



Not Your Usual Power Plant.

AT THE UNIVERSITY OF GEORGIA, CONSERVATION AND RENEWABLE ENERGY ARE ON *FAST FORWARD*

The Grand Challenge:

BY THE YEAR 2025, AMERICA'S FARMS, RANCHES AND FORESTS WILL PROVIDE 25 PERCENT OF THE TOTAL ENERGY CONSUMED IN THE UNITED STATES, WHILE CONTINUING TO PRODUCE SAFE, ABUNDANT AND AFFORDABLE FOOD, FEED, AND FIBER.

Imagine the strength and stability of a nation with two million energy producers: the individuals that comprise our country's agriculture and forestry industries. From biofuels to the capture of energy from wind, water, solar and geothermal sources, agricultural land, agricultural producers and agricultural scientists are playing increasingly important roles in energy production and conservation. Within 10 years we expect 17 percent of the United States liquid fuels and electrical energy to be from renewable sources, the majority of that produced on U.S. farms and forests.

Georgia's warm, humid climate and vast agricultural and forested lands produce huge quantities of biomass each year. Our research, extension and education efforts in renewable energy mirror

these resources. Georgia farm efficiencies and conservation efforts—in natural resource use, fuel, electricity and other purchased inputs and human talent are increasing, and UGA is aiding this movement.

Not Your Usual Power Plant presents some of the key conservation and renewable energy programs at the University of Georgia, which is at the hub of bioenergy in Georgia. Focused through UGA's Biofuels, Biopower, Biomaterials Initiative (B3I) (www.bioenergy.uga.edu), over 80 scientists, engineers, entrepreneurs, policy and communications experts representing UGA's research, extension and teaching programs are helping forge the state's and the country's bioenergy future. Highlighted here are major UGA efforts notable for their collaboration—internal, external, public and private.

It's not just our country's economic future that's linked to the outcomes—it's the future of generations to come, the world over.

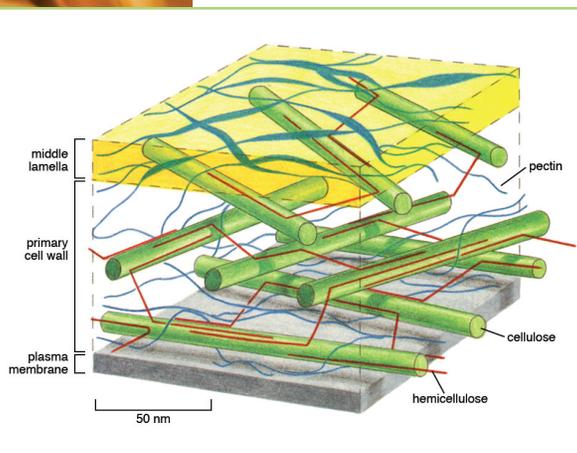


THE CHALLENGE AND PROMISE OF RENEWABLE ENERGY ARE HUGE.

AT UGA, THE COMMITMENT IS, TOO.

Cell Wall Secrets

University of Georgia scientists are partners in the Bioenergy Science Center (BESC), a cross-disciplinary team of world-leading experts aiming to make revolutionary advances in overcoming biomass recalcitrance using biotechnological approaches. The BESC is one of three new \$125 million research centers funded by the U.S. Department of Energy whose aim is to make cellulosic biofuels cost competitive with gasoline by 2012.

