A STRATEGIC ROADMAP FOR THE NORTHEAST REGION OF THE SUN GRANT RESEARCH INITIATIVE

RESEARCH, EDUCATION AND OUTREACH PRIORITIES

BIOBASED ENERGY AND PRODUCT TECHNOLOGIES FUELING AMERICA'S FUTURE

July 2004

Front cover laboratory and research scene photos
courtesy of USDA/ARS Image gallery photographer, Scott Bauer

Executive Summary

The *Sun Grant Research Initiative Act of 2003* was created by U. S. Senators Tom Daschle and William Frist to tap the intellectual resources of our nation's great land grant institutions for addressing issues of national energy security, economic diversification in rural areas, environmental sustainability of agricultural production and bioenergy and bioproducts research competitiveness. This roadmap has evolved from an intense dialogue between the land grant colleges and universities and other stakeholders in the Northeast region. The Northeast Sun Grant States are: Connecticut, District of Columbia, Delaware, Maine, Maryland, Massachusetts, Michigan, New Hampshire, New Jersey, New York, Ohio, Pennsylvania, Rhode Island, Vermont and West Virginia. This document presents our collective vision for research, education, and outreach that will increase regional bioenergy and bioproducts production.

The Northeast region land grant institutions are taking important strides in agricultural biotechnology and the development of biobased "greener" products. They bring strong research and development capabilities to meet the challenges of the Sun Grant Research Initiative Act and to bring a second green revolution to the US rural communities.

Production and consumption goals for bioenergy, biofuels and bioproducts in the Northeast region were defined to be consistent with the recommendations of Biomass Technical Advisory Committee that advises the US Secretary of Agriculture and the US Secretary of Energy. The Biomass Technical Advisory Committee recommends the following increases by the year 2030: 1) increase in Biomass consumption for the production of BioPower from the current 4% (2.7 quads) to 5% (4.8 quads) by 2030; 2) an increase in biofuels from the current 0.5% to 20% by 2030; and 3) an increase in biobased chemicals and materials from the current 5% to 25% by the year 2030.

Three strategic areas are proposed for focused research, education and outreach activities: 1) BioPower, 2) BioFuels, and 3) BioProducts. BioPower is energy produced using renewable biomass as a fuel source for heat and electricity. BioFuels are liquid and gaseous transportation fuels, such as ethanol, biodiesel, and hydrogen, made from biomass resources. BioProducts are chemicals and materials made from biomass resources that may traditionally be made from petroleum-based resources, such as plastics, fibers and industrial chemicals.

Research Priorities

Each of the three strategic areas has the following enabling activities for research through the Sun Grant programs: 1) feedstock development, 2) conversion processes, 3) systems integration, and 4) biomass public policy issues. These four enabling activities are critical to the development of newly emerging national industries for biopower, biofuels and bioproducts.

Feedstock Development research priorities include 1) performing a rigorous inventory of existing biomass resources including waste and residue streams, 2) developing new plant breeds to develop desirable traits for biobased energy and products, and 3) characterizing residue composition before or after energy extraction for new potential value-added products.

Conversion Processes research priorities include 1) refining and developing improved separation technologies, 2) improving the efficiencies of biomass conversion, such as optimizing microbial fermentation processes, 3) analyzing and developing small scale distributed conversion systems.

Systems Integration research priorities include 1) developing efficient harvesting, storage, and transportation systems and equipment, 2) analyzing material and energy flow models (beyond state boundaries) using GIS or other advanced tracking mechanisms, 3) performing analyses of the region's biobased power production strengths, weaknesses, opportunities, and threats (SWOT analysis), 4) demonstrating process integration and synergy in small farm-scale biorefineries to optimize economic, social, and environmental returns (the triple bottom line).

Marketing, Economics and Policy Issues research priorities include 1) developing models of the circulation of currency in the local bioeconomy, 2) reviewing current policies for land use preservation and use of marginal lands, 3) analyzing the regions bioindustry's influence on the environment and on job creation 4) assessing the impact of the variability of laws and regulations between states on the bioeconomy.

Education Priorities

Working group participants determined that the Northeast Sun Grant Initiative's investment in education should include a suite of programs for the kindergarten through graduate school (K through PhD) education community. The education community includes students, teachers, guidance counselors, education researchers, and education administrators. The education programs are expected to impact the future of education and industry in many positive ways. The development of science modules, innovation competitions, capacity development, web-access training programs, topical meetings, and the support of scholarships, fellowships and industry internships for students and teachers will help build a strong core of future researchers, engineers, and instructors working in the area of biobased industries. The involvement of industry partners with education programs was identified as a priority method that will improve communications and will increase the function of universities to solve real-world problems.

Outreach Priorities

Working group participants identified potential audiences and specific activities. The potential audiences for outreach activities include the public, consumers, farmers, landowners, industry (CEO's), processors, policy makers, regulators, decision makers, stakeholders, and advocacy groups. Multi-state and international applications of outreach were identified as important efforts. Priorities include enhancing public familiarity and exposure to biobased industries and sustainability concepts to create more informed producers, processors, consumers and decision makers. Activities such as holding stakeholder conferences, supporting demonstration projects, providing technical information packets, identifying new markets for bioproducts, providing credible criteria and data to policy makers and new business venture groups will help optimize the transfer of information and technology for the public's benefit.

The Northeast Sun Grant Initiative

The Northeast region working group participants have formed a collective vision and have set the research, education and outreach priorities that will lead to increased bioenergy, biofuels, and bioproducts production and distribution in the Northeast Region of the United States. The Sun Grant Initiative programs hold the potential to bring a second green revolution to our nation's rural communities while simultaneously addressing issues of national energy security. With this collective vision and set of priorities in hand and the resources of our great land grant institutions on board, we are prepared to forge ahead, fueling America's future with the rich resources of our homeland.

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Introduction

This document provides a roadmap for advancing the research, development, and implementation of Bioenergy and Bioproducts Technologies in the Northeastern United States, consistent with the *Sun Grant Research Initiative Act of 2003*[(1)],introduced to the United States Congress by Senator Daschle and Senator Frist and authorized under Title IX, Sec. 9011 of the Farm Security and Rural Investment Act of 2002 .

The Sun Grant Initiative Act of 2003 objectives are to:

1) Enhance national energy security through the development, distribution, and implementation of biobased energy technologies;

2) Promote diversification in, and the environmental sustainability of agricultural production in the United States through biobased energy and product technologies;

3) Promote economic diversification in rural areas of the United States through biobased energy and product technologies; and

4) Enhance the efficiency of bioenergy and biomass research and development programs through improved coordination and collaboration between the Department of Agriculture and the Department of Energy, and the land-grand colleges and universities.

This roadmap for the Northeastern Region Sun Grant States has evolved through critical and intensive dialogue between the land-grant colleges and universities and other stakeholders in the Northeast Region including industry and government representatives.

The specific objectives of the roadmap are to:

1) Serve as a vehicle for synthesizing the collective wisdom and vision of faculty and administrators of our Northeast land grant institutions and other stake holders in the region;

2) Assess the current state of biomass resources and energy use patterns;

3) Establish targets for bioenergy and bioproducts production, and;

4) Identify research, education, and economic challenges and opportunities for bioenergy and bioproducts development;

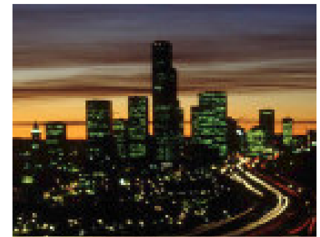
5) Define the research, education and outreach priorities for the Northeast Region Sun Grant Initiative.

The Northeast Region Sun Grant States are Connecticut, District of Columbia, Delaware, Maine, Maryland, Massachusetts, Michigan, New Hampshire, New Jersey, New York, Ohio, Pennsylvania, Rhode Island, Vermont and West Virginia. The Northeast Region Sun Grant Center is located in New York State at Cornell University. The National Lead Sun Grant Center is located at South Dakota State University.

Taking Stock in the Northeast Region

GREAT PEOPLE, GREAT CITIES, GREAT LAKES,
GREAT SNOWFALL, and GREAT INDUSTRIAL HISTORY

The residents of the Northeastern Sun Grant Region of the United States comprise 30% of the total U.S. population[2]. Once a significant farming region, the face of agriculture in the Northeast has changed dramatically over the last twenty years. Farmland is being rapidly converted to other uses, such as housing and commercial developments. An estimated 110,000 acres of farmland in the Northeast Sun Grant states are lost each year[3]. Projections from the *Monthly Labor Review* show that farmers are expected to have the largest sector of job loss in the near future, when there will be an estimated 173,000 fewer farm jobs in 2008 compared to 1998.[4,5] Thus, in addition to decreasing dependence on foreign oil, a major goal of the Northeast Sun Grant Initiative is to stem the loss of jobs from rural communities through participation in the new "bio-economy" . This new bio-economy will open countless opportunities for rural communities to provide important raw materials that support increased biomass needs for biobased power, biofuels, and bioproducts. In addition, the low mass density of biomass materials limits how far they can be economically transported; thus encouraging local and regional manufacturing.




The Northeast Sun Grant States comprise 29.8% of the total USA population.

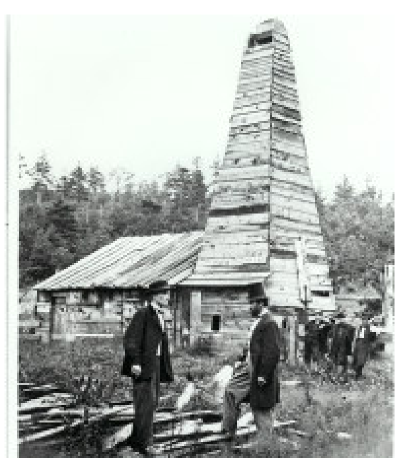
Each year, an estimated 110,000 acres of farmland in the Northeast Sun Grant States are lost to other uses.

E.I. Dupont opened a gunpowder factory in Delaware in 1802 using nearby willow trees as a source of the charcoal ingredient. In 1903 the company opened an experiment station laboratory in Wilmington, DE and is a world-class leader in innovation through science. (Photo is courtesy of DuPont.)

The Northeast region also has enjoyed an great industrial and entrepreneurial history. The birthplace of the global petroleum industry, the Drake Well, was drilled in 1859 near Titusville, Pennsylvania and began the international search for petroleum[6]. American industrialists Andrew Carnegie settled in Pittsburgh, Pennsylvania, building the steel industry[7] and John D. Rockefeller settled in Ohio[8], building the oil industry. In 1879, Thomas Edison provided the first public demonstration of his electric light bulb, developed in Menlo Park, New Jersey[9]. Delaware's duPont du Nemours Company was founded in 1802, when E.I. Dupont opened a gunpowder factory on the Brandywine River[10]. Interestingly, a biomass source of willow trees nearby served as the charcoal ingredient for the black gunpowder. The first course in electrical engineering was held at Cornell University in 1883[11]. The first AC power plant opened in Great Barrington, Massachusetts in 1886[11]. In Bridgeport, Connecticut, 1904, Harvey Hubble filed a patent for the first detachable electric plug[11].

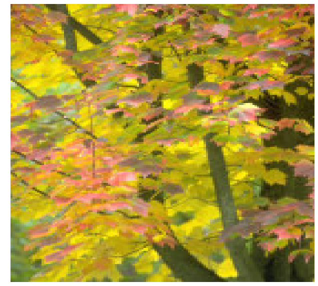
Today, the Northeast Region Sun Grant States have engaged industry partners, eager to invest in the future of the bio-economy products and technologies industry and to move new biotechnologies and bioproducts to the marketplace.

The birthplace of the global petroleum industry, The Drake Well in Pennsylvania was drilled on Oil Creek in 1859, beginning the international search for petroleum. Photo is courtesy of Pennsylvania Historical and Museum Commission, Drake Well Museum, Titusville, PA.



A LOT OF VALUE ON SHRINKING LANDS

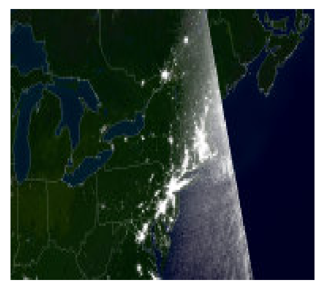
There is an interesting trend in Northeastern US agriculture. Although the Northeast Sun Grant Region States rank among the lowest in net farm income, the value of what is being produced per acre in the Northeast ranks among the highest in the country[12]. More than half of the country's mushrooms, cranberries and blueberries, and more than one fifth of the country's greenhouse/nursery crops, apples, sweet corn, and cabbage come from Northeast Sun Grant States[13]. Another important resource of the Northeastern Sun Grant States is the forested lands and forest products. The land area of the Northeast Sun Grant States combined are 55% forested. Maine, New Hampshire, Vermont, and West Virginia are more than 75% forested[14].



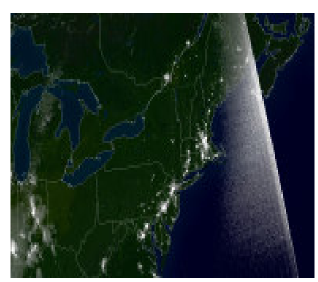
The Northeast Sun Grant States combined are 55% forested.

WHERE WERE YOU WHEN THE LIGHTS WENT OUT?

The Northeast Sun Grant states consume 25% of the nation's electricity[15]. The method of distribution of electricity on the "electric power grid" allows electricity to flow both within and between states in order to meet power demands and fluctuations in a given region. The Northeast Region Sun Grant States are located within the Eastern Interconnect power grid[16]. The Energy Information Administration (EIA) reports energy consumption and net interstate flow of electricity including normal losses during transmission along power lines. Local production of power reduces transmission losses. The data for 2000 show that more electricity was transferred into the Northeast than went out of the Northeast Region Sun Grant States[17]. Sources of electrical energy in the Northeast region states originate from both nonrenewable fossil fuel sources and renewable energy sources. In the Northeast Region, renewable hydroelectric, wind,



East coast before August 2003 blackout.

