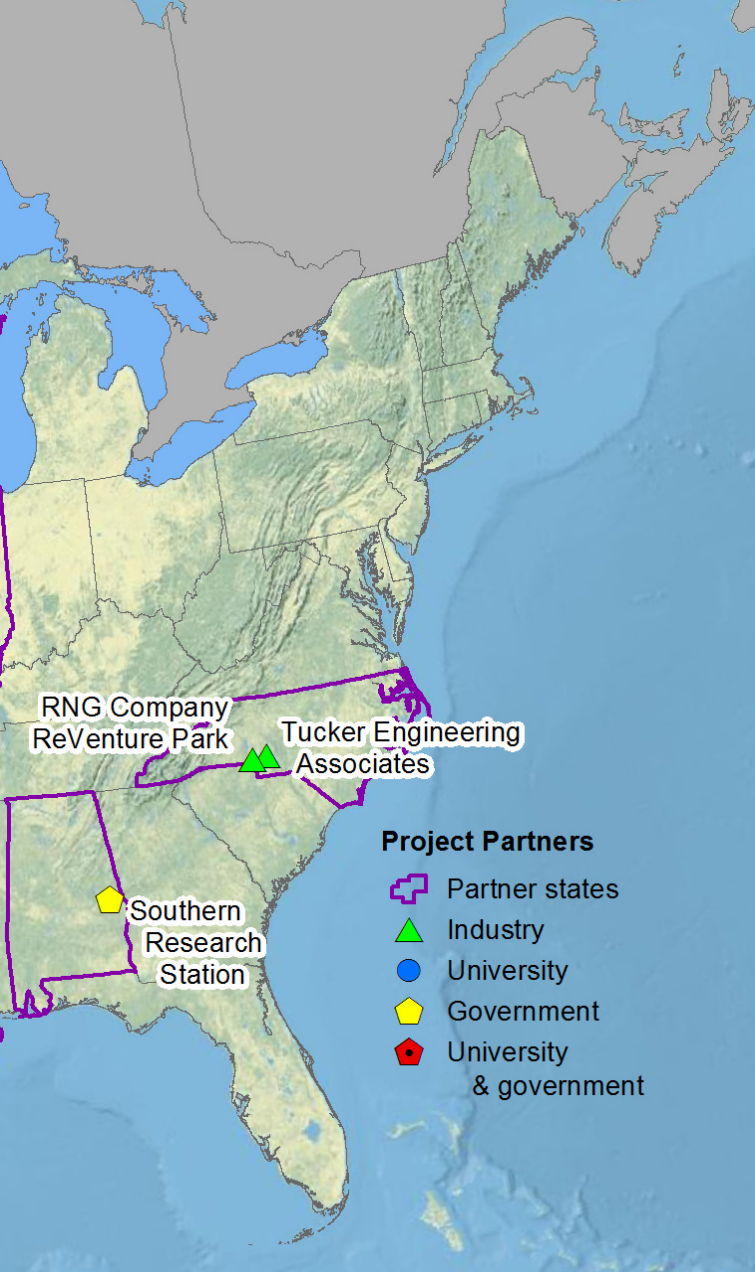
Forwarder Mounted Biochar Spreader



*Biochar spreader
computerized design*

When combined, these three technical areas embody a fully integrated biomass research and development project that cuts across all aspects of the supply chain, emphasizing not only the engineering of more effective and economically efficient production systems, but also systems that result in fewer negative impacts on the environment and greater benefits for stakeholders and communities.





Coast-to-Coast Collaboration

This project brought together an unprecedented team representing five universities, three USDA Forest Service Research Stations, a USDA Forest Service Technology and Development Center, and six industry partners. Research, development, and outreach activities were conducted in eleven states, and resulted in critical advances in biomass feedstock logistics, conversion technology, bioproduct development, and our understanding of the social, environmental and economic impacts of using forest biomass for bioenergy and bioproducts.



SECTION 1

Feedstocks Development

This team focused on improving systems of harvesting, processing, and transporting forest biomass feedstock from the forest to biomass conversion facilities, with an emphasis on developing new systems and new equipment to minimize costs and improve productivity. They also worked to improve ways land managers and private companies evaluate biomass supply on the landscape. Specifically, they developed tools that help these stakeholders quantify and map biomass across complex landscapes and predict the sustainable biomass quantities that might be delivered to specific facilities under different market and management conditions.



Enhanced Feedstock Harvesting System Logistics

Lead: Han-Sup Han, Professor of Forest Operations
Humboldt State University

Biomass harvesting systems and supply logistics that provide the highest operational efficiency are key to minimizing costs, improving access to biomass, and producing quality feedstock. Enhanced biomass operations and supply logistics were tested and system improvements were quantified.

Outcomes

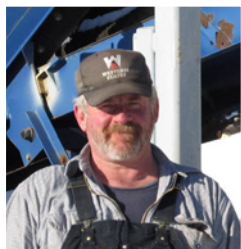
1. Developed strategies for cost-effective operations for harvesting, processing, and transportation with emphasis on system balance in operations logistics.
2. Quantified the amounts of biomass removed from biomass operations compared to biomass left onsite.

Accomplishments

1. Enhanced planning and equipment selection for in-woods biomass operations and transportation.
2. Accurate assessment of biomass amounts recovered from operations.