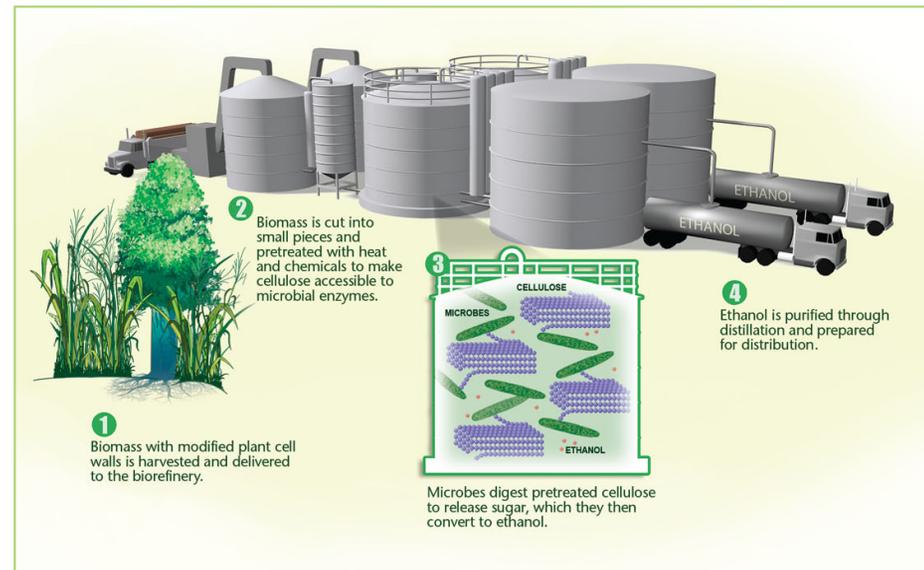


The UGA BESC team builds on the University's strengths in carbohydrate science and plant and microbial genetics. Its researchers conduct fundamental science that bridges the gap between the potential of cellulose-based fuels and

their reality. Their goal: to find the plants, microbes and enzymes that enable biomass to release their energy stores easily.



UGA's partners in the BioEnergy Science Center include the Oak Ridge National Laboratory, University of Tennessee, Dartmouth College, Georgia Institute of Technology, the National Renewable Energy Laboratory, Samuel Roberts Noble Foundation, ArborGen, Diversa Corp. (now Verenum Corp.), and Mascoma Corp.



Cellulosic Biomass Processing: *The Future*

The resistant nature of cellulosic biomass makes processing plants for conventional fuel ethanol very costly. To date, no cost-effective bioprocessing methods for cellulose-based bioenergy sources have been demonstrated, although there are many promising concepts being developed in the labs at UGA and across the country.

The BESC project at UGA uses biotechnology approaches to consolidate enzymatic breakdown of cellulose and microbial fermentation of sugars into a single step.

Development of consolidated bioprocessing will result in the largest cost reduction of all R&D-driven improvements.

Using Nature's Biorefineries as Models

Microbes have a critical role in bioenergy conversion, yet less than 1 percent of the microbial world has been characterized. The extent of all that these highly adaptable microorganisms—bacteria, archaea and fungi—can do remains largely unknown. Examining how microorganisms in concert with plants and animals take apart biomass reveals useful mechanisms for an efficient process that can be mimicked on an industrial scale. Using the tools of molecular biology and genomics, researchers ask, “What can we learn from these microorganisms about breaking down biomass—like a tree, or switchgrass?”

One such habitat rich with diverse and previously undiscovered organisms and enzymes is insect digestive systems, which are chock-full of microbes that enable them to digest their biomass food for energy.



Putting It All Together

Over the next five years, researchers in a variety of scientific disciplines at 10 BESC partner institutions will collect immense quantities of data about the expression of genes in the cell wall, the chemical and structural features of the cell wall, and the interaction of biomass and microbes as a system.

The tools of computational biology enable scientists not only to archive, search and retrieve these data, but more importantly, to integrate them, turning disparate pieces of data into valuable informa-

UGA BIOCHEMIST MIKE ADAMS AND OTHER BESC RESEARCHERS SEEK TO IDENTIFY NEW MICROBES OR MICROBIAL COMMUNITIES AND FIND WAYS TO EMPLOY BIOTECHNOLOGY TO INCREASE THE EFFICIENCY OF BIOMASS CONVERSION.

AS PART OF THE BESC PROJECT, WILL YORK STUDIES THE STRUCTURE AND DYNAMICS OF CARBOHYDRATES IN PLANT CELL WALLS USING ANALYTICAL TOOLS SUCH AS THE 900 MHZ NUCLEAR MAGNETIC RESONANCE SPECTROMETER. THIS NMR USES SUPERCONDUCTING MAGNETS TO LET RESEARCHERS CHARACTERIZE BIOLOGICAL STRUCTURES AT THE MOLECULAR LEVEL.



tion and insights into the plant cell wall. Their goal: to generate and then test hypotheses about how proteins and genes control the assembly—and deconstruction—of the plant cell wall.