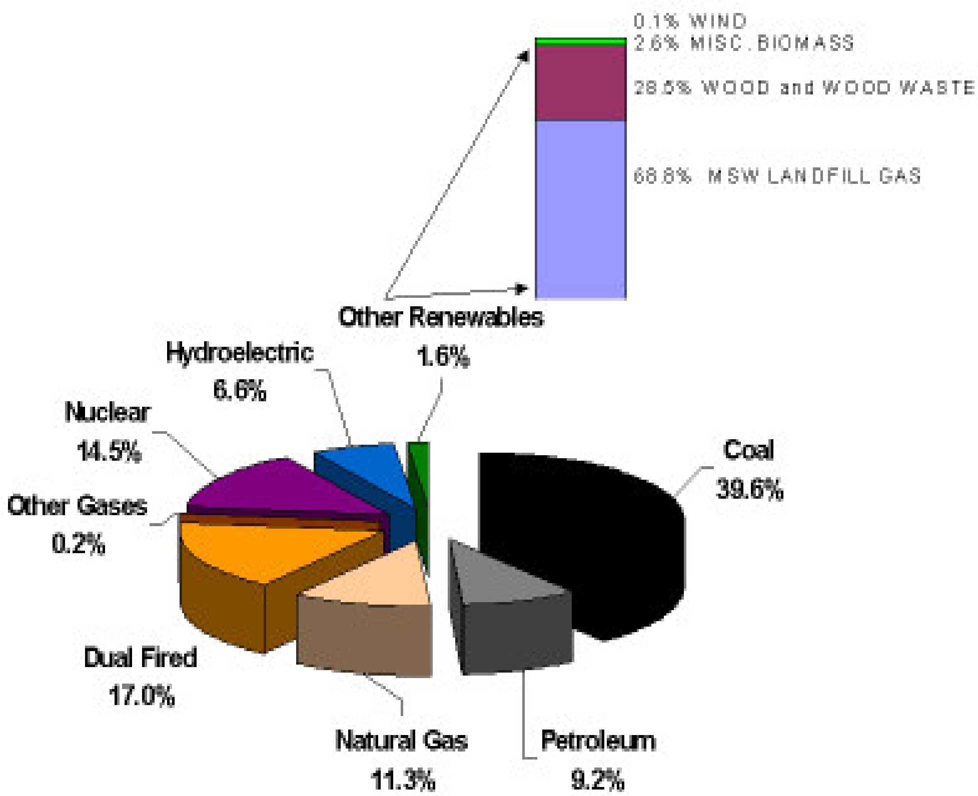


East coast during August 2003 blackout.

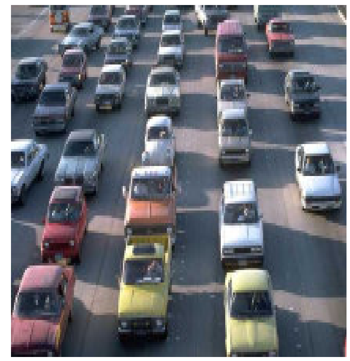
Source of Northeast satellite images: NOAA and Air Force Weather Agency and biomass related generation are underway. Biomass-related energy production in the Northeast region (including ethanol production, landfill gas and wood/wood waste sectors) is occurring in Connecticut, Maine, Maryland, Massachusetts, Michigan, New Hampshire, New Jersey, New York, Ohio, Pennsylvania, Rhode Island, and Vermont[19]. Wood, wood waste, and other biomass power generation in the Northeastern Sun Grant Region accounts for a full 44% of the United States biomass power generation and 57% of the Nation's municipal solid waste land fill gas power generation[20].

The Northeast Sun Grant States consume 25% of the nation's electricity.

The primary fuel sources for electricity generation in the Northeast Sun Grant States include 1.6% Renewables other than hydroelectric. Of this, 0.1% is from wind, 28.5% is Biomass Energy from wood and wood waste and an additional 2.6% is from other sources of Biomass. MSW Landfill gas accounts for 68.8% of the other renewable energy sources.[18]



In August 2003, a massive-scale blackout occurred in the Northeastern United States. The cause of the Northeast 2003 blackout is still under investigation at this writing, but initial examination of a timeline sequence of events indicates a critical "choke point" in the Northeast grid[21]. As demand for electric power increases, our complex and antiquated electric grid system is likely to experience other "choke points." We need to develop new ways to manage electric power production in the Northeast that will reduce our dependence on foreign sources of energy. There are some intriguing challenges for the Northeast and some exciting opportunities for renewable biomass power as an alternative energy source in the Northeastern Sun Grant Region States. The transition to distributed bio-based energy systems would reduce the likelihood of widespread power outages and could provide backup energy sources for critical users, such as hospitals.



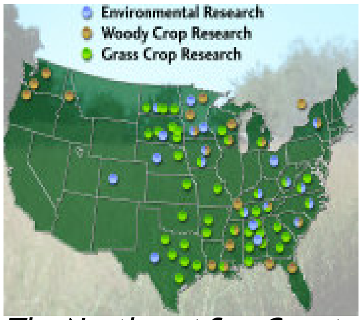
Residents of the Northeast Sun Grant States own 27% of the Nation's motor vehicles and drive an average 11.8 thousand miles per year per household vehicle.

ARE WE THERE YET?

Transportation fuels in 2001 (including motor vehicles, air and rail transport) accounted for 68% of our nation's oil consumption[22]. The United States depends on foreign sources for 53.3% of petroleum consumed[22]. Residents of the Northeast Sun Grant States own 27% of the Nation's motor vehicles (including publicly and privately owned automobiles, buses, trucks and motorcycles)[23]. Residents in the Northeast drive an average 11.8 thousand miles per year per household motor vehicle[24], contributing to the nation's consumption of 135.6 billion gallons of gasoline per year[22].

University of Vermont's Biodiesel bus...smells like french fries, but runs like a bus! Public Transit in the United States consumes 2.4 million gallons of fuel each day.[74]

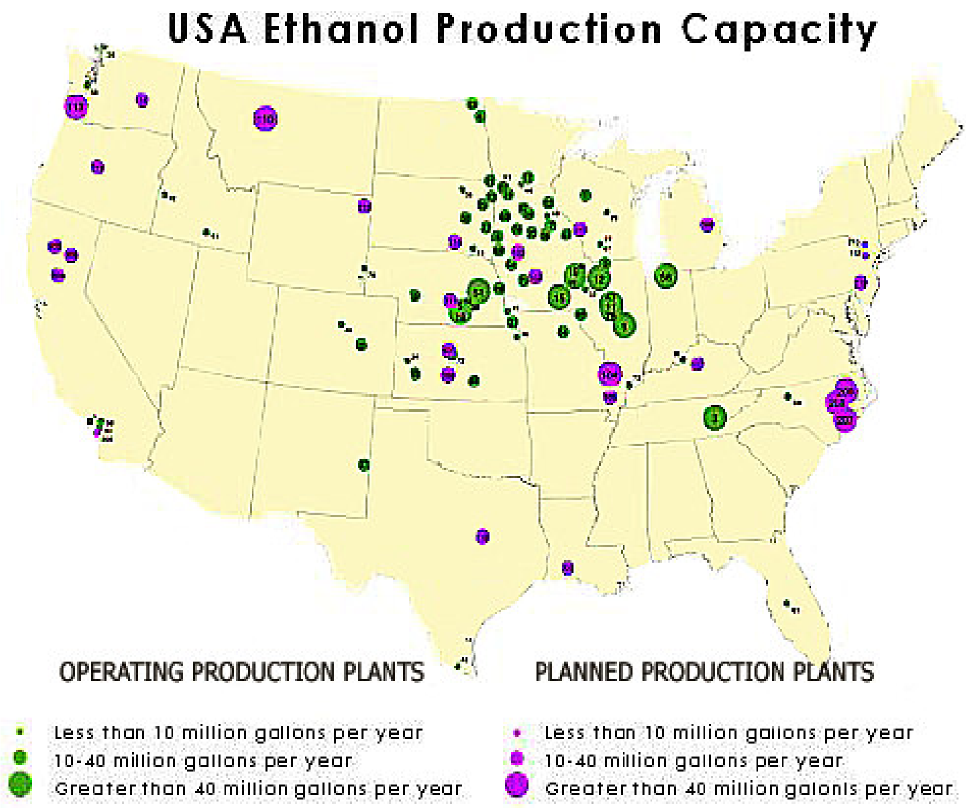
The United States produces 2,707 million gallons of ethanol fuel per year.[25] The soils and climate in the Northeast will support soybean and corn production, however not as efficiently as the more optimized growing conditions in the Midwest region[26]. The Renewable Fuels Associations identifies 77 plants in the US, with one in the Northeast Region (Caro, Michigan's Michigan Ethanol, LLC) that utilizes corn to produce 40 million gallons of ethanol per year[27]. The Northeast Sun Grant Region currently has plans for four new ethanol pro-



The Northeast Sun Grant States are participating in research in Environmental Research (Ohio West Virginia and New York), Woody Crop Research (Michigan and New York) and in Grass Crop Research (Michigan, New York and West Virginia) through the Biomass Feedstock Development Program. (Map Source: Oak Ridge National Laboratory Bioenergy Information Network Image Gallery)

duction facilities in the states of New York, New Jersey, and Pennsylvania. A Masada OxyNol plant in Middletown, NY will utilize municipal solid waste (MSW) for the 10 million gallons of ethanol per year. In Fulton, NY, Northeast Biofuels plans to convert a former brewing facility into a corn-to-ethanol plant (100 million gallons per year). In West Deptford, New Jersey, a new ethanol plant will produce 40 million gallons per year. The Mayfair Energy /Stand Energy plant in Philadelphia, PA will use MSW to produce 15 million gallons per year(28) and the Penn-Mar Ethanol, LLC, a group founded by farmers and agribusiness persons, has proposed the construction of an ethanol plant (40 million gallons per year) in Lancaster County. In nearby Ontario, Canada, Suncor Energy has announced plans to build a 50 million gallon capacity ethanol plant.

The National Biodiesel Board(29) identifies several Northeast Region companies producing or distributing biodiesel or soybean oil fuels. In Ohio there are two companies (Peter Cremer TRI-NI, producer and Procter & Gamble, marketer). A second regional marketer is located in Chelsea, Massachusetts (World Energy Alternatives). In New York, NOCO Energy Corporation and the New York State Energy Research and Development Authority (NYSERDA) announced the arrival of NOCO's first shipment of biodiesel fuel totaling 20,000 gallons for the Buffalo-Niagara region. There is a new biodiesel production plant proposed in Delaware City, Delaware (Mid-Atlantic Biodiesel), where the National Biodiesel Board recently presented Delaware Governor Ruth Minner the first Trailblazer Award (2003) for broad-reaching initiatives for incorporation of Biodiesel in Delaware's autofleet and a successful test of biodiesel use in the Middletown Middle School boiler systems(29).

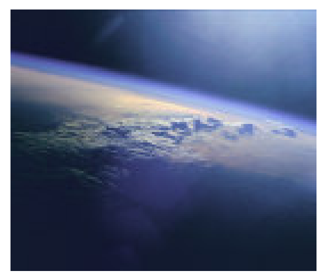


Ethanol and Biodiesel production plants are located primarily in the Midwest near the feedstock source. There are four ethanol production plants operating or planned in the Northeast Sun Grant Region. (Map Source: Oak Ridge National Laboratory Bioenergy Information Network Image Gallery)

Biofuels hold the exciting potential of improving the environment through reduced emissions and at the same time boosting the economy through the use of American-made renewable biofuels.

BREATHING EASY

In addition to the economic benefits to our rural communities, energy produced from Biomass yields several environmental advantages over traditional energy from fossil fuels. The National Biotechnology Council reports that the production and use of fossil fuels contributes a very high portion of pollutants. For example, of the total national pollutant emissions, fossil fuels contribute 97% of NOx, 85% of CO, 91% of SO_2, and 98 % of CO_2.[30] Biofuels are relatively carbon-neutral. That is, they consume as much CO_2 as they produce.[31] Transition to the production and use of more biomass energy would reduce pollutant and greenhouse gas emissions.



The Earth's biosphere contains all life as we know it. The thin layer of gases surrounding the planet holds all of the air we breathe and all of the air pollutants we produce. Global carbon emissions (98% from fossil fuels) may contribute to global warming. Biofuels have the advantage of being carbon-neutral and would not contribute to global warming. Photo source: NASA.