A centralized biomass recovery operation using modified dump trucks and all-wheel-drive chip trucks.



New Equipment for Biomass Harvest and Processing

Lead: Kevin Jump, Owner and President
John Jump Trucking, Inc.

John Jump Trucking Inc. led the development of innovative forest equipment to meet three primary objectives: reduce the cost of biomass operations, improve slash recovery, and access difficult sites, especially sites inaccessible to large chip vans.

Outcomes

1. More efficient, lower cost biomass collection and harvest, especially from sites with dispersed slash piles inaccessible to chip vans.
2. Increased stocks of economically viable biomass feedstocks from timber harvests and other forest treatments.

Accomplishments

1. Developed a road-legal mobile wheeled grinder that can move efficiently between dispersed piles, paired with a long-reach grapple system for efficient roadside recovery.
2. A nested truck and trailer prototype to provide better access to difficult sites located on low-quality forest roads.

In-field testing of the grinder outfitted with a control cab, drive wheels, and other modifications.





Integration of Whole Log Microchipping and Screening

Lead: Angelo Ververis and Charlie Sells
Tricon Timber, LLC

Tricon Timber developed the capacity to use low grade logs not suitable for lumber production to make pulp chips and microchips for bioenergy and bioproducts, including feedstocks for Tucker RNG system trials.



Accomplishments

1. Installation of a whole-tree chipping line with a screening system that can meet narrow biomass specifications required by some conversion technologies.
2. Contributions to Life Cycle Assessment (LCA) analysis of Tricon Timber microchips used for pyrolysis conversion.

Hongmei Gu collecting LCA data on the chipping and screening line at Tricon Timber, LLC, St. Regis, MT.

Outcomes

1. Production of high-quality feedstocks from low-grade materials for bioenergy and bioproducts applications.
2. Increased chipping and screening capacity to meet demand for new biomass markets, as well as conventional pulp markets.



Spatial Analysis of Feedstock Supply

Lead: Woodam Chung, Associate Professor
Oregon State University

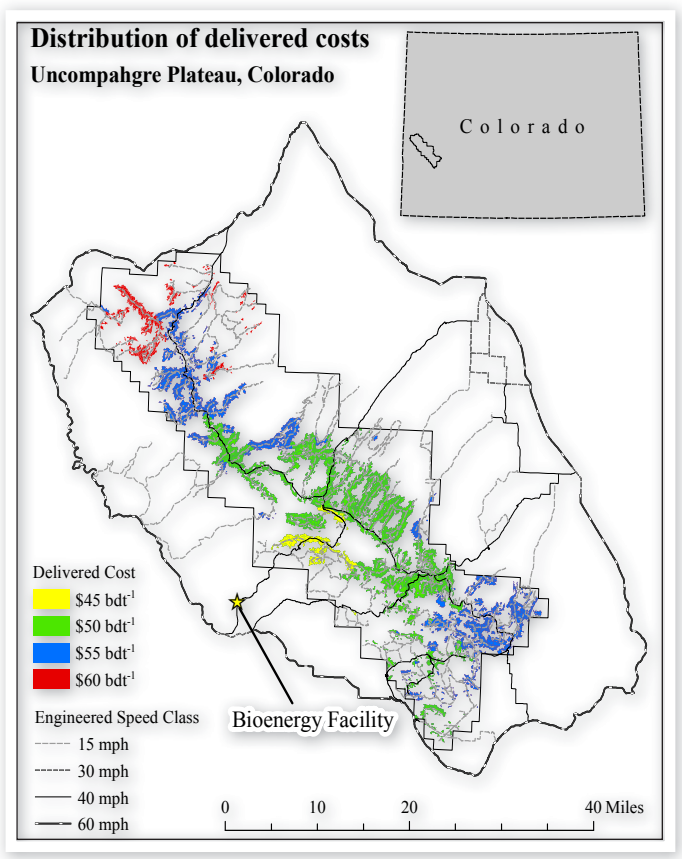
Woody biomass utilization has many economic and practical uncertainties. We developed a framework that accounts for forest inventory, infrastructure, and forest management objectives to provide accurate supply and cost estimates.

Outcomes

1. More realistic estimation of biomass supply and costs across a large landscape.
2. More informed decision-making on woody biomass projects.

Accomplishments

1. Developed spatially-explicit, management objective-driven biomass feedstock supply models.
2. Developed spatially-explicit biomass feedstock cost models.



Spatial distribution of available treatment residues over a range of delivered prices (BDT).