“Ultimately,” says Will York, biochemist and bioinformaticist at UGA’s Complex Carbohydrate Research Center, “understanding the relationship between the cell wall structure and recalcitrance will enable researchers to develop plants with cell walls that are more amenable to bioprocessing.”

Breeding a Better Biofuel

Researchers are working to develop better bioenergy crops: low-cost, high-quality biomass plants that can replace corn as the conventional biofuel source. The poplar tree and switchgrass, a native grass that can be easily grown in most of the U.S., including Georgia, have been identified by the Department of Energy as the model crops for bioenergy production. At UGA, the BESC team focuses on switchgrass, while partners focus on poplar.

Using the tools of molecular biology and genetics, plant geneticists on the BESC research team at UGA are identifying the genes responsible for promoting characteristics that make plants well-suited for cellulosic biomass feedstocks—fast growth, short rotation, drought tolerance, and pest and disease resistance. Genetics can also be used to “design” plants with cell walls that are less resistant to breakdown, and thus require fewer resources for bioprocessing.



SOME PLANT GENOMES ARE EASIER TO STUDY THAN OTHERS. BESC TEAM MEMBER JEFFREY BENNETZEN, A PLANT GENETICIST, STUDIES SWITCHGRASS. HE ALSO IS STUDYING FOXTAIL MILLET, A CLOSE RELATIVE OF SWITCHGRASS, NAPIERGRASS, AND PEARL MILLET – ALL BIOFUEL CANDIDATES. SWITCHGRASS HAS BEEN TARGETED AS A BIOFUEL WITH HIGH POTENTIAL BECAUSE OF ITS ADAPTABILITY, BUT ITS LARGE GENOME SIZE MAKES IT A TOUGH PLANT TO CHARACTERIZE GENETICALLY. BECAUSE FOXTAIL MILLET LAST SHARED A COMMON ANCESTOR WITH SWITCHGRASS LESS THAN 30 MILLION YEARS AGO, THEY HAVE ENOUGH IN COMMON THAT FOXTAIL MILLET CAN “STAND IN” FOR SWITCHGRASS AS RESEARCHERS SEEK TO IMPROVE ITS CHARACTERISTICS.

Switchgrass, a native grass of the prairies, has been cultivated for a very short time, and little is known about its genome. In contrast, the entire genome of another top biofuel candidate, the poplar tree, was mapped in 2004. UGA plant biologist Katrien Devos is one of the researchers recently funded by the U.S. Department of Energy and the U.S. Department of Agriculture to provide the scientific foundation for improving switchgrass as a bioenergy crop. Devos and collaborators will construct a detailed genetic map of switchgrass and align it with maps produced in rice, maize and sorghum – cereal crops whose genes and traits are well-studied. This will help breeders enhance those traits that are critical to bioenergy production.

“DOUBLING THE ENERGY OUTPUT PER ACRE OF SWITCHGRASS WITHIN FIVE TO EIGHT YEARS IS A REALISTIC GOAL,” SAYS DEVOS.

“Crops like switchgrass will be an important part of the mix of approaches that replace U.S. oil dependence, and thus our development of foxtail millet as a genetic model will hasten the day of U.S. energy independence.”

– Jeff Bennetzen, professor of genetics



Fueling Georgia

Georgia, a state teeming with biomass, is primed to tap into the nationwide push to convert switchgrass, soybeans, poultry litter, animal fats, forestry residues and many other biomass waste products into biofuels. As a state that imports all its petroleum-based energy products and has a rapidly growing population and vibrant economy, Georgia's investment in sustainable supplies of renewable energy is key to its future. UGA has responded to this opportunity over the years. Since the late 1970s when UGA engineers ran campus and city buses on peanut oil, UGA engineers have continued to contribute to the knowledge base required to produce alternative fuels. In the 1990s UGA engineers were the first to use waste poultry fat to produce heat and power, and biodiesel. Today the poultry industry realizes significant value from what was a burdensome waste a decade ago; Georgia has one of the largest poultry-fat-based biodiesel plants in the U.S.