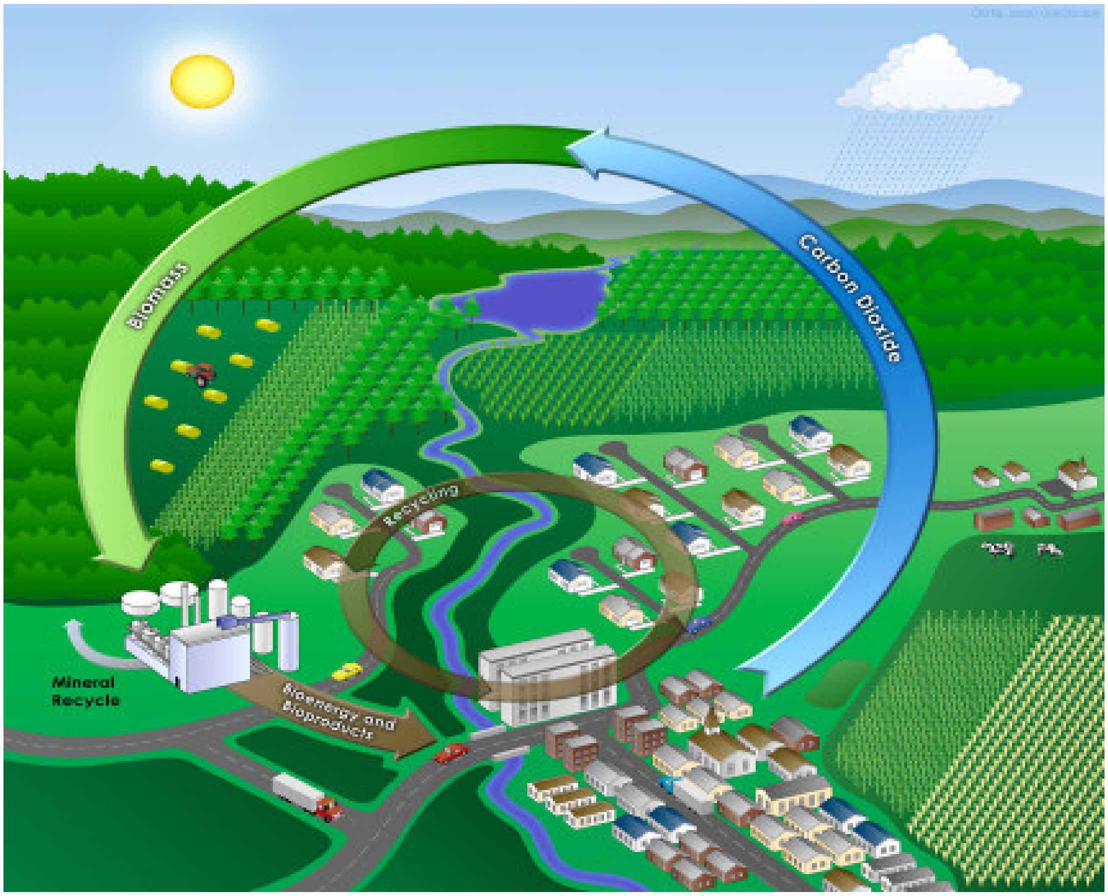
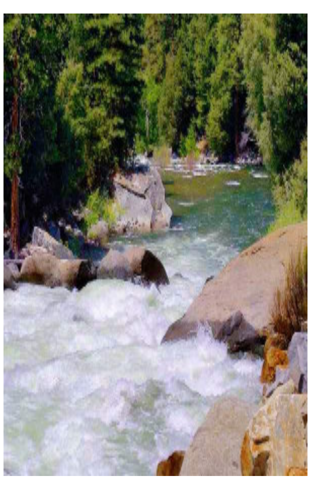


Image Source: Oak Ridge National Laboratory Bioenergy Information Network Image gallery.

GROUNDWATER PROTECTION

The US Geological Survey detected MTBE in 5% of groundwater samples nationwide. The US EPA took regulatory action to eliminate MTBE from gasoline.



The Clean Air Act Amendments of 1990[32] require the use of oxygenates (such as ethanol or MTBE (methyl tertiary-butyl ether)) in gasolines. The added oxygen boosts the gasoline's octane quality, enhances combustion for cleaner burning fuels, and reduces carbon monoxide exhaust emissions. In the fall of 1996, MTBE was detected in two groundwater wells in Santa Monica, California[33]. The US Geological Survey detected MTBE in 5% of groundwater samples nationwide[34]. When consumed in drinking water MTBE is a suspected carcinogen based on studies on laboratory rats[35]. In March of 2000, the US Environmental Protection Agency (EPA) took regulatory action to eliminate MTBE from gasoline[36].

Several States have placed bans on MTBE in gasoline[37]. In the Northeast Sun Grant States, the MTBE ban began in Michigan (January 2003), followed by Connecticut in (January 2004), New York (January 2004) and Ohio (July 2005). Maine's law is not a ban, but expresses the state's goal to ban MTBE[37].

Energy Information Administration's report on the Supply Impact of the MTBE Ban states that while there is no equivalent substitute to MTBE, ethanol should play a significant role in filling the gap and is the only practical alternative to meet the oxygen requirement

Ethanol is an alternative to MTBE for the oxygenation of fuel. The Energy Information Administration's report on the Supply Impact of the MTBE Ban states that while there is no equivalent substitute to MTBE, ethanol should play a significant role in filling the gap and is the only practical alternative to meet the oxygen requirement[38]. According the USDA, ethanol production may add 14 cents to the value of a bushel of corn[39]. Many areas are working to create farmer-owed ethanol production facilities to reap the benefits of added value of corn.

University of Vermont researcher Mingruo Guo coats a piece of wood with the whey-based varnish he is developing. Unlike commercial wood finishes that contain chemicals that are volatile and toxic to handle, this water-based finish made from a by-product of cheese-making will be environmentally benign and safe to humans. (Source: VT Agricultural Experiment Station Annual Report, 2002: Working Together to Meet Vermont's Challenges).

IT ISN'T EASY BEING GREEN

The environment is increasingly a priority in the high-population areas of the Northeastern Region Sun Grant States. Consumer demand for "greener", more environmentally-friendly products has led to the need for greener industrial chemicals. As Kermit the Frog sings, "It isn't easy being green…" Biotechnology companies realize the challenges of producing "greener" products with qualities similar to products traditionally made from petroleum. For example, researchers at the University of Vermont have developed an environmentally friendly whey-based wood varnish[40].

The Northeast region of the United States is extremely active with respect to investment in biobased and biotechnology companies. While much of the focus of the field of biotechnology is currently in the medical and pharmaceutical fields, advances in molecular and cellular biology, proteomics, and nucleic acid engineering have paved the way for similar advances in industrial biotechnology. For example, designer enzymes have profound implications for releasing the potential fuel and chemical feedstock potential in plant waste products such as corn stalks and other non-edible portions of plant biomass.

The Northeast region of the United States is home to 44 companies that produce biobased products or have a biobased focus in their product line. However, when the larger picture of biotechnology in the Northeast is considered, it is clear that not only start-up companies, but also a significant number of law firms, investment firms, major companies, cooperatives, and universities also are involved in this exciting frontier. When considering these organizations(private, state and public) with an interest in biotechnology in the Northeast, the number climbs to at least 416 companies in the Northeast Sun Grant Region with a specific interest in this area.[41,42,43,44,45,46] The nation's largest chemical company (Dow) is based in Midland, Michigan. Dow and Cargill have formed a joint venture to produce biobased corn-derived chemicals.

The Northeast Region is home to over 400 companies with a specific interest in biotechnology and/or biobased products. (Photo credit: Scott Bauer, USDA ARS Image Gallery)

The weather climate of the Northeast region has provided incentive for the significant advances in Controlled Environment Agriculture (CEA) technology where the weather can be controlled over small areas of land under protected greenhouse cover. CEA technology has been used to control the environment in specific ways to optimize biomass production[47] and improve the nutritional content of plants[48]. This exciting frontier in agriculture of enhancing plant chemical composition with environmental control rather than traditional breeding methods sets the stage for optimal commercial scale bimolecular farming.

The weather climate of the Northeast region has provided incentive for the significant advances in Controlled Environment Agriculture (CEA) technology where the weather can be precisely controlled over small areas of land. Here, plants are growing while snow is on the ground outside in New York State. (Photo source: Cornell CEA Program)

Controlled environment agriculture research is also being conducted at the exciting New Jersey-EcoComplex. The NJ-EcoComplex is the nation's first research, technology development, teaching and outreach center that is dedicated to enhancing the environment and agriculture through education, outreach and "green" business development.*

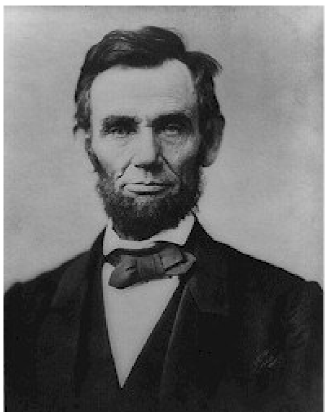
As described in the mission of the EcoComplex this multi-institutional, multidisciplinary environmental center harnesses research and education resources towards the development, and industrial application, of innovative environmental technologies.* The EcoComplex works to promote economic development in the environmental arena, including the remediation and protection of environmental quality, and the compatible sectors of food and innovative agriculture. By targeting these areas with integrated programmatic thrusts in research, education and economic development, the EcoComplex provides a distinctive focus.*

Photo source: NJ-EcoComplex

* Information is courtesy of the New Jersey Econoplex. For more information: http://ecocomplex.rutgers.edu/aboutUs_ourMission.html

GREAT LAND GRANT INSTITUTIONS

The Land Grant mission of research, teaching and outreach has a solid history of improving lives. The foundation of the Land Grant colleges dates back to the 1860's, when half of the US population lived on farms. The United States was primarily an agrarian economy near the time of the Civil War, when Congress passed the Morrill Act (also known as The Land Grant Act) of 1862 to allow the creation of the land grant institutions. Each US Senator and Representative received 30,000 Acres of land, which was to be sold, with the money being used to establish a land grant college in each state.



"The Land Grant University System is being built on behalf of the people, who have invested in these public universities, their hopes, their support, and their confidence."

Abraham Lincoln

The Land Grant Institutions were founded based on three revolutionary ideas: 1) Higher education should be made available to all people, 2) Universities should teach practical subjects such as agriculture, engineering, and home economics, and 3) Universities should share the knowledge with peoples in their states. The first "Agricultural Colleges" were Michigan, and Pennsylvania (Chartered 1855). Iowa, Michigan and Maryland were the first states to form land grant agricultural colleges. Vermont Senator Justin Morrill was one of the driving forces behind the act. Numerous Morrill Halls on campuses in the US honor his efforts. Within 8 years of the Morrill Act's passage, 37 states had authorized an educational institution. A second Morrill Act provided direct appropriations to land grant institutions that could demonstrate race and color were not admissions criteria. In the south, "separate but equal" colleges called the "1890 Land Grants" were formed.

Today, there are 105 land grant colleges and universities, including land-grants in US territories and 29 Native American land-grant universities. The 19 Land Grant Institutions in the Northeast Sun Grant States are: University of Connecticut, Delaware State College, University of Delaware, University of the District of Columbia, University of Maine, University of Maryland Eastern Shore, University of Maryland College Park, University of Massachusetts, Massachusetts Institute of Technology, Michigan State University, University of New Hampshire, Rutgers – The State University of New Jersey, Cornell University, The Ohio State University, Pennsylvania State University, University of Rhode Island, University of Vermont, West Virginia University, and West Virginia State College.

Capitol Building in Washington, DC in the mid 1800's

Today, Land Grant Institutions in the Northeast Region and throughout the country continue to lead the way in world agricultural research, education and outreach. As the face of agriculture has changed, the land grant institutions have evolved to meet the needs of the new frontiers, with tools such as molecular biology, genomics, proteomics, bioinformatics and nanotechnology. The Sun Grant Initiative expands the role of the land grant institutions to address the most recent change to the face of agriculture: new biomass and bioresource needs for energy, fuels and bioproducts. The land grant approach to the new bioresource needs are reflected in the inclusion of research, education and outreach activities in environmental quality, sustainability and renewable resources activities.

Biotechnology research in the Northeast Region Sun Grant States is actively advancing at each of the Land Grant Institutions in the Region. The Northeast Land Grant Institutions bring strong research and development capabilities to meet the challenges of the Sun Grant Initiative. The Sun Grant Initiative opens the gateway to bring the best in science, engineering, and agriculture together at the revolution occurring in biotechnology. The following chapters describe a strategic plan in setting priorities for the research, development, and implementation of new bioenergy and bioproducts technologies for fueling America's greener future. The Sun Grant Initiative programs hold the potential to bring a second green revolution to the US and Northeast Region rural communities.

The Sun Grant Initiative opens the gateway to bring a new green revolution to the US and Northeast Region farming communities as we meet the challenges of making more of our energy on domestic lands.

Establishing Targets and Strategic Areas for the Northeast

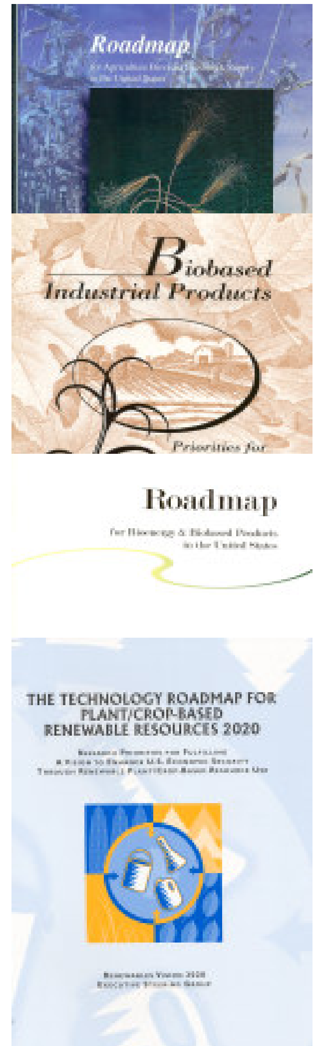
THE WHEEL IS ALREADY ROLLING

Production and consumption goals for bioenergy, biofuels and bioproducts in the Northeast Region are needed to establish the Northeast Sun Grant research, education, and outreach priorities and for identifying viable policy needs and industry constraints. There is no need to reinvent the wheel, indeed the wheel is already rolling in some areas of the bio-economy. Several existing resources can be consulted in our effort to establish targets and priorities for the Northeast Region Sun Grant States.

The Biomass R&D Act of 2000 established a Biomass Research and Development Technical Advisory Committee. The committee advises the U.S. Secretary of Energy and the U.S. Secretary of Agriculture on Biomass Research and Development priorities. This committee has generated two important documents.