Spatial Quantification of Existing Biomass Stocks at High Resolution

John Hogland, Biological Scientist
Rocky Mountain Research Station

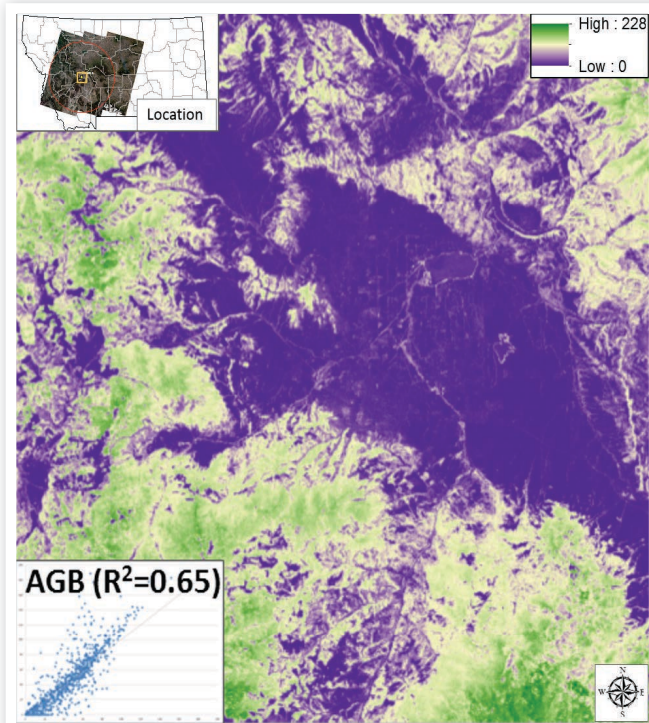
Spatially accurate estimates of feedstock are an important aspect of biomass supply chain management. Our research demonstrated how these estimates can be made at fine spatial resolution using readily available remotely sensed imagery and field plots.

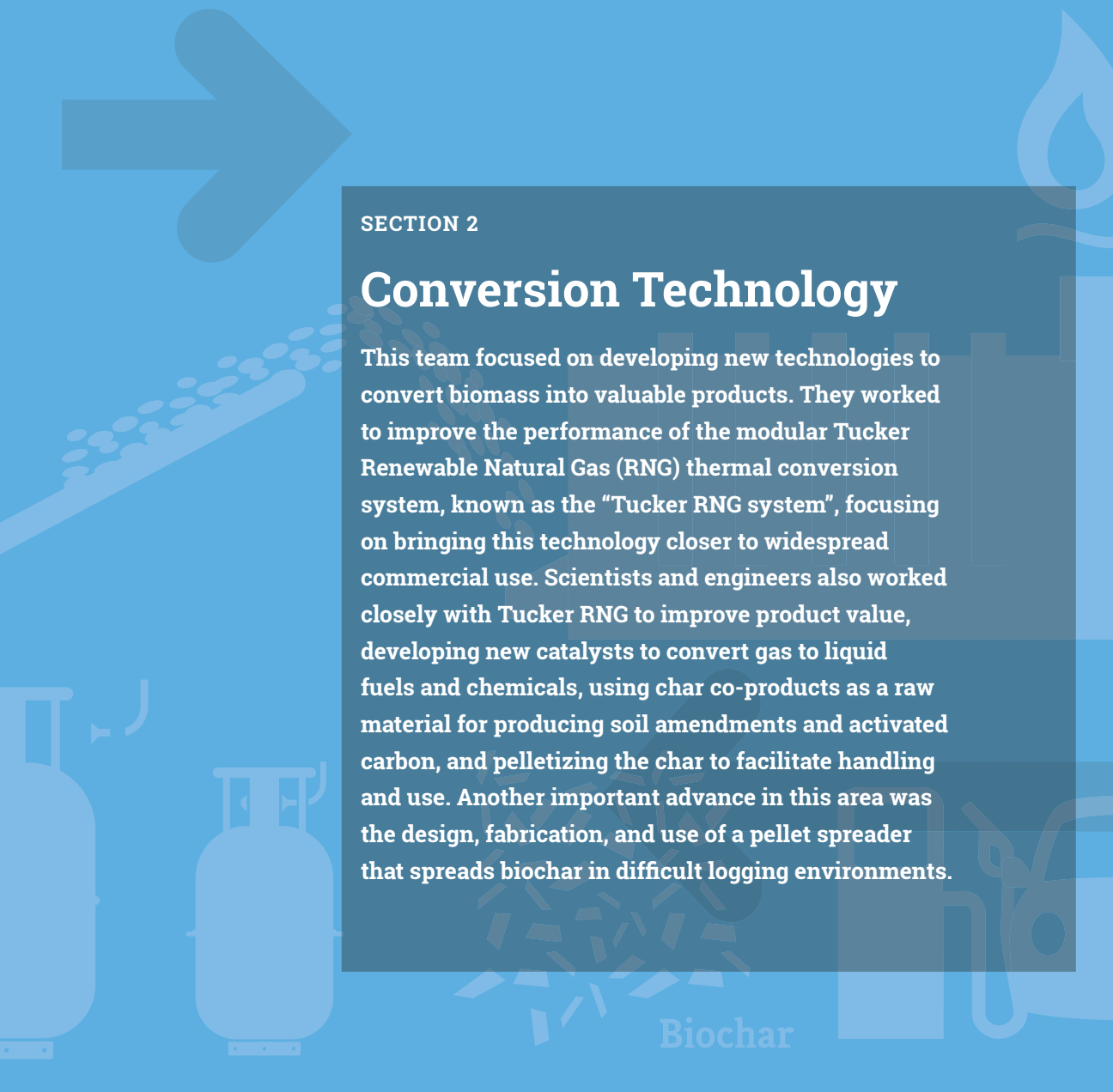
Outcomes

1. Precise depictions of existing feedstock inventory.
2. Improved tools for spatial analysis and modeling of biomass logistics.

Accomplishments

1. Spatially quantified above-ground biomass stocks across large landscapes in Colorado and Montana.
2. Developed new spatial techniques and software to efficiently process "big data".