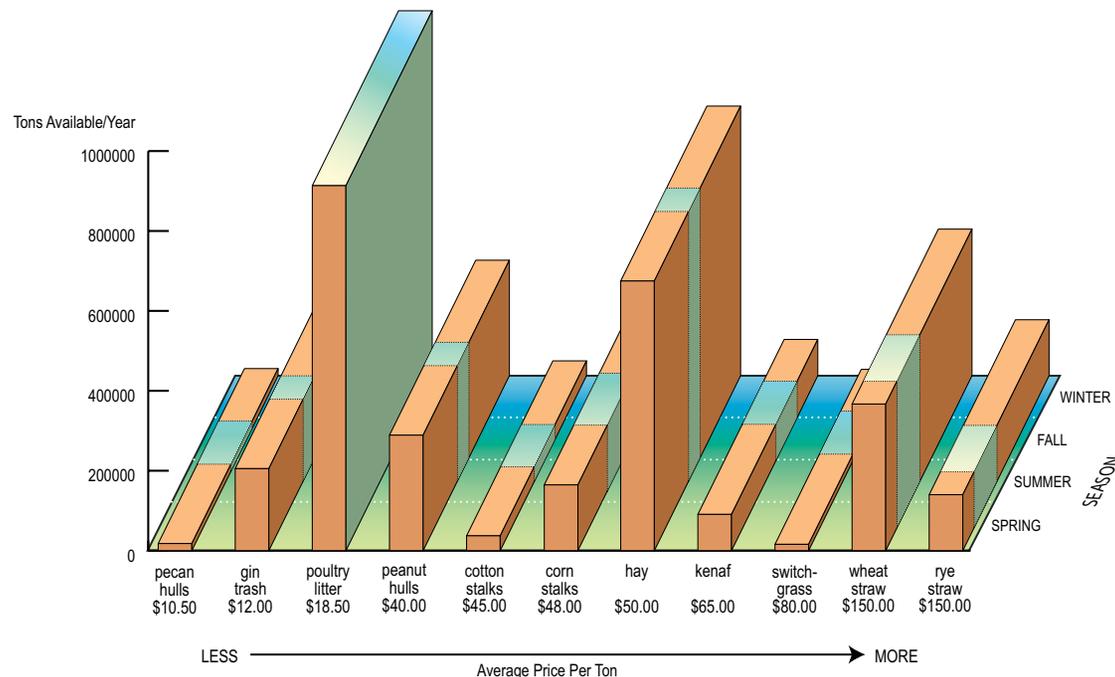


PHOTOGRAPH COURTESY OF DAVID J. MOORHEAD, UNIVERSITY OF GEORGIA, BUGWOOD.ORG

FORESTS COVER ALMOST TWO-THIRDS OF THE STATE, GENERATING 18 MILLION OVEN-DRIED TONS PER YEAR AT APPROXIMATELY \$48/TON DELIVERED. GEORGIA'S BIOMASS MAKES IT AN ATTRACTIVE LOCATION FOR BIOENERGY AND BIOREFINING INDUSTRY INVESTMENT.

Further expanding the potential of using our forestry and agricultural resources to develop a sustained bio-based economy, UGA engineers and scientists have developed a Biorefining and Carbon Cycling research and development program. Program goals include developing fuels and chemicals technology based on Georgia's plentiful forestry and agricultural residues.

GEORGIA AGRICULTURAL AND FORESTRY BIOMASS SUPPLY AND DELIVERED PRICES
UGA CENTER FOR AGRIBUSINESS AND ECONOMIC DEVELOPMENT – 2007



Georgia's Bioenergy Wealth

Using renewable resources that are close to home keeps research, development—and, eventually—production costs down. Oilseed crops grown in Georgia, such as soybeans, cottonseed, canola, sunflowers and peanuts, are among Georgia's ready sources of feedstock for biodiesel fuel production. Waste stream or by-product products, which are both a reliable resource and easy to convert into energy, are also significant feedstock resources in Georgia. Forestry residues, waste animal fat, industrial and municipal wastes, restaurant grease, agricultural products that can't be sold to supermarkets—including bruised watermelon and peaches—and even outdated cola and juice products are being used to produce biofuels.