(1) Biomass Technical Advisory Committee (*Vision for Bioenergy and Biobased Products in the United States*[49]);

(2) Biomass Technical Advisory Committee (*Roadmap for Bioenergy and Bioproducts in the United States*[50]);



Existing resources[31,51,53,54,55,56,57,58,59,60] *can be consulted in our assessment of establishing targets and priorities for the Northeast Region Sun Grant States.*

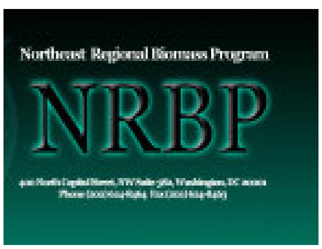
The Biomass Research and Development Technical Advisory Committee recommends an increase in Biomass consumption for the production of Biopower at an annual rate of 2 % through the year 2030, increasing from 2.7 quads in 2001 to 4.8 quads in 2030[49]. The committee also recommends that transportation fuels from biomass increase from the current 0.5 percent to 20 percent by 2030. Biobased chemi-

The Biomass Research and Development Technical Advisory Committee advises the U.S. Secretary of Energy. The Vision and Roadmap documents from this committee recommend: 1) an increase in Biomass consumption for Biopower to 4.8 quadrillion BTU's (quad) by the year 2030; 2) an increase in biofuels from the current 0.5% to 20% by 2030; and 3) an increase in biobased chemicals and materials from the current 5% to 25% by the year 2030.

Biomass Technical Committee Vision Goals for BioEnergy and BioBased Products

	2001	2010	2020	2030
BioPower Biomass share of electricity & heat demand in utilities & industry	2.7 quads (4%)	3.2 quads	3.9 quads	4.8 quads (5%)
BioFuels Biomass share of demand for transportation fuels	0.5% (0.2 quads)	4% (1.3 quads)	10% (4.0 quads)	20% (9.5 quads)
BioProducts Share of target chemicals that are biobased	5% (12.5 billion lbs)	12%	18%	25%

cals and materials production is targeted to increase from the current 12.5 billion pounds (5 % of total production) to 25 % of total production by the year 2030[50].



The Northeast Regional Biomass Program (NRBP) has reviewed the availability of biomass for energy in the Northeast region and related state policies, concluding that renewable biomass energy can play a significant role in meeting the Northeast Region's state Renewable Energy Portfolio Standards

In addition to the Biomass Research and Development Technical Advisory Committee documents there is the Northeast Regional Biomass Program (NRBP) review of biomass energy in the Northeast region. NRBP concluded that the abundance of biomass in the Northeast region makes renewable biomass energy a significant resource for meeting the Northeast Region's state Renewable energy Portfolio Standards (RPS)[51,52]. In addition the NRBP report concludes there is a significant growth potential for biomass electricity industry in the Northeast based on estimates of available biomass. NRBP estimates the current biomass electricity production is 7.1 million MWh (million watt hours)and the potential production (using biomass delivered at a price of less than $3.50/mmBtu) is 42.3 million MWh (nearly six times current level.)

Northeast Regional Biomass Program: (*Securing a Place for Biomass in the Northeast United States: A Review of Renewable Energy and Related Policies*[51]);

ADOPTION OF ADVISORY COMMITTEE GOALS

The Sun Grant Initiative Act charges the various Sun Grant Regions:

" to enhance the efficiency of bioenergy and biomass research and development programs through improved coordination and collaboration between the Department of Agriculture, the Department of Energy, and the land-grant colleges and universities."

The adoption of the national goals set forth by the Biomass Technical Committee (summarized in chart on page 18) is a good starting place for setting priorities in the Northeast Region for Sun Grant strategic planning.

The Secretaries of Energy and Agriculture are advised on biomass goals by the Biomass Research and Development Technical Advisory Committee through the committee's Roadmap and Vision documents (goals are summarized in chart on page 15). The adoption of the committee's biomass utilization goals is a good starting place for setting priorities for the Northeast Region Sun Grant strategic planning. However, these priorities must reflect the regional resource base and the economic and social characteristics.

At the national level, the Biomass Research and Development Technical Advisory Committee identified three strategic areas[49,50]:

A) BIOPOWER
B) BIOFUELS
C) BIOPRODUCTS

BioPower is the use of renewable biomass as a fuel to produce heat and electricity. Biopower production utilizes similar equipment and conversion technology, such as thermal gasification, as is used for petroleum-based fuels. The United States currently has 10 gigawatts of installed capacity.

BioFuels are biomass resources that are used to displace fossil fuels for transportation. Ethanol, biodiesel, and hydrogen are the three principal biofuels under consideration.

BioProducts are chemicals and materials made from biomass resources that may traditionally be made from petroleum-based resources (e.g., biodegradable plastics and biobased industrial chemicals).

BioPower

BioFuels

BioProducts

Three strategic areas identified by the Biomass Technical Advisory Committee.

Each of these strategic areas (BioPower, BioFuels, and BioProducts) has the following **enabling activities** for research, education, and outreach:

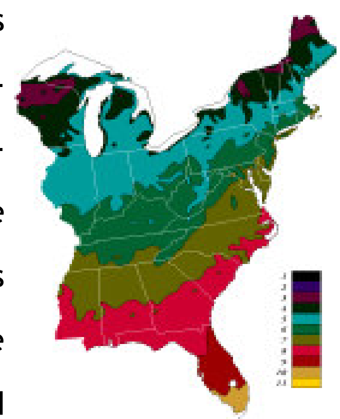
1) FEEDSTOCK DEVELOPMENT
2) CONVERSION PROCESSES
3) SYSTEMS INTEGRATION
4) BIOMASS POLICY OPTIONS

The following four sections discuss these four enabling activities for the Northeast Region Sun Grant states.

Sun Grant Enabling Activity 1
Northeast Feedstock Development

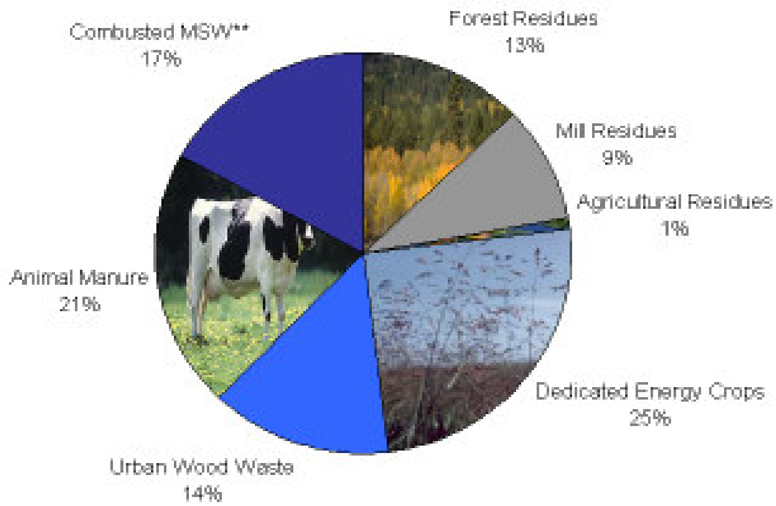
THE LAY OF THE LAND

The availability and type of biomass feedstock resources vary considerably across the Northeast region as one crosses the ecosystems of the 15 states. The Chesapeake estuary region of Maryland and Delaware is in the Southeastern corner of the region. To the northeast from the Chesapeake Bay, the states of Maryland, Delaware, New Jersey, New York, Connecticut, Rhode Island, Massachusetts and Maine have Atlantic Ocean shoreline ecosystems. To the north and west from the Chesapeake Bay, the landscape rises through a plateau leading to the Appalachian Mountain range. The Appalachian Mountains are among the oldest mountains on Earth. Parallel chains of the Appalachians also run through the northeast region, including the Allegheny Mountain range through Pennsylvania and New York, the Blue Ridge Mountain range through West Virginia, and the Catskill Mountains through New Jersey and New York. Moving further northwest to the Great Lakes Region, the states of Michigan, Ohio, Pennsylvania and New York border the Great Lakes of Huron, Erie and Ontario. Located between Lake Erie and Lake Ontario is Niagara Falls, the second largest waterfall in the world. In addition to changing terrain throughout the region, the Northeast Sun Grant States include 5 of the 11 USDA plant hardiness planting zones[61], indicating a wide range in annual minimum temperatures over the region and a wide range of biomass production opportunities.



The Northeast Sun Grant Region States include 5 of the 11 USDA Plant Hardiness Zones indicating a wide range of plant-growth climate opportunities for biomass production. (Map Source: USDA/US National Arboretum)[61]

Feedstocks identified as potential sources of Biomass in the Northeast Sun Grant States and their relative availability at the delivered price of less than $50 per dry ton. ***Combusted MSW calculated based on per capita production of MSW and % combusted reported by EPA. **Animal manure data from Census of Agriculture.*



NORTHEAST FEEDSTOCK DEFINITION

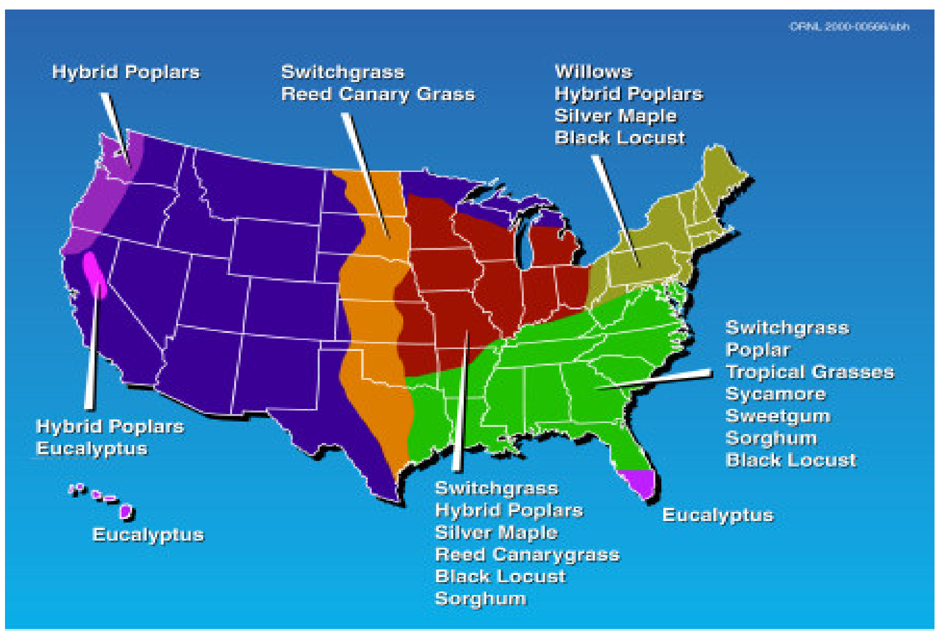
For program planning and priority-setting purposes, the Northeast Region Sun Grant States needed to develop a consensus on the definition of "Biomass" feedstock sources. For example, some state renewable energy programs do not recognize Biomass as a renewable energy source and some do not recognize Municipal Solid Waste (MSW) as a biomass feedstock because of the potential emissions challenges in burning raw MSW. The figure above shows the type and composition of potential Northeast biomass feedstock sources that currently could be delivered at less than $50 per dry ton[52]. From a technological standpoint, all of the feedstocks identified (forest residues, mill residues, agricultural residues, dedicated energy crops, MSW, urban wood and construction waste, and farm animal manure) could be used for BioFuels, BioPower, and BioProducts. However, there remains uncertainty over biomass availability in the Northeast region thus there is a need for a rigorous regional biomass feedstock and bioenergy capacity inventories in the Northeast[51] Bioenergy feedstock production on marginal (non-prime) farmland could increase the value these nutrient-poor or environmentally-sensitive areas.

NORTHEAST FEEDSTOCK RESEARCH OPPORTUNITIES

Forest and Mill Residues. The Northeast region contributes a significant portion (23%) of the total US Forest Residues and this resource is plentiful in most NE States[52]. Forest residues such as logging residues, dead wood, wood stumps, and excess saplings are potential biomass feedstocks. Reclaiming abandoned farmland, developing improved trees for wood composites, improving the quality and quantity of trees produced, and examining issues of forest monoculture are research and economic development priorities for the Northeast region. Mill, furniture factory, and manufactured home factory wastes are another potential source of biomass in the Northeast region. Economic research is needed regarding the cost to these industries for disposal of waste wood and their proximity to electricity generation facilities. There is a need for life-cycle analyses of feedstock options.

Agricultural Waste. The Northeast is home to many farm animals (including hogs, sheep, dairy cattle, beef cattle, horses and poultry). Manure from these animals can serve as a biomass resource for the production of energy. Agricultural and food processing residues are also a potential source of Biomass. Currently, 73% of the agricultural residues identified in the Northeast are corn residues[52]. This estimation including primarily corn residues supports the need for an updated rigorous biomass feedstock inventory. Studies are needed in the Northeast to identify new agricultural waste streams and to assess their potentials for value-added products. For example, apple and grape waste from sauce and juice processing in the northeast might be further utilized not only as a biomass energy source, but may be further processed to obtain anthocyanin compounds for use in natural pharmaceutical and nutriceutical products.

Dedicated energy crops. The Oak Ridge National laboratory Biomass Feedstock program has examined the potential for dedicated energy crops in the Northeast (currently 26% of NE Biomass material)[52]. Crops that may do well in the Northeast Sun Grant states include trees such as hybrid poplar, hybrid willow, silver maple, black locust, sycamore and sweetgum and grasses such as switch grass, reed canary grass. Plant breeding and plant engineering efforts should include crop and cultivar analysis including the development of new crops and analysis of the comparative biomass emissions. Cultural methods to modify the biochemical composition of plants also should be studied. Improved pathogen resistance for energy crops (e.g., soybean, corn) will increase yields and reduce pesticide requirements.