SECTION 2

Conversion Technology

This team focused on developing new technologies to convert biomass into valuable products. They worked to improve the performance of the modular Tucker Renewable Natural Gas (RNG) thermal conversion system, known as the “Tucker RNG system”, focusing on bringing this technology closer to widespread commercial use. Scientists and engineers also worked closely with Tucker RNG to improve product value, developing new catalysts to convert gas to liquid fuels and chemicals, using char co-products as a raw material for producing soil amendments and activated carbon, and pelletizing the char to facilitate handling and use. Another important advance in this area was the design, fabrication, and use of a pellet spreader that spreads biochar in difficult logging environments.

Biochar



Liquid Transportation Fuels Production from Biomass-Derived Syngas

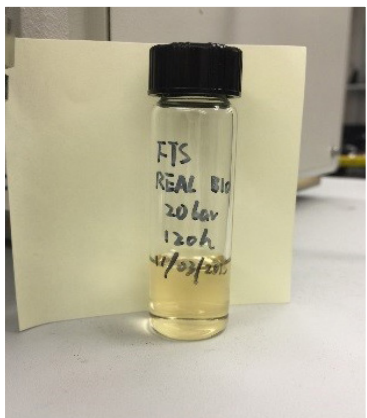
Lead: James Spivey, Professor
Department of Chemical Engineering, Louisiana State University

Biomass-derived syngases produced using a pilot-scale gasifier were upgraded into clean fuels and high-value chemicals using chemical reactions. This project aimed to convert biomass-derived syngas into liquid hydrocarbons using a Fischer-Tropsch synthesis (FTS) process.

Outcomes

1. New approach for converting low-cost biomass materials to high-value products.
2. Developed FTS catalysts with commercial potential.

Liquid fuel synthesized from biomass-derived syngas.



Pilot-scale gasifier in operation.

Accomplishments

1. Synthesized liquid fuels from the syngas derived from the gasification of coniferous wood chips.
2. Designed specific catalysts for carrying out Fischer-Tropsch synthesis (FTS) with unconventional biomass-derived syngas.



Research and Development of Bioenergy Technology

Lead: Richard Tucker, President
Tucker Engineering Associates

The Tucker Renewable Natural Gas (RNG) System is the core conversion technology of the project and produces a methane-rich energy gas and a high-carbon char output from a wide range of feedstocks.

Outcomes

1. Adoption of a new commercial-scale thermochemical conversion technology that can use many different feedstocks to meet a wide range of needs.
2. Lower dependence on fossil fuel systems for energy and broader use of biomass as fuel and feedstock.

Accomplishments

1. Upgraded the prototype, including improved feedstock delivery, secondary heating, char cooling, parallel fuel systems, computer controls, and gas cleanup and storage.
2. Successfully installed and demonstrated the commercial-scale Tucker RNG System at ReVenture Park, Charlotte, NC, including delivering biopower to the grid and producing char for carbon activation trials.



The Tucker RNG thermal conversion system deployed at ReVenture Park, Charlotte, NC.



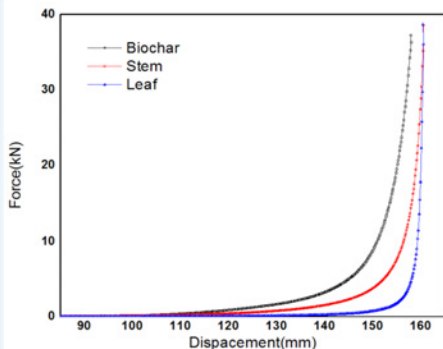
Pelletization of Biochar for Soil Amendments

Lead: Karl Englund, Associate Research Professor
Washington State University

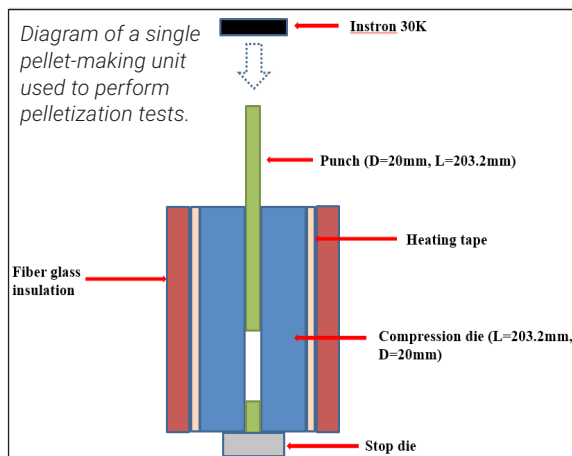
Compression tests were conducted to investigate how biomass materials consolidate during pelletization. Energetic indices were used to characterize consolidation in different stages.

Outcomes

1. Biochar consumed more energy than stem and leaf grinds during pelletization.
2. Better pellet formulations, especially using leaf and slash as a low cost and energy efficient natural binder for biochar pellets.



A typical force-displacement curve.