An Economic Engine

A few bioenergy companies are now operational in Georgia, several have broken ground, and dozens more are interested in locating in the state. Entrepreneurs recognize the state's bioenergy receptivity, a ready market for several hundred million gallons of ethanol (used as an oxygenate in gasoline), growing markets for fuel, heat and power, and the ready availability of biomass. Georgia is projected to produce one-half billion gallons of biofuel—100 million in biodiesel and 400 million in ethanol—by 2012.

The state's Agriculture Innovation Center, located on UGA's Tifton Campus, offers companies interested in developing new bioenergy technologies using Georgia's agricultural crops and byproducts access to UGA bioenergy research and development experts.

New Ways of Thinking

The greatest challenge to advancing energy conservation and renewable resources is the human side—the conversion of thinking about a different path. We must recruit new talent into an old industry that has not been considered as a career path by most talented young people. Today in Georgia, we bring K-12 teachers into our labs for the summer, engage high school students in “young scholars” programs and send stimulating scientists to local

schools to excite the minds of students. Through undergraduate, graduate and post-doctoral programs, new courses, and repurposed old ones, we will develop the next generation of scientists, engineers, and policy experts who will provide the vision for the future of sustainability, energy conservation and energy efficiency. Active workforce development partnerships with community colleges and trade schools accompany renewable energy workshops and conferences held each year.

Our Extension Service reduces risk associated with change by providing solid information and constant contact with all members of this still emerging industry. By 2012 advanced communication tools have enabled our Extension Service to be in more than one place at a time, and better responses to questions come quicker because of this. Our model of information delivery has become more like a network than a pipeline. Field days at UGA's Midville station continue to overflow as this site has emerged as one of the region's best for information on energy crop performance, on-farm energy conservation, and generation technologies. The field

day lets attendees touch tomorrow's technologies. During the past decade our Center for Agribusiness has helped over 100 renewable energy start-up companies successfully launch, and diverted a few less than stellar ideas into the circular file before too much time and energy was wasted.

“We probably wouldn't be here if it weren't for UGA.”

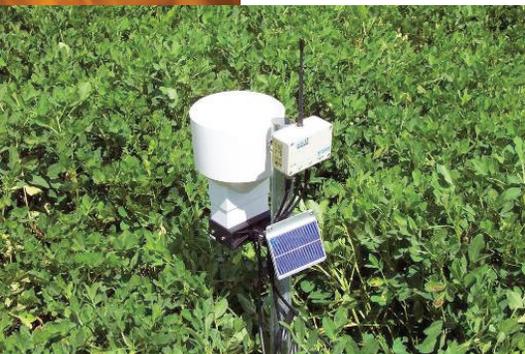
- Alterra president Wayne Johnson



MANY OF THE EMPLOYEES AT ALTERRA'S BIODIESEL PLANT IN GORDON, A SMALL TOWN IN MIDDLE GEORGIA'S RURAL WILKINSON COUNTY, LEFT SECURE JOBS IN OTHER INDUSTRIES, BETTING ON BIOFUELS' FUTURE IN GEORGIA. ALTERRA PRESIDENT WAYNE JOHNSON (FAR RIGHT) SAYS HE RELIED HEAVILY ON THE TECHNOLOGICAL EXPERTISE OF UGA RESEARCHERS AND ENGINEERS. ALTERRA IS BUILDING ANOTHER BIODIESEL PLANT IN PLAINS AND PLANS TO OPEN OTHER FACILITIES IN THE STATE.

The Future Farmstead

Years before we reach 2017, improvements in energy conservation and efficiency will become important personal, state and national goals. Over the next 10 years we will see net energy outputs from agriculture continue to climb as farm machinery becomes more energy efficient and cultural practices that save time, energy and natural resources increasingly are adopted. Crop cultivars, better adapted to local conditions and tailored to a market, will enhance profitability while conserving energy.



UGA's Future Farmstead group focuses on efficiency as a way to save energy, time and natural resources. With public and private partners, we look to plant genetics, advanced communication technologies, and common sense strategies for help. A mixture of communication technologies, sensing and control systems promise to save a minimum of 15 percent in energy costs.