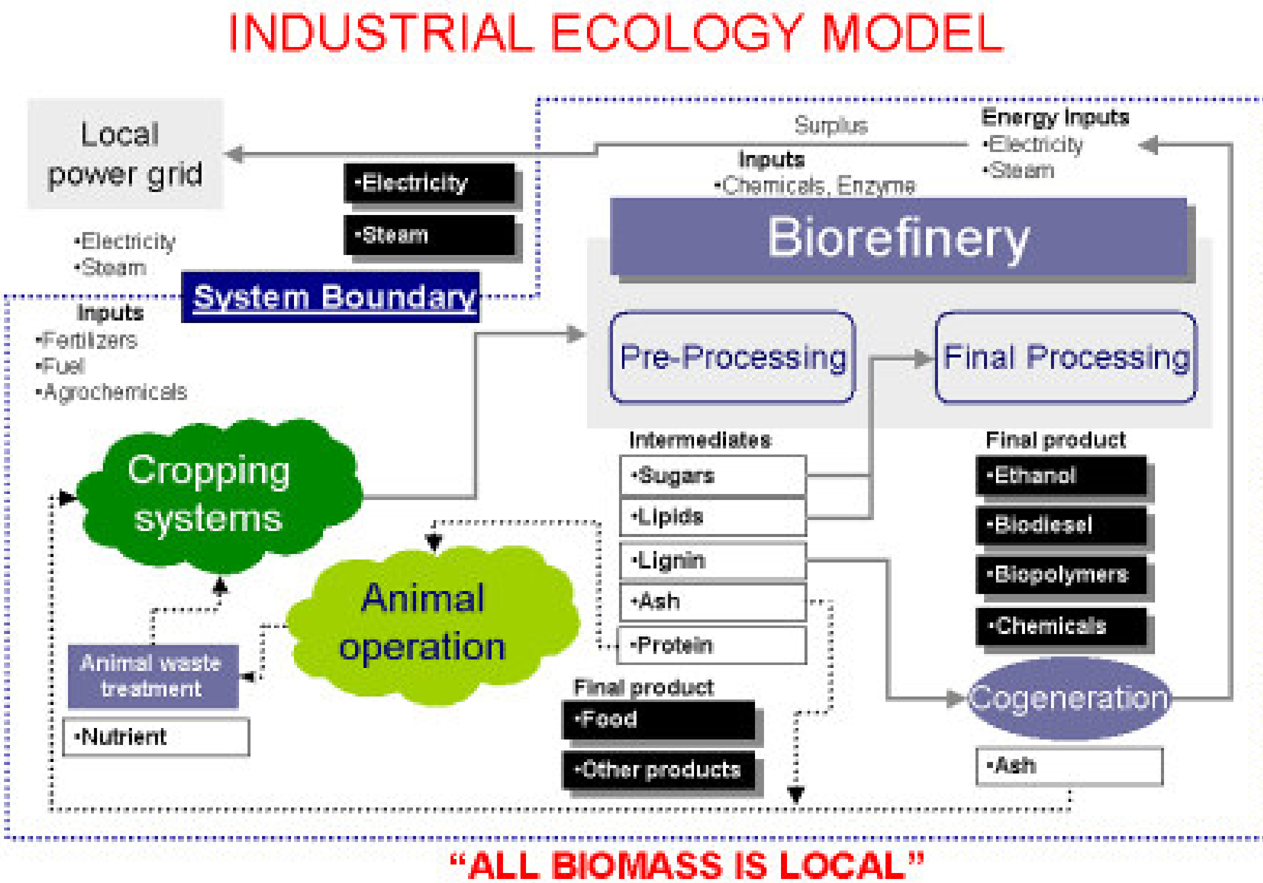
Previous work through the Oak Ridge National Laboratory Biomass Feedstock Development Program has identified several promising species for the Northeast Sun Grant Region and other regions of the US. (Map Source: Oakridge National Laboratory)

Urban wood and construction debris waste. The Northeast generates 20 % of the total US urban wood and construction debris and wood waste including yard trimmings, landscaping materials, grass, leaves, wood for compost, brush, and construction and demolition wastes such as pallets, boxes, packaging, and wood debris[52]. Incineration-plants are faced with many emissions challenges when MSW is used as a fuel source. Improved affordable technologies to clean emissions are needed. The high population centers in the Northeast region generate millions of tons of solid waste each year. For example, in New York alone, 29.7 million tons of solid waste is generated each year. Of this, 12.6 million tons are recycled, 3.6 million tons were incinerated for power generation, 9.4 million tons were placed in landfills, and 4.1 million tons were exported out of the state(62).

MSW Landfill gases. As organic matter in landfills decomposes, methane is produced and is released to the atmosphere. Several landfill sites in the Northeast region collect the landfill gases, containing approximately 50% methane, and utilize the methane for energy production or a fuel source for heating. Technologies to remove sulfur compounds and other contaminants from methane are needed. Clean methane also can serve as a renewable fuel source for fuel cells.

A SUSTAINABLE PRODUCTION SYSTEM

In addition to making a rigorous inventory and developing technologies to increase biomass production in the Northeast region, issues of sustainability must be examined, defined, and put into practice. The amount of crop residues to return to the soil will depend on the crop, cultivation technology, soil types, climate, and land use. Guidelines must be developed through research for sustainable practices for bioenergy, biofuel, and bioproducts crops. Equipment technologies to simultaneously harvest and return a fraction of biomass to the soil need to be developed. Sustainability of biobased products, biofuels and biopower will revolve around issues such soil organic matter levels, nitrogen cycling in the farm/forest ecosystem, water quality, integration of the biorefinery with the cropping systems and many other such system level questions. Most of these questions are best addressed by life cycle analysis (LCA) applied to the integrated cropping/biorefinery systems. The figure below "All Biomass is Local" illustrates this point of view and outlines how such life cycle analyses might be conducted.



Industrial Ecology figure is courtesy of Bruce Dale, University of Michigan

SETTING THE GOAL

Development of biomass resources for the Northeast Sun Grant States biobased industries must include detailed identification and quantification of the existing potential feedstocks. A key issue is dry matter density of the biomass materials. It is also important to identify potential end-user's needs and to quantify the geographical distances between feedstock producers and potential end-users. Optimization studies are needed that evaluate trade-offs in crop selection, plant engineering and breeding of new crops, harvest technologies, and sustainability issues such as soil erosion, and water availability. Feedstock development for the Northeast Region of the Sun Grant Initiative must adopt the long-term goal of delivering reasonably priced biomass to the Industry Gate.

Photo credit: Scott Bauer, USDA/ARS Image Gallery

Sun Grant Enabling Activity 2
Conversion Processes

BIOMASS CONVERSION TECHNOLOGIES

Extracting valuable power, fuels, and products from biomass feedstocks requires a suite of conversion technologies. The specific conversion process used depends on the final product, the feedstock composition, the conversion equipment efficiencies, and public policy incentives. The conversion of biomass to an end product becomes more difficult when the feedstock composition varies in content of moisture, carbon, oil, or particle size. One approach for addressing issues of feedstock variability is pretreatment of feedstocks. Another approach is to develop conversion technologies that are more flexible with respect to feedstock composition and condition, such as thermal depolymerization process (TDP)[63], used to convert a wide variety of waste feedstocks to oils and other valuable products. The intended end-use of the final product will influence the choice of conversion process. The following briefly describes the main conversion process technologies for BioPower, BioFuels, and BioProducts.

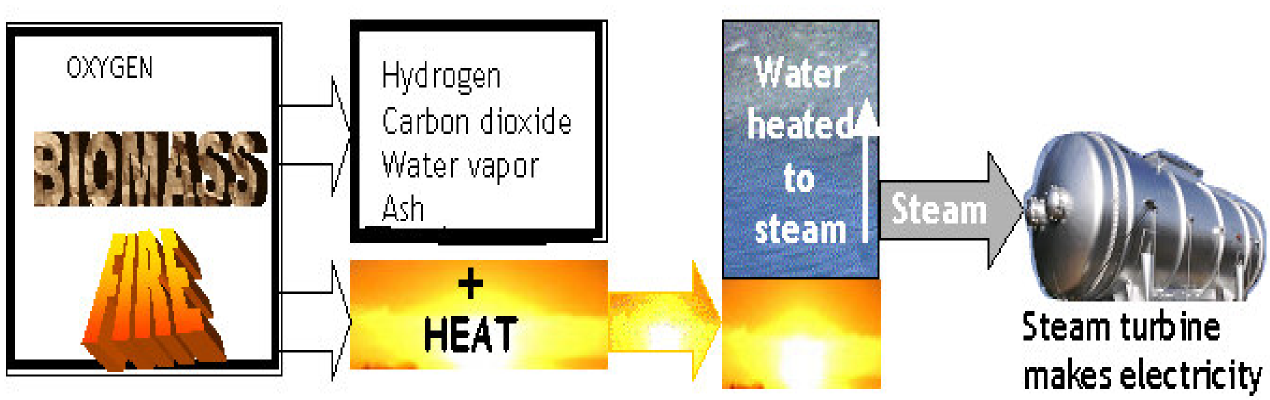
BIOPOWER CONVERSION TECHNOLOGIES

BioPower conversion technologies can be divided into two main categories:

1) Traditional combustion technologies which are more established but less efficient, and
2) Advanced gasification/pyrolysis technologies which are evolving into more efficient technologies.

The advanced technologies with conversion efficiencies in the range of 80% - 95% [64] tend to require higher capital investment for fuel pretreatment and gasification/pyrolysis equipment. The more established combustion technologies tend to have significant heat loss to stacks and condenser cooling-water, yielding efficiencies of 20-22%.[64]

Direct Combustion. Direct combustion is the direct burning of biomass and is the most common form of biopower conversion in US power plants today. The process is similar to fossil-fuel combustion. Heat generated from combustion of biomass heats water to produce steam. The steam turns a turbine and electricity is generated. Direct combustion of biomass is currently used in the Northeast Region on a small scale for power production.



Direct combustion and co-firing combustion conversion processes produce heat. The heat is applied to water to make steam, which in turn drives a steam turbine to generate electricity.

Co-firing Combustion. Co-firing is the replacement of a portion of coal or natural gas fuel with biomass. Co-firing reduces emissions of SO_x, NO_x, and CO_2 compared to burning coal alone[51]. The biomass is combusted simultaneously with the coal (or natural gas) to produce steam in a boiler and generate electricity. Co-firing of biomass is accomplished in several ways including the use of pulverized coal burners, coal-fired cyclone burners, fluidized bed, or spreader stoker combustors. Co-firing is identified by Department of Energy as the nearest-term lowest-cost option for biomass energy. The U.S. Department of Energy Biomass Power Program estimates that co-firing biomass could replace 8 GW of energy by 2010 and 26 GW by 2020[(65)]. There are seven co-firing demonstration or validation projects underway in the Northeast Sun Grant States[(65)]:

1) Dunkirk, New York (willow and coal);

2) Dresden, New York (wood furniture factory residues and coal);

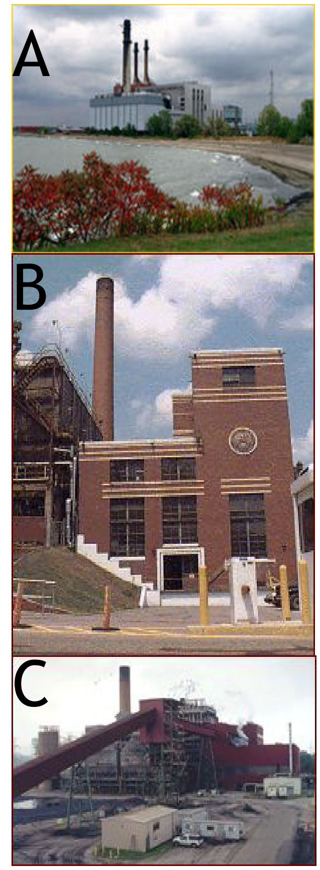
3) Pennsylvania State University, University Park, PA (multiple biomass fuels on a fluidized bed);

4) National Institute of Occupational Health and Safety, Pittsburgh, PA (urban wood waste and coal);

5) University of Pittsburgh, Pittsburgh, PA (urban wood/ construction waste wood and coal);

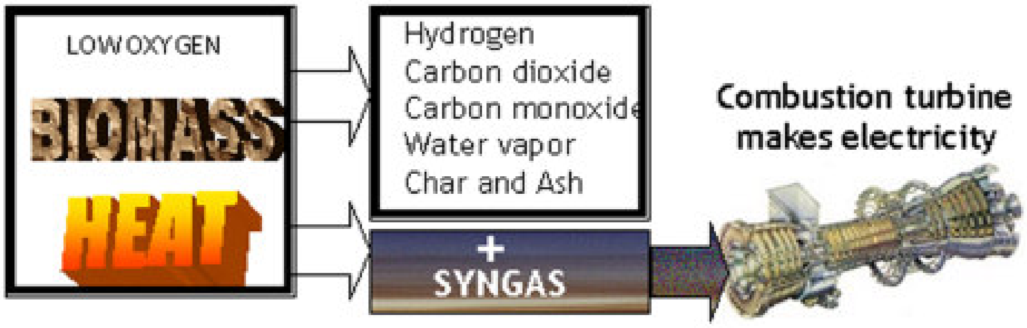
6) Allegheny Energy, Albright, WV (sawdust and pulverized coal);

7) Allegheny Energy, Willow Island, WV (sawdust and tire-derived fuel (TDF)).



Northeast co-firing plants in (A) Dunkirk, NY, (B) Pittsburgh, PA, and (C) Willow Island, WV . Co-firing is the replacement of a portion of coal or other fossil fuel with biomass for electrical power generation. (Photo Source U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy).

Thermal Gasification. Thermal gasification the use of high temperatures to break down biomass into simple gaseous compounds such as CO, CO_2, H_2, and hydrocarbon gases. Other compounds produced from gasification are char and ash. The hydrocarbon gas (syngas) is then burned in a combustion turbine to produce electricity.



Thermal gasification of biomass uses high temperatures (though lower than combustion or pyrolysis) and low oxygen conditions to break down biomass into simple compounds and hydrocarbon gas (syngas). The syngas is then burned in a combustion turbine to produce electricity.

There are four basic types of gasifiers currently under development[30,64]. They are: 1) fixed bed updraft gasifier, 2) fixed bed downdraft gasifier, 3) fluidized bed gasifier, and 4) the low-pressure gasifier. All of these technologies are in various stages of research and commercialization development. The fixed bed updraft gasifier is suitable for feedstocks with high moisture content, but requires large, dense uniformly sized fuels and the products cannot be burned in internal combustion engines. The fixed bed downdraft gasifier is preferred for feedstocks with high concentration of volatile compounds but requires feedstock moisture contents below 20%. The fluidized bed gasifier demonstrates superior heat-mixing and feedstock moisture contents up to 55% are acceptable. The fluidized bed allows higher throughput at lower cost than the other methods. The low-pressure gasifier products can be used in a standard gas turbine[64].