Accomplishments

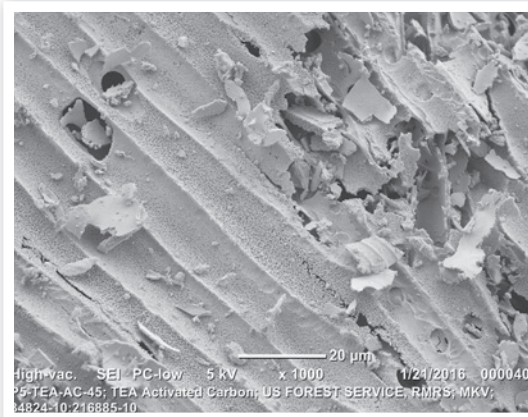
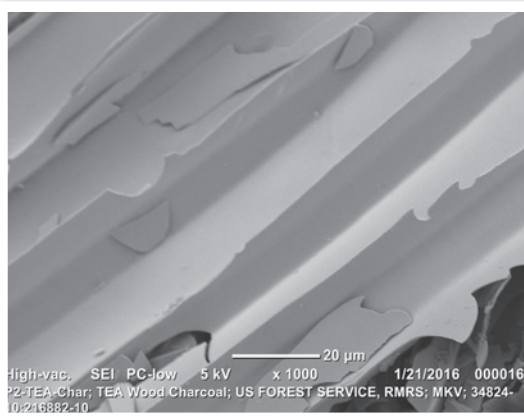
1. Four tons of biochar-based pellets were produced to study forest application using a commercial-scale spreader and its influence on soil properties.
2. Leaf material provides a good binder for pellet durability and also minimizes the energy required to process the pellets, likely indicating the leaf material is also acting as a lubricant.



Activated Carbon from Biochar Co-Products

Lead: Nate Anderson, Research Forester
Rocky Mountain Research Station

This research demonstrated that biochar co-products can be used as a precursor in the manufacture of activated carbon (AC) that has market potential for filtering and other industrial uses.



SEM photos of bulk biochar (left) and activated carbon from that biochar (right) at x1000 magnification.

Accomplishments

1. Activated biochars from three different thermochemical conversion systems, including the Tucker RNG System.
2. Characterized the biochar precursors and resulting ACs for market potential and identified conditions for successful industrial activation.

Outcomes

1. New value-added uses for bioenergy and biofuels co-products, including marketable soil amendments and sorbent products.
2. Better cost competitiveness for bioenergy and bioproducts, leading to wider acceptance and use.



Development of a Prototype In-Woods Biochar Spreader

Lead: Keith Windell, Mechanical Engineer
Missoula Technology & Development Center

Developed a mobile biochar distribution system that allows pelletized or bulk biochar to be spread on logging sites. Soil impacts, operator safety, and operational efficiency were all considered in design.



Use of bulk bags to improve transport and filling efficiency.

Outcomes

1. The ability to apply pelletized and bulk biochar on a commercial scale.
2. Application of biochar can improve soils across large areas and sequester carbon.

Accomplishments

1. A working prototype in-woods biochar spreader was designed and fabricated to help mitigate soil impacts from logging operations on skid trails and landings.
2. An adjustable spinner disk was developed which allows a more consistent distribution of pelletized material than a conventional spinner design.



Applying material on a log skid trail with prototype biochar spreader.



Biochar Soil Application Rates and Impacts

Lead: Deb Page-Dumroese, Research Soil Scientist
Rocky Mountain Research Station

Spreading biochar can be difficult in forests because of the need to keep the forest floor intact and to avoid stumps and residual trees. Using a biochar spreader allows for various application rates with few soil impacts.

*Biochar pellets
applied to forest
sites.*

*Collecting soil
data after biochar
application.*

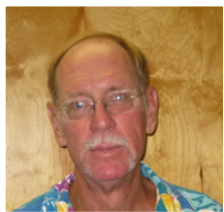


Outcomes

1. Biochar can be easily applied to forest sites to minimize compaction, retain nutrients and water, and sequester carbon.
2. Biochar application rates can be altered depending on site conditions and restoration objectives.

Accomplishments

1. Determined that 10 tons per acre of biochar is an ideal rate for many forest sites and soils in the western United States.
2. Determined that when a forest floor is present, there are few compaction problems associated with the spreader.



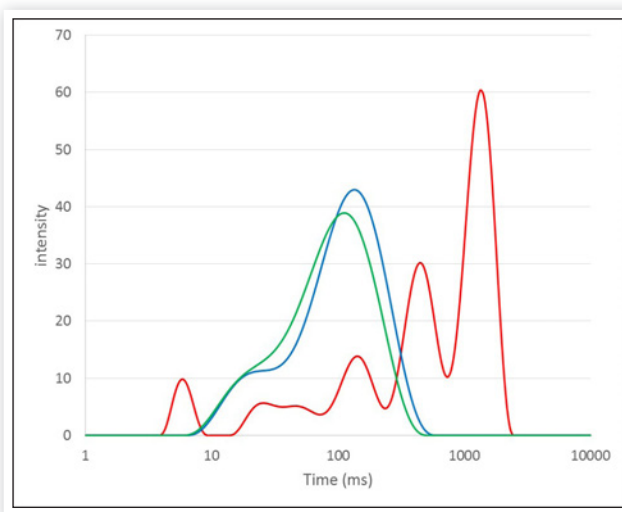
Low-Field Nuclear Magnetic Resonance Analysis of Biochar

Lead: Thomas Elder, Research Scientist
Southern Research Station

Low-field nuclear magnetic resonance spectroscopy (NMR) can provide information about how activation alters the surface chemistry and porosity of biochars. These results are used to complement other analyses to determine the effect of activation.

Outcomes

1. Activation processes can now be tailored to yield particular properties amenable to specific uses.
2. Activated biochar is much more consistent, and therefore more marketable.