Farmers from Georgia to North Dakota are already using UGA-developed variable rate irrigation systems that reduce water and energy use by 12 percent while increasing yield. USDA and UGA plant breeders just released new peanut cultivars that require less inputs and trips over the field; the best is always yet to come as improvements are constantly developed. Cell phones connected to wireless Internet systems check on dryer temperatures,

irrigation systems, and operations in a vegetable packing shed—reducing travel and saving time. Tiny, fuel-efficient autonomous tractors guided by GPS spray, cultivate, mow or even plant seed as they work 24 hours a day, receiving instructions from anywhere an Internet connection is found.



MOST FARMS ARE SCATTERED OVER A LARGE GEOGRAPHIC AREA. THIS MEANS A LOT OF TIME AND ENERGY IS SPENT ON THE ROAD, JUST CHECKING ON THINGS. WIRELESS INTERNET CAN DELIVER SENSOR INFORMATION, PICTURES, ANIMAL LOCATION AND CONTROL EQUIPMENT—ALL FROM A CELL PHONE.

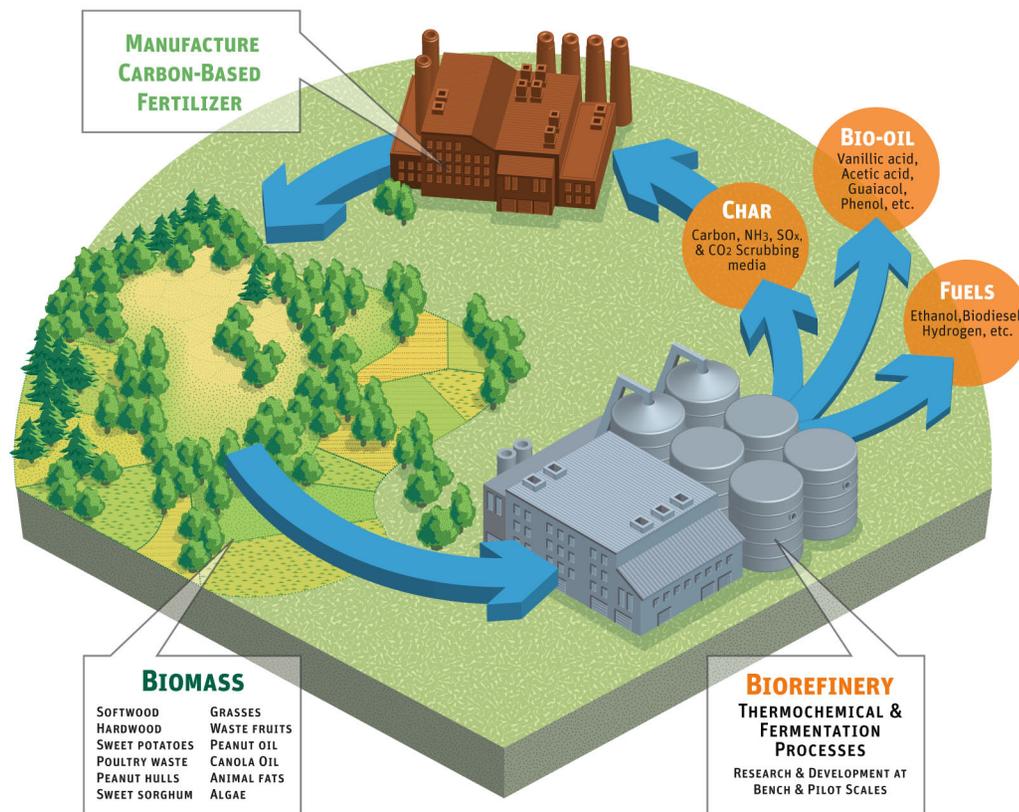
Biorefinery and Carbon Cycling

Following the model of the petrochemical industry, the biorefining industry is looking to produce multiple alternative fuels—ethanol, biodiesel, green diesel, heating oil—and also provide renewable bio-oil to chemical companies that manufacture consumer and industrial products.

UGA engineers and scientists have collaboratively launched an innovative and multi-disciplinary Biorefining and Carbon Cycling Program centered around the integrated biorefinery. The pilot-scale integrated biorefinery processes a myriad of biomass feedstocks, including agricultural waste and forest biomass, to produce a variety of fuels and a diversity of revenue-generating products.