The McNeil Station plant in Burlington, VT demonstrates gasification of biomass for electricity generation. (Photo Source Department of Energy, Office of Energy Efficiency and Renewable Energy).

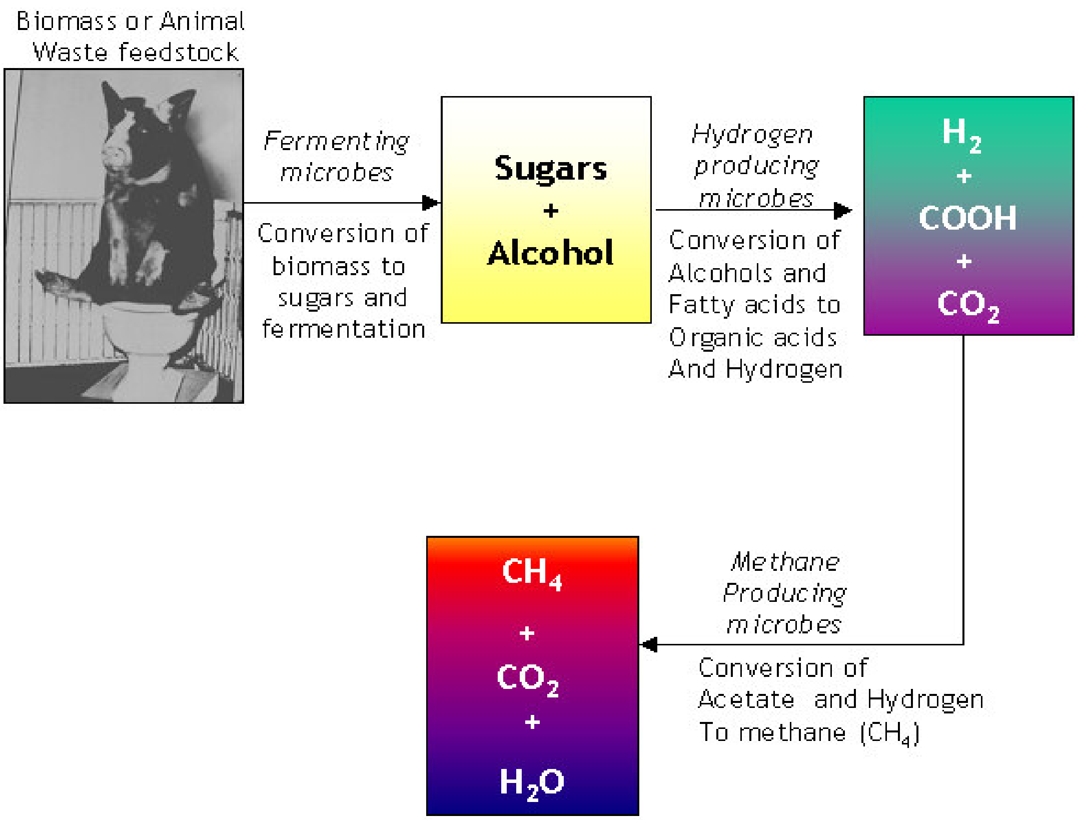
In the Northeast, Burlington Electric's McNeil Station in Burlington, Vermont is a power plant demonstrating gasification of biomass to produce electricity. The McNeil Station utilizes a circulating fluidized bed to produce syngas from dried wood. McNeil also co-fires wood biomass with natural gas and syngas (from the fluidized bed system) in a spreader-stoker boiler unit. The project is designed to validate a large-scale integrated gasifier and gas turbine combined cycle (IGCC) technology. The McNeil Station has been operating since June of 1984 with an availability rating of over 90%.[66]

Anaerobic Digestion. Anaerobic digestion of animal wastes and Municipal Solid Wastes (MSW) both produce methane gas that can be collected and utilized for either heat or combined heat and power (CHP) generation systems. Methane from biogas can be used to heat boilers and also used to generate electricity through gas turbine or internal combustion driven generators. Additional processing and cleanup is needed for biogas use in internal combustion engines. Also, if sulfur contaminants are removed, methane from biogas can be used to power fuel cells. A sulfur removal system for landfill gas is being demonstrated at the EcoComplex that will allow the EcoComplex to power a fuel cell in a future demonstration. The EcoComplex in NJ is incubating a company that cleans landfill gas to levels acceptable for fuel cells. This technology can also produce renewable compressed natural gas (CNG) or liquid natural gas (LNG) for use by heavy trucks in place of diesel fuel engines. LFG use for Controlled Environment Agriculture is demonstrated at the EcoComplex.

"COW POWER"
Biogas can come from a variety of sources including farm animals, landfill gas, and municipal sewage waste. (Photo source: Cornell University Cow Power Program)

Anaerobic digesters utilize microbes to break down biomass into methane (CH_4) and carbon dioxide (CO_2). Bacteria are the primary biological agents in anaerobic digesters, but anaerobic fungi and protozoa may also be found in the system's microbial community. Anaerobic digestion can be done using thermophilic microbes (active from 45 - 75 ^{o}C), or mesophilic microbes (active at lower temperatures, 25 - 35 ^{o}C). In addition to the temperature-divisions, the microbes also can be divided into metabolic groupings.

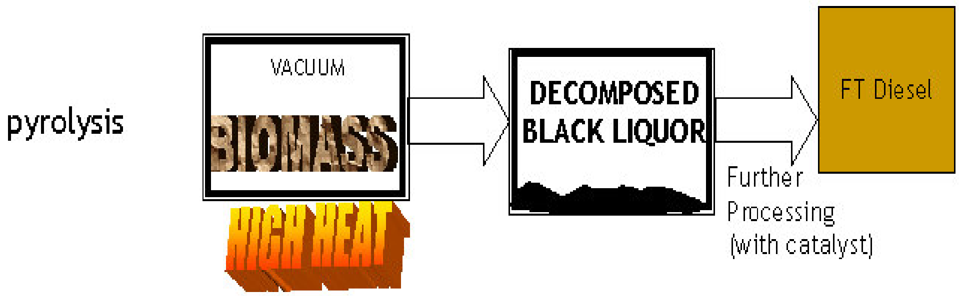
"Landfill POWER"
Landfill gas powered microturbines at the NJ Ecocomplex and Rutger's CEA greenhouse complex. (Photo source: NJ Ecocomplex, Rutgers, The State University of NJ)



Anaerobic digestion involves three stages of interacting microbial digestion to produce methane from biomass: fermenting, hydrogen-producing, and methane-producing microbes

The first set of microbes break down the organic material into smaller molecules such as sugars and the sugars are fermented. The next group (hydrogen producing microbes) breaks down alcohols and long chain fatty-acids to produce hydrogen and organic acids such as acetate. Finally the methanogenic microbes utilize the hydrogen to form methane gas[68,69]. The products of one group of microbes are the feedstock of another, thus the interactions of the between microbial communities are important to the process of anaerobic digestion. Anaerobic digesters are currently used on farms in the Northeast as a waste treatment method for dairy, poultry and swine. Efficient use of biogas not only can supply heat and energy but also reduces odor and methane emissions. The biogas collection systems are relatively simple and well developed technologies. Advances are needed in gas clean-up technologies to remove contaminants from methane in biogas.

Thermochemical Conversion. Thermochemical conversion processes (such as gasification and pyrolysis) can use a combination of heat and chemical catalysts (acids, bases, solvents) to break down biomass. The biomass is broken down (fractionated) into fermentable sugars, cellulosic fiber and lignin.

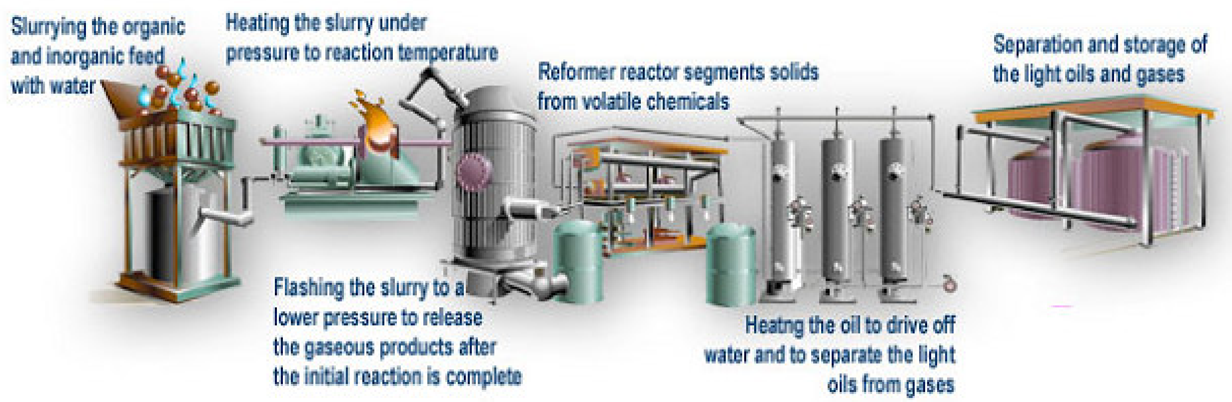


The thermochemical process pyrolysis breaks down biomass into a black liquor that can be further treated to produce biofuel.

Primary products of the conversion (such as hydrogen) can be further processed to produce biofuels. For example, hydrogen and carbon monoxide (syngas mixtures) from gasification processes can be further treated with a catalyst (Fischer Tropsch catalyst) to form a hydrocarbon fuel or "FT Diesel"(64).

Thermal Depolymerization Process (TDP). Thermal depolymerization process (TDP) is a commercial thermochemical conversion process that mimics the geological processes of nature in an accelerated timescale(63). The process controls temperature and pressure to produce high quality products (light oils, purified minerals, carbon, natural gas, and water) from waste. This innovative process has been demonstrated at a pilot plant in Philadelphia, Pennsylvania by the developer and owner of the processes, Changing World Technologies (CWT). Unlike pyrolysis, TDP has the ability to work with wet feedstocks.

TDP pilot plant in Philadelphia, PA produces oil from turkey processing waste. Photo is courtesy of Changing World Technologies (CWT).

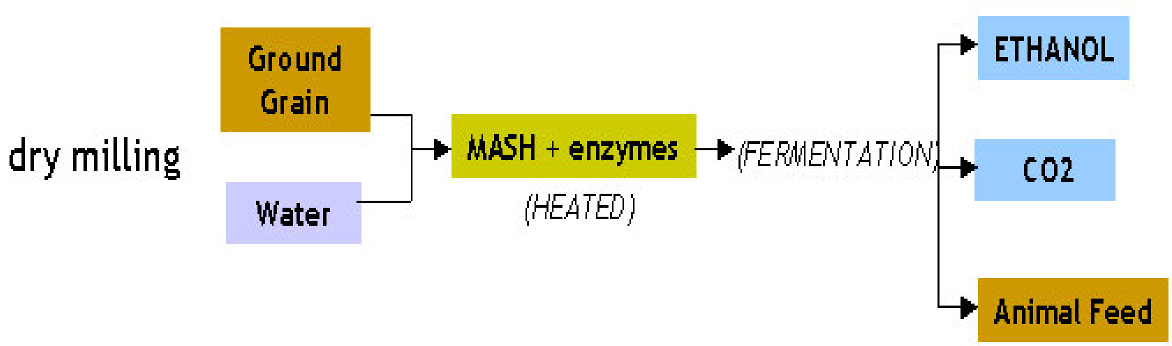


Thermal Depolymerization Process (TDP) utilizes controlled temperature and pressure to mimic Earth's geological processes at an accelerated timescale. TDP converts waste into oil and other valuable products. Process diagram is courtesy of Changing World Technologies.

BIOFUELS CONVERSION TECHNOLOGIES

Transportation fuels also can be made from biomass resources. Biofuels include ethanol, biodiesel, hydrogen, methanol, and Fischer-Tropsch diesel.

Ethanol. Petroleum fuels burn more cleanly when they are oxygenated. Ethanol can be used as an oxygenator for petroleum fuels[(36)]. Ethanol is produced commercially using milled grain. The dry-milled grain is combined with water to form a mash. The mash is heated and enzymes are added to convert starches into sugars that can be fermented into ethanol[(27)]. Carbon dioxide is produced in the fermentation process and the remaining material is used as animal feed.



Ethanol is produced from milled grain starch compounds that are enzymatically converted to sugars and then to ethanol through the biological process of fermentation.

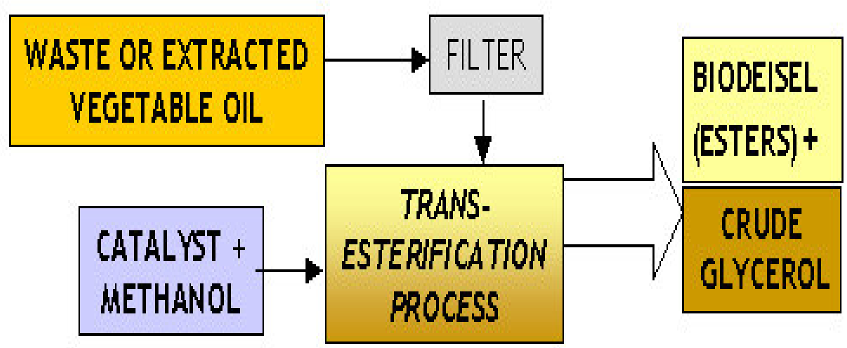
Ethanol can also be produced from a wide variety of lignocellulosic crops, crop residues and woody plants. An effective and economical large scale biofuels industry based on lignocellulose conversion would dramatically improve the rural economy and national security. The technical roadblocks to such an industry are well known and include: 1) development of pretreatments to increase the yield of fermentable sugars from lignocellulosics, 2) development of inexpensive, effective enzymes that hydrolyze pretreated biomass to mixed sugars, and 3) organisms that ferment these mixed sugars to ethanol and other biocommodity products. Research is needed in these and related areas. Fuel ethanol also is produced from low-cost cellulosic feedstocks such as municipal solid waste paper refuse, cardboard, and "green" wastes. A company in Wooster, Ohio (Genahol Co.) is currently converting MSW-green waste to ethanol through a patented process on a commercial scale.