Relaxation distribution of water in bulk biochar (red) and activated biochar (blue and green).

Accomplishments

1. Differences in the surface chemistry and/or porosity were detected between biochar and activated biochar indicating increases in filtration or adsorption properties.
2. Activated samples were consistent, while the bulk biochars were variable with numerous populations of water.





SECTION 3

Sustainability

This team worked to evaluate the social, environmental, and economic impacts and potential costs and benefits of biomass systems. Researchers quantified the net greenhouse gas emissions of biomass products compared to alternatives and quantified the soil and watershed impacts of forest biomass harvest. Economists and social scientists on the team developed financial models for distributed scale biomass conversion, evaluated potential rural economic development impacts, characterized social preferences for biomass energy, and conducted research to examine the attitudes and perceptions of various stakeholder groups, including National Forest managers.



Biochar





Environmental Performance of New Bioenergy and Biochar Technology

Lead: Richard Bergman, Forest Products Technologist
Forest Products Laboratory

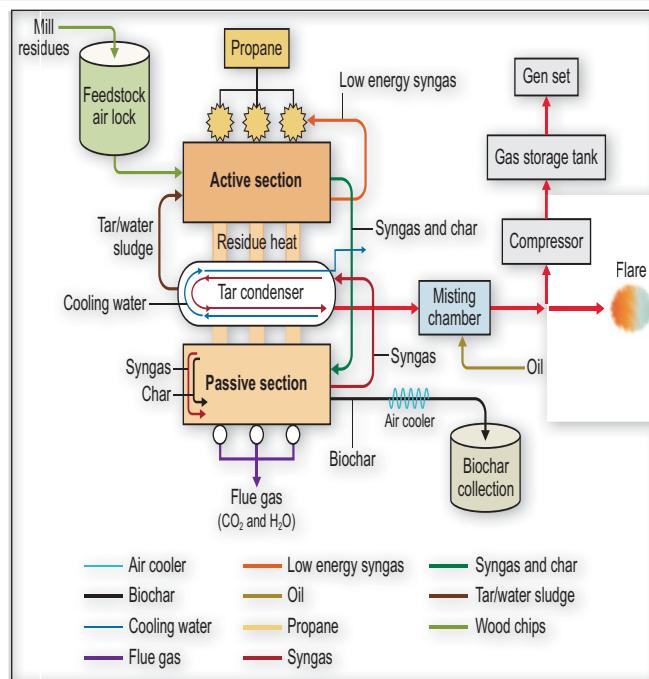
Life Cycle Assessment categorized the environmental impacts of the entire supply chain associated with all steps of the biochar system, from biomass harvesting through novel biochar and syngas production to high-value biobased products.

Outcomes

1. Reduced greenhouse gas emissions at wood product production facilities operating the new distributed-scale thermochemical conversion units.
2. Produced a low-carbon, high-grade activated carbon to use for gas and liquid filtration applications.

Accomplishments

1. Categorized the emissions and energy profiles for biochar and synthesis gas production of the Tucker RNG system.
2. Categorized the emissions and energy profiles for production of high-grade activated carbon from biochar.



Tucker RNG system process flow diagram.



Evaluation of Watershed Impacts of Biomass Utilization

Lead: William Elliot, Research Engineer
Rocky Mountain Research Station

We measured erosion and hydraulic conductivity on three sites where biomass harvesting had occurred and measured snow accumulation and melt on a fourth site.

Outcomes

1. Minimal watershed impacts occur from onsite biomass harvesting, but best management practices are recommended to minimize erosion on adjacent trails and roads.
2. An online tool is now available to evaluate the erosion risks associated with biomass utilization.



Highly disturbed soil with an increased risk of erosion on an access road to the site.

Accomplishments

1. Primary watershed impacts of harvesting biomass are increased erosion risk from access roads and decreased snow interception by forest canopy.
2. Decreases in canopy following a biomass harvest could result in small increases in water yield and earlier, higher peak flow rates in the spring from treated watersheds.



A hydrologist measuring hydraulic conductivity on a biomass utilization site.



Long-Term Vegetation Impacts of Bioenergy Harvesting

Lead: Christopher Keyes, Research Professor of Silviculture
University of Montana

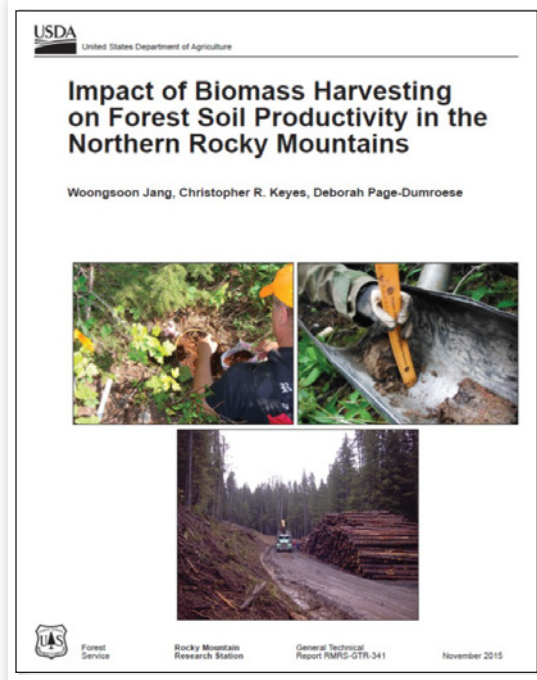
There are many concerns over adverse impacts on productivity after intensive biomass utilization. We demonstrate that vegetation production after these types of harvests was not significantly affected.