The highly flexible biorefinery subjects various biomass to high-temperature processes, such as pyrolysis and gasification, to produce a gas called “synthesis gas,” or SynGas, made mostly of carbon monoxide and hydrogen, or alternatively, to produce bio-oil and char. The syngas or bio-oil can be further processed into fuels such as ethanol and methanol; a diesel fuel extender that can be blended into petroleum diesel; fuel gases (hydrogen and downstream products); and bio-oils that can be mined for valuable byproducts, such as flavorings and adhesives.

CELLULOSIC CROPS ARE NOT THE ONLY ALTERNATIVE FUEL PRODUCTS PLENTIFUL IN GEORGIA. POULTRY LITTER, MANURE MIXED WITH BEDDING MATERIAL, IS ONE OF THE STATE’S ENERGY-RICH WASTE BY-PRODUCTS. K.C. DAS, COORDINATOR OF UGA’S BIOREFINING AND CARBON CYCLING PROGRAM, AND HIS RESEARCH TEAM ARE DEVELOPING TECHNOLOGIES TO SEPARATE THE LITTER INTO TWO TYPES OF MATERIAL: A FERTILIZER AND AN ENERGY SOURCE. THE LATTER IS THEN SUBJECTED TO PYROLYSIS, AND SEPARATED INTO BIO-OIL, WHICH CAN BE USED AS DIESEL-LIKE FUEL, AND CHAR.



In the integrated biorefinery, the environment is also a big winner. Since the bio-refinery uses agricultural waste like peanut hulls and poultry litter, waste wood like forest residues and lumber byproducts, as well as other byproducts, the technology also turns an environmental obstacle into an environmental advantage. The solid carbon product (char) generated in the integrated biorefinery can be used as a soil amendment, returning carbon to the earth, thus promoting the growth of another biomass feedstock and completes the carbon cycle.

THE INTEGRATED APPROACH HAS BEEN IDENTIFIED AS THE MOST PROMISING ROUTE TO MAKING THE BIOREFINERY ECONOMICALLY VIABLE AND SELF-SUSTAINING.



The Transformational Process for 2025

To meet the aggressive goals set forth for America, the passion of the 25x'25 Alliance must also inspire the thoughts and actions of scientists, policymakers, journalists, and advocacy groups. The science and technology that underpin cellulose to ethanol conversion, crops that generate biomass, the production of biofuel-based by-products, and energy efficiency will not be the barriers to attaining the 2025 goal. A commitment to the vision of a sustainable future—one that is shared by consumers in every segment of society, industry, media, and policymakers—is the essential requirement.

The critical transformation process is change of perception, which is at the heart of our opinions, beliefs and value system.

A vision for that transformation process includes:

- Broad understanding of why America's farms, ranches and forests must intertwine renewable energy generation with the production of safe, abundant and affordable food, feed and fiber and how this process will impact the consumer and the country in the short and long term. What happens if we choose a different path?



- Clear goals for achieving renewable, sustainable energy. What actions are needed by individuals, by communities, state and national goals? What are the consequences of not achieving these goals?
- A roadmap for progress, with achievable milestones. The public wants to know what to do, how to do it, and why now.
- Widely-held recognition that to be sustainable, real change is incremental. We cannot lose focus on the problem to be solved and get caught up in the technologies of the moment, which are simply means to an end, not the solution.
- Data and real-life demonstrations, communicated broadly by media, of the transformation to renewable, sustainable energy in real lives, across America.

Achieving the 25x'25 Alliance goal means changing perception to tip the scales towards systemic change. What's needed is a groundswell of support and a clear recognition by every citizen that the 25x'25 Alliance goal is achievable and the shared responsibility of individuals and society.



The University of Georgia

The University of Georgia, the nation's first land-grant university and the state's largest and most comprehensive public university, plays a key role in meeting projected increases in energy demand while decreasing dependence on foreign sources of energy and protecting the environment.

UGA's conservation and renewable energy program unites the University's agricultural, environmental and engineering legacies with its strengths in carbohydrate science, genetics and microbiology to provide a scientific and practical foundation to support an economic and sustainable bioenergy future.