P-Series Fuels. P-series fuels are made primarily from renewable resources and yield improved emissions compared to reformulated gasolines. P-Series fuels are blended fuels containing natural gas fuels, ethanol, and a biomass-derived co-solvent methyltetrahydrofuran (MTHF). A company in New Jersey (Pure Energy Corp.) has developed a process for the production of P-series fuels and has refined the process at the laboratory, pilot and demonstration scales. Plans are being prepared to move the process to the commercial scale.

Biodiesel. Biodiesel is a liquid fuel manufactured from vegetable oils, such as soybean oil. It is also possible to use waste-oils from restaurants as the biodiesel feedstock. Biodiesel is not the same thing as raw vegetable oil. To make biodiesel, raw vegetable oil is filtered and then combined with an alcohol (such as methanol or ethanol) and a catalyst (such as sodium hydroxide or potassium hydroxide). The alcohol and catalyst convert the raw vegetable oil through a chemical process (transesterification) to form crude glycerol and methyl esters (biodiesel). The methyl esters are mono-alkyl esters of medium-chain (C16-18) fatty acids. Straight biodiesel can be used in diesel engines or can be combined with any portion of petroleum diesel into a "biodiesel blend".(41)

In recent years, air emission regulations have targeted reduction of sulfur and aromatics in petroleum diesel fuel. However, reduction of sulfur has the unwanted side-effect of reduced lubricity of the fuel. The biodiesel blends improve lubricity of low sulfur petroleum diesel fuels. In tests performed by the International Standards Organization (ISO) it was determined that as little as 0.4% biodiesel blend was sufficient to provide the lubricity required by the US Military specifications and ASTM regulations for lubricity.[41]

trans-esterification

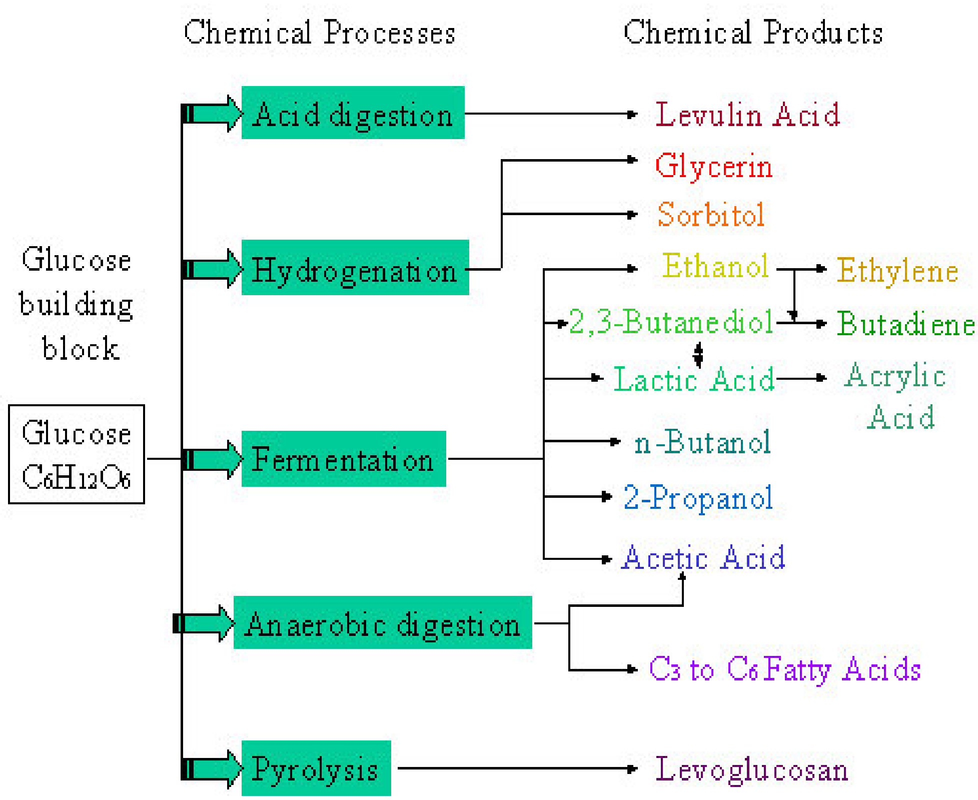


Biodiesel from vegetable oil (extracted from soybeans or other oil seeds and filtered) is produced through a transesterification process.

A primary issue of concern with biodiesel is the ability to produce enough feedstock oil for it to play a large role in our fuels of the future. For that reason, research in this field should focus on the development of novel feedstocks which can yield larger quantities of vegetable oil, or valuable coproducts in addition to the oil itself.

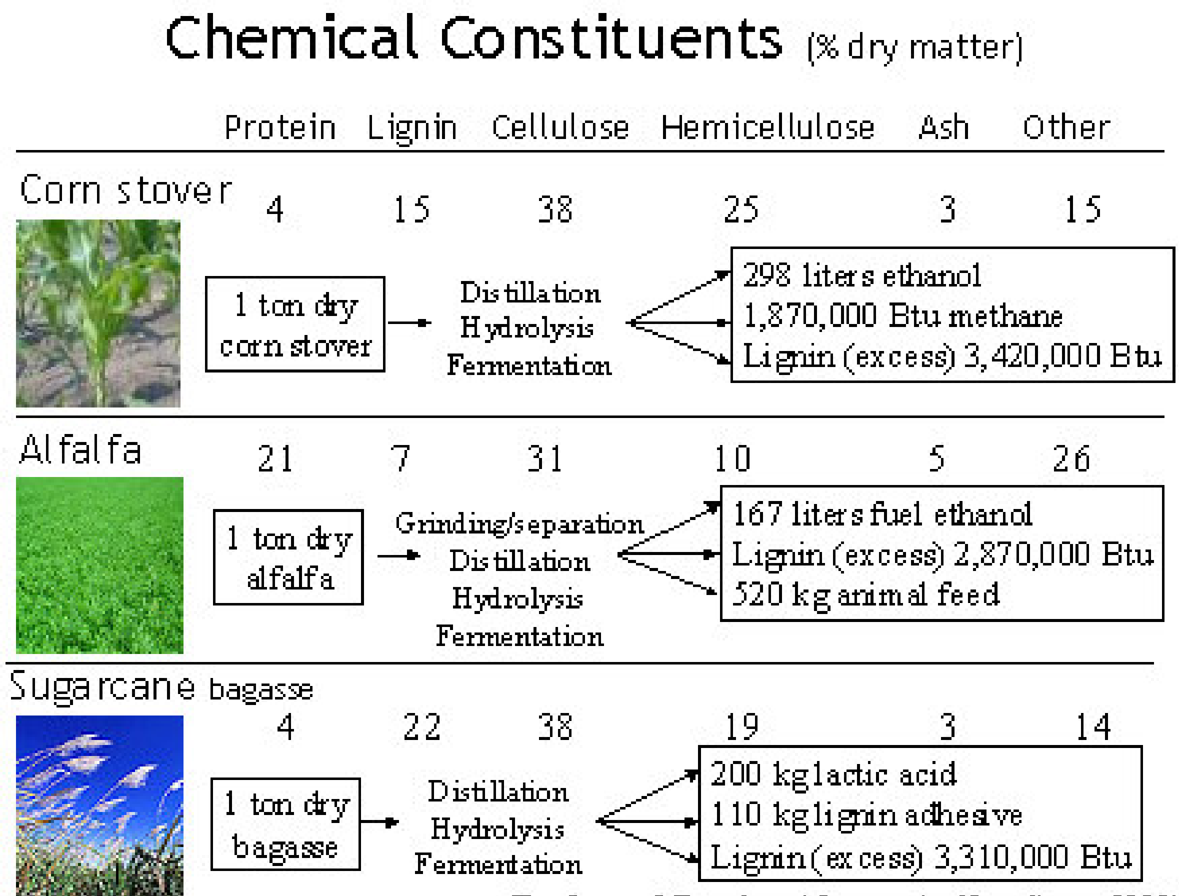
BIOPRODUCTS TECHNOLOGIES

Plant molecules and petroleum molecules can both be used as building blocks for many industrial products such as plastics, solvents, paints, inks, adhesives, polymers, resins, oils, gums, textile fibers and drugs. Petroleum molecules have been the more commonly-used building block during much of the industrial revolution and in some cases (e.g., superglues) still out-perform plant-derived products. However, simple sugars from biomass can be converted to high value chemical products.



Beginning with a simple sugar (glucose) as a building block, different conversion processes can be used to produce a wide variety of chemical products.

Biochemical Conversion. Biochemical conversion processes such as fermentation of sugars are used to convert biomass into useful products. Microorganisms such as yeast are used commercially to ferment sugars into ethanol. Bacteria can break down sludge or manure to produce methane. Cell walls of plants contain complex carbohydrates that are more difficult to break down such as cellulose, hemicellulose and lignin. Development of cost-effective cellulase and hemicellulase enzymes that break down these carbohydrates to fermentable sugars is important for the conversion of biomass to fuels and industrial chemicals[59,70].



(Broder and Barrier, *Advances in New Crops*, 1990)

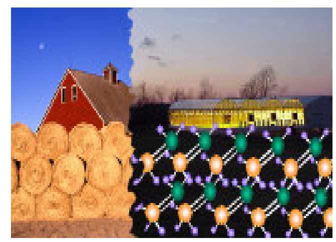
Plant materials are rich in carbon. Even after removing the food value from corn and sugarcane plants, the remaining plant residues can be further processed to produce ethanol, lactic acid, adhesives and still provide excess lignin as fuel for biomass power production.

A wide variety of catalysts are needed to transform molecules derived from plants into useful products. Enzymes, cells and chemical catalysts will all play a role in commercializing a variety of bioproducts. These biochemical and chemical catalysts will be evaluated in terms of yield, selectivity, concentration and rate of product generation, exactly as is done in the conventional chemical industry.

BIOMOLECULAR FARMING

Plants respond biochemically to their environment in predictable ways. Biomolecular farming is the control and utilization of optimized environmental conditions to induce production or elimination of a specific biomolecule using plants as the biomolecular factory. The biomolecules can then be collected with the plant material or plant growth medium and can be sequestered through filtration and other post-harvest processing techniques.

This type of environmental control is available through Controlled Environment Agriculture (CEA) sytems. CEA has created a new cropping paradigm, demonstrating unprecedented biomass productivity and quality assurance in plant production. For example, biomass production in excess of 450 tons/acre/year has been demonstrated in a CEA prototype commercial-scale module at Cornell University (compared to 45 tons per acre typical in traditional California field agriculture for the same plant species (Lactuca sativa)[71]. In addition, the capability to control the level of the secondary metabolite, oxalic acid, in spinach has been demonstrated using CEA by manipulating the environment of the root zone[48]. Environmental manipulation of plant production is a powerful control mechanism fully enabled by CEA techniques.



Cornell's Controlled Environment Agriculture module has demonstrated unprecedented biomass production and control of plant biochemistry through environmental stimuli. The marriage of CEA technology with genetically modified plants may make biomolecular farming economically feasible for industrial enzyme production and pharmaceutical protein production. (Photo source: Cornell University CEA Program)

The genetic modification of plants to produce human proteins is well established. The marriage of CEA technology with genetically modified plants may make biomolecular farming economically feasible for industrial enzyme production, nutriceutical therapeutic bioproducts, and pharmaceutical protein production at significantly lowered cost compared to microbial and animal protein production systems.

Sun Grant Enabling Activity 3
Systems Integration

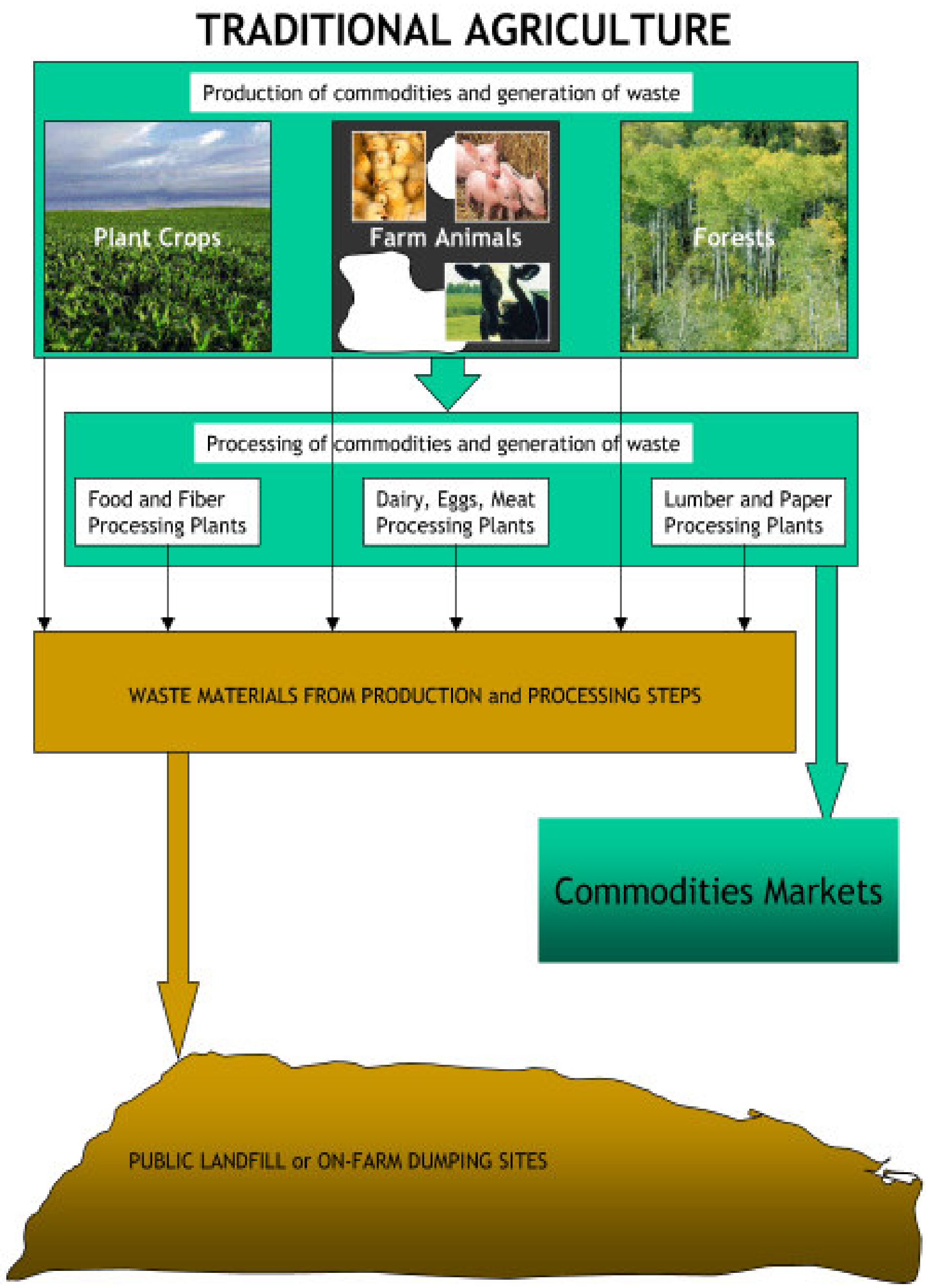
Industrial Ecology

Building a biobased industry in the United States will require integration of many individual sectors. For example, feedstocks must be harvested, then packaged for transport to a processing facility. Location of the feedstock source close to the processing facility will increase efficiency. The processing facility will probably need to grade, sort and mix incoming feedstocks. The feedstock materials will be processed to extract the highest value and waste-streams from this processing might be utilized at a second facility for power generation. Products from the first facility and power from the second facility need to be distributed to markets and customers. This network of material and energy flow resembles an "industrial ecology"[72] where the resources (feedstocks) are optimized by integrating the entire industrial process, minimizing the waste generated (energy and materials) at each step of the process, and maximizing the reuse of waste at each step of the process. For example, the use of waste for new products such as a compost tea, may substitute for a few of the chemicals used in agriculture.

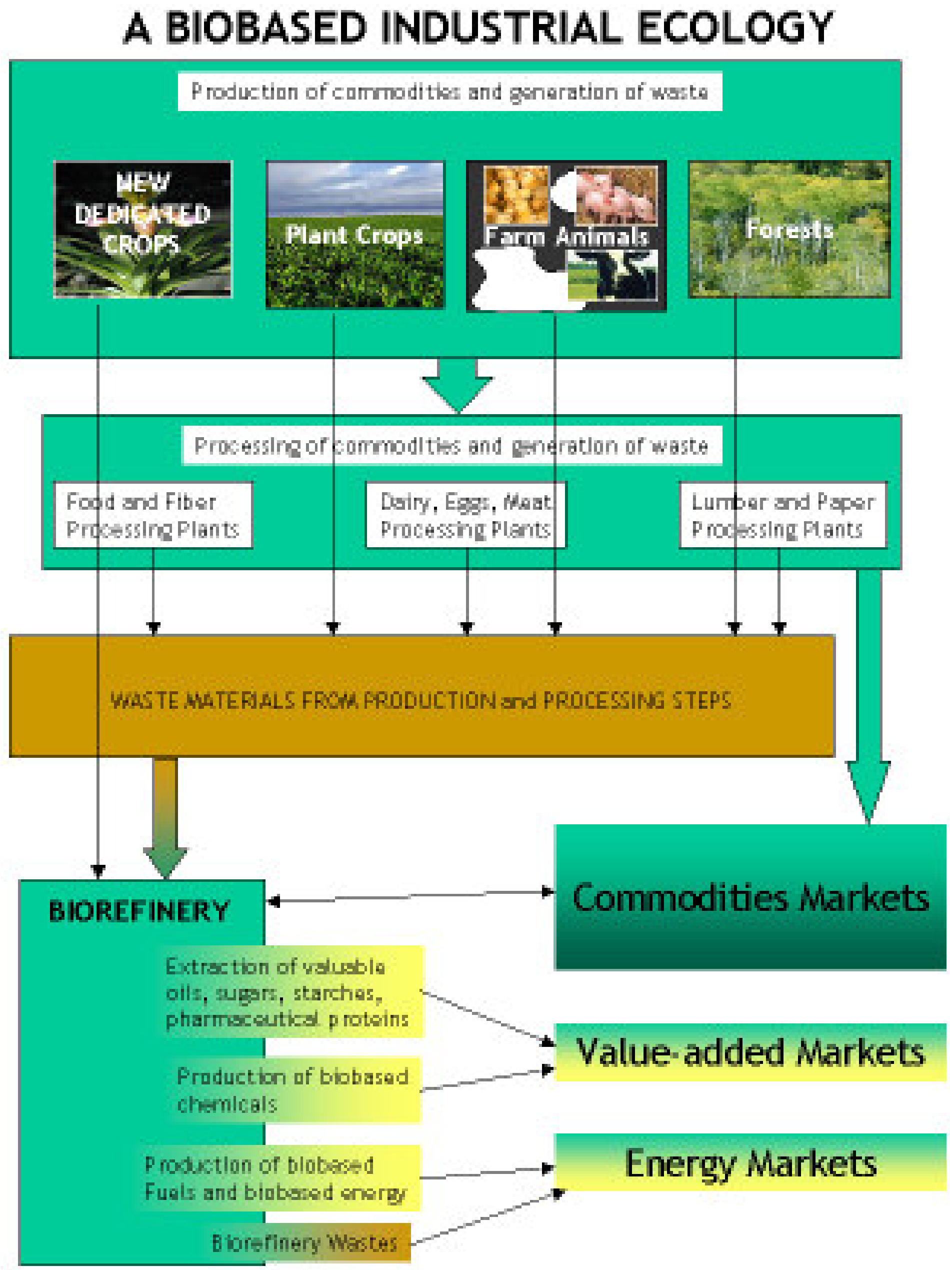
The integration of many subsystems will occur naturally as the biobased economy evolves, however some systems integration testing can be completed at the demonstration scale of a new technology. The various components of the whole-system, scale-up issues, feedstock transportation and power plant location issues, and even marketing issues may be framed within the concept of the Biorefinery.

Biorefinery

Biorefineries are equipment and processes that convert biomass into fuels, electricity and chemicals. The Biorefinery is the biobased economy's corollary to the petroleum refinery of the fossil fuel based economy[59]. Liquid fuel is the primary product made in the 152



petroleum refineries in operation in the United States today. However the smaller quantities of value-added petroleum-based chemicals and products are vital to the refineries' profitability. The integrated Biorefinery will take the same approach in the inclusion of value-added products manufacturing.



The "Biorefinery" is a central strategy for the Department of Energy's Biomass Program[59]. The Biomass Program is planning two pioneering projects including the establishment of the first large-scale sugar biorefinery based on agricultural residues and start-up demonstrations of biorefineries producing fuels, chemicals and power.

Whole-systems and scale-up issues

The new technologies developed through the Sun Grant Initiative will most likely be tested first on a laboratory scale. Unforeseen challenges often emerge when small-scale prototypes are scaled up to commercial-size. Scale-up issues will be addressed through commercial scale demonstration of promising technologies. Additionally, the commercial scale demonstrations will include integration into whole-systems to identify potential parts-supply issues, marketing issues, or other unforeseen challenges from the laboratory bench scale.

Environmental Sustainability Issues

An important area of research is the issue of increased generation of the greenhouse gas, carbon dioxide, resulting from hydrogen and other energy production technologies. Carbon sequestration modeling is needed to understand the recycling of this molecule into useful and stable products to reduce free evolution of carbon dioxide into the atmosphere.

A new frontier of opportunities

We have an opportunity that a new industry has never had before. We can design these biopower/biofuels/bioproduct systems so that they deliver not only economic benefits but also environmental and social benefits—the so-called triple bottom line of sustainability. The tools of industrial ecology, life cycle analysis, biorefinery simulation and ecosystem modeling can be combined to determine the likely environmental and many social impacts of integrated biorefinery systems. With this knowledge, we can configure these systems so that they deliver the maximum benefits and so that we can anticipate and avoid problems."

Sun Grant Enabling Activity 4
Marketing, Economic and Policy Analysis

Analysis of the market demand for biobased products is a critical for moving any new product to market. The economic impacts of the transition to a biobased economy also must be considered. Analysis of public policy will be instrumental in building the new biobased economy.

Marketing Issues

Marketing is important in the creation of new technologies that will support a new national industry. Emerging technologies must communicate their value to potential users and identify potential markets. As markets develop there will be pressure on suppliers to make continuous improvements in their products and services. Companies must continually assess the value of current markets and if necessary, enter new markets for growth or even survival.

Marketing expertise will assist researchers to identify additional potential markets (such as Agri-tourism or other nonagricultural markets) as the industrial ecology of a biobased economy evolves. Social acceptance of new products or processes and of potential state or federal subsidy programs will need to be evaluated.

Economic Issues

The use of bio-industrial processes to add value to traditional agricultural commodities has great potential to impact the demand for agricultural commodities and to increase farm commodity prices and farm incomes. However, any change in production technology has the potential to induce substantial social and economic consequences for both producers and society. Increased demand for selected agricultural commodities might be expected to increase commodity price. Such price increases likely will stimulate production of that commodity perhaps by inducing producers to switch land from production of other crops (and thus reducing supply and increasing price of the substituted crops) or inducing additional (perhaps marginal, environmentally fragile) land into production. Land prices may be bid upward. The combined effect of these changes could result in increased cost of food and fiber to society. If new bio-industries are located in rural communities near the production of the agricultural feedstock, these rural communities may benefit from increased employment and a heightened tax base, but also may face substantial costs for infrastructure development to support the industry or realize other unintended social impacts. Research is needed to address this broad range of issues. Assessment of economic profitability of proposed new products or processes will aid those making investment or policy decisions. Research is needed to evaluate the impact of new products on competing product prices, agricultural commodity prices, farm incomes, and costs of food and fiber.

Policy Issues

The relationships between federal and state regulatory regimes and the problems and potentials for licensing and approval of processes and products are important policy aspects. Policy analyses will provide information needed to solve regulatory problems and enhance technological applications and product development. Program communications must be responsive to public values, attitudes and norms while specifically addressing the benefits and any risks of technologies and products.

Scientific discoveries and practices can contribute to identifying and developing solutions to permitting/location challenges, addressing the regulatory atmosphere for promoting biofuels and bioproducts, and options for improving current energy/environmental regulations.

Adopting the specific goals set forth by the Biomass Research and Development Technical Advisory Committee for the Northeast Region Sun Grant States is possible for planning purposes for the NE Sun Grant Initiative Research, Outreach and Education programs. However, the adoption of the same goals as public policy within each state will require a great deal of effort and collaboration between the Northeast Region state legislatures.

Tax incentives currently provided to ethanol producers have provided the boost in production and have been instrumental in the growth of the US ethanol industry. In addition to tax and economic incentives, public policy barriers that may discourage private investment in the biobased economy must be identified, considered, and revised where appropriate. For example, Northeast states not only have vastly different portfolio standards for renewable energy, they also have different definitions of renewable energy (i.e., some states specifically exclude biomass).

Feedstock Transportation Issues

Biomass feedstocks tend to be bulky and difficult to handle. The feedstocks will need to be transported from the field or forest to the processing facility or electricity power plant. Electricity generation plants tend to be located near large population centers. Transportation of the feedstocks from rural areas to processing plants could be cost-prohibitive. US oil refineries are located nearest to the imported source (shorelines) and major waterways. Similarly for bio-based processing, transportation costs will be reduced if the processing or power generation plants are located near the feedstock resources.

US Oil Refineries are located near the imported source (shorelines) and major waterways.

Economic Development Outreach

The Sun Grant Initiative Act places a strong focus on this same vision of healthy sustainable communities and environmental protection. The addition of an Economic Development expert through Cooperative Extension at various multi-state regions within the Northeast will facilitate the commercial implementation of Sun Grant Initiative technologies.

A Northeast Region STTR Program

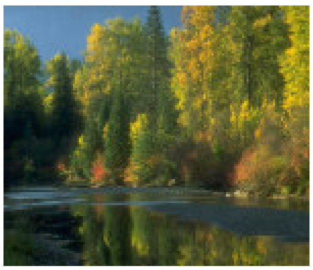
Another method of technology development and implementation is through establishing a Small Business Technology Transfer (STTR) Program for the Northeast Region Sun Grant Initiative. Congress established the STTR program as a companion program to the Small Business Innovative Research (SBIR) Program. The STTR program is executed in the same manner as the SBIR program, however, there are a few distinct differences. While STTR has the same objectives as SBIR regarding the involvement of small businesses and the commercialization of their innovative technologies, the STTR Program also provides a mechanism for participation by universities, federally-funded research and development centers, and other nonprofit research institutions. The STTR Program is designed to provide incentive for small companies, and researchers at academic institutions and non-profit research institutions, to work together to transfer emerging technical ideas from the laboratory to the marketplace. Each STTR proposal must be submitted by a team that includes a small business (as the prime contractor for contracting purposes) and at least one research institution, which have entered into a Cooperative Research and Development Agreement for the purposes of the STTR effort. The project must be divided such that the small business performs at least 40% of the work and the research institution(s) performs at least 30% of the work. The remainder of the work may be performed by either party or a third party.

Policy and Economic and Environmental Feasibility

In addition to whole-system issues (e.g., feedstock location, harvest and transport, conversion processing plant location, optimization of conversion processes, marketing, economic development) public policy plays an important role in the economic and environmental feasibility of the commercialization of an industry or industry segment. The following section lists additional policy issues and several options for public policy consideration in the Northeast Sun