Outcomes

1. An understanding of long-term biomass utilization and burning impacts on forest vegetation in the Inland Northwest.
2. We understand productivity changes in cool, moist Inland Northwest forest, but future work on different sites and soil types will help provide additional information on long-term impacts.

Accomplishments

1. Results show long-term vegetation changes after intensive utilization and burning are related to regeneration dynamics or burning.
2. Cool, moist forest sites are resilient to regeneration cutting methods and broadcast burning.



General Technical Report RMRS-GTR-341, published November, 2015.



Long-Term Soil Impacts of Bioenergy Harvesting

Lead: Deb Page-Dumroese, Research Soil Scientist
Rocky Mountain Research Station

Bioenergy harvest operations are thought to impact nutrients, carbon pools, and productivity. We demonstrated that 38 years after harvest soil properties have nearly returned to pre-disturbance levels and there were few long-term soil impacts.

Outcomes

1. An understanding of what constitutes sustainable biomass harvest operations in the Inland Northwest.
2. Improved harvest operations that maintain the forest floor and minimize effects on above- and below-ground productivity.

Accomplishments

1. Results show long-term impacts from bioenergy harvesting are minimal on productive forest sites, especially if skyline logging is used in-place of ground equipment.
2. Identified site conditions where soil carbon is resilient to harvest operations.



Brian Morra and Eric Doubet (RMRS-Moscow) collecting soil cores from the Coram Experimental Forest.



Using Biomass for Rural Economic Development

Lead: Dan McCollum, Research Economist
Rocky Mountain Research Station

Products from woody biomass enhance the feasibility of silvicultural and fuel treatments. Processes used to collect and convert the biomass lead to rural economic development, more sustainable communities, and social and ecological benefits.

Outcomes

1. Relying on multiple diverse products and uses based on woody biomass rather than a single use, such as energy or wood pellets, can be a more stable path to creating and maintaining more sustainable rural communities.
2. Increased utilization of woody biomass contributes to mitigating and living with climate change by: reducing greenhouse gas emissions, offsetting fossil fuels, sequestering carbon, and retaining soil moisture.

Accomplishments

1. Biochar pellets manufactured from slash piles remaining after forest operations can transform a costly disposal problem into a value-added product.
2. Forests are a sustainable source of biomass that can be used to produce multiple value-added products, and production processes can be a source of social and ecological benefits beyond the products themselves.

Thinning and fuel reduction treatments, such as those in beetle-killed forests, can yield value-added biochar.





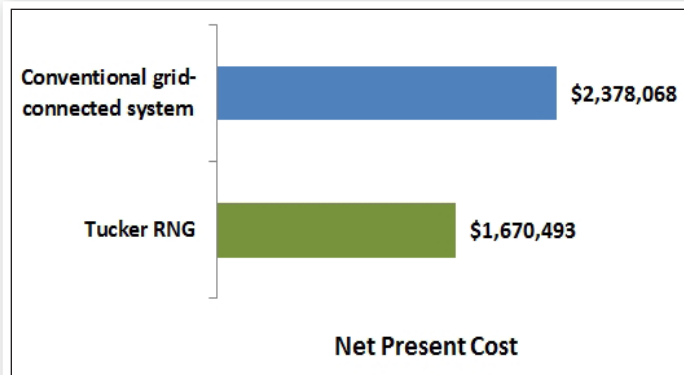
Economic and Financial Analysis of the Tucker RNG System

Lead: Martin Twer, BioEnergy Associate Specialist
University of Montana & Montana State University
Extension Service

Understanding the economics of converting woody biomass into electricity, heat, and biochar is important to assessing feasibility. This work focused on the costs of energy and feedstocks, the value of products, and policies that affect the adoption of conversion technology.

Outcomes

1. Better understanding of profitability for investors and communities interested in bioenergy.
2. Detailed understanding of key financial parameters may lead to the increased use of distributed-scale renewable energy systems.



Comparing costs and revenues from the Tucker RNG system and a conventional heat and power source over a 20-year period.

Accomplishments

1. Determined key financial parameters of operating the Tucker RNG system at a sawmill using wood waste.
2. Developed a better understanding of the relative importance of cost, revenue, and productivity variables in determining woody biomass conversion technology profitability.



Needs Assessment & Social Science Research

Lead: Maureen Essen, Research Associate
Rocky Mountain Research Station and
University of Montana

Listening to people and understanding the social landscape of forest management and woody biomass is important for identifying new avenues of research and development. As a result of this work, we understand many of the questions managers struggle to answer as they strive to improve forest stewardship.



*Forest Service employees at a workshop in
Utah in December, 2015.*

Outcomes

1. Better understanding of the use of science in forest planning and the needs of forest planners, including human dimensions of forest management, wildlife, and climate change.
2. Improved communication between scientists and practitioners.

Accomplishments

1. Interviewed 35 forest managers regarding forest planning and the use of science in the forest planning process.
2. Planned and facilitated a workshop with scientists and forest managers focused on using and accessing science for forest management.

***“That is what planning is about:
what do people want to see
from their land, their public
lands, so doing the best we can
to actually understand that is
what I am talking about”***

- Forest Planner



Socioeconomic Effects of Woody Biomass Energy

Lead: Tyron Venn, Senior Lecturer in Economics

University of the Sunshine Coast, Australia (formerly UM)

The harvest and utilization of woody biomass for energy generation can create external environmental effects. Although often not captured in markets, they affect public wellbeing and influence the socioeconomic efficiency of the technology.

Outcomes

1. The average household is willing to pay extra for energy produced with woody biomass harvested on public forests.
2. Public preferences can inform decision making by public land managers and policy makers.

Accomplishments

1. Conducted a choice modeling survey in Montana, Colorado, and Arizona.
2. Quantified willingness to pay for woody biomass energy, forest health, air quality and wildfires.

Choice Set 1				
Attribute		Expected outcomes over 10 years		
		Strategy A	Current Strategy	Strategy B
Homes powered with wood in my state		30,000 homes	20,000 homes	10,000 homes
Unhealthy air days in my community		5 days per year	10 days per year	30 days per year
Large wildfires in my state		12 large wildfires per year	12 large wildfires per year	9 large wildfires per year
Forest health in my state		60% healthy forests	20% healthy forests	20% healthy forests
My household's monthly energy bill		\$200 (\$2,400 annually)	\$100 (\$1,200 annually)	\$120 (\$1,440 annually)
I would choose (select one only)		☐	☐	☐

Example of a choice set to quantify preferences toward woody biomass energy and attributes.



Cover of choice modeling survey.



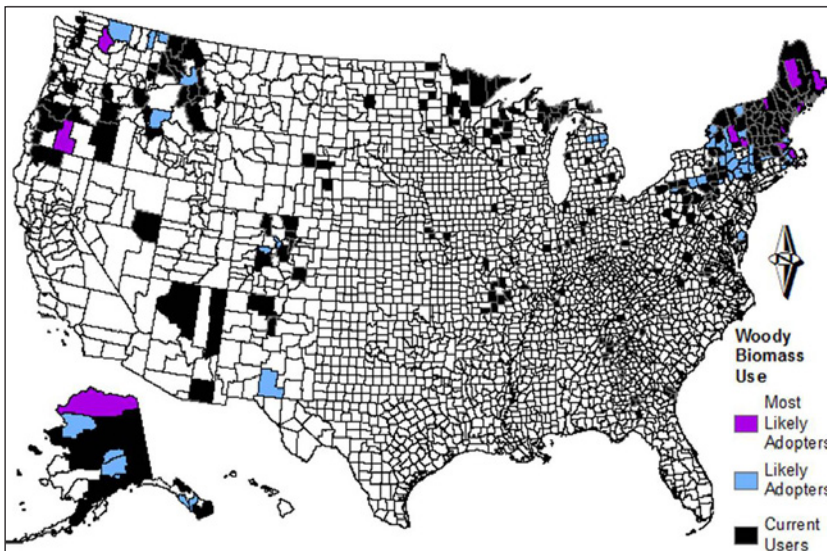
Economics of Institutional Biomass Heating

Lead: Jesse Young, Research Associate
Rocky Mountain Research Station and
University of Montana

Accomplishments

Forest management produces abundant woody biomass suitable for bioenergy applications. This research examined the economic and policy factors that influence the adoption and operation of small-scale biomass combustion systems.

1. Identified economic and policy factors influencing the adoption of decentralized biomass heating systems.
2. Influential factors included heating needs, fossil fuel prices, policies relating to National Forests and the National Fire Plan, and proximity to woody biomass resources, specifically logging residues.



Outcomes

1. Key stakeholders can inform successful installation and operation of decentralized biomass heating.
2. Better information to guide future policies designed to incentivize decentralized use of woody biomass energy.



Education and Outreach

Lead: Maureen Essen, Research Associate
Rocky Mountain Research Station and
University of Montana

Sharing new information with practitioners and stakeholders is important to successfully implement research findings. Ensuring the full range of stakeholders are aware of and involved in promoting project successes also helps highlight and identify future areas of research.



Outcomes

1. Better informed land management that takes into considerations the best available science concerning forest biomass utilization and conversion technology.
2. Better communication among stakeholders and scientists.

Accomplishments

1. Wrote and published two practitioner-oriented RMRS "Science You Can Use" bulletins highlighting BRDI project results and applications.
2. Conducted two companion research webinars broadcast nationwide.



Next Steps

This project developed new technologies and processes necessary for abundant commercial production of bioenergy, biofuels, and bioproducts from biomass, and facilitated the development of economically and environmentally sustainable sources of biomass feedstocks.

This work has already spawned new and exciting opportunities to apply project results and outcomes in all three technical areas and in both the private and public sectors, informing sustainable practices, investment decisions, and public policy. Collectively, these impacts will undoubtedly continue to strengthen the U.S. bioeconomy by expanding the production and use of sustainable woody biomass to meet a wide range of energy and product needs.



Jump Trucking ready to grind biomass at F.H. Stoltze Land and Lumber.



A break from winter fieldwork in Lubrecht Experimental Forest.

More Information

For more information about the project, as well as pdf versions of this book and project publications, please visit the project web page at:

www.fs.usda.us/rmrs/projects/integrating-sustainable-biofuels-and-bioproducts-forest-industry-supply-chains
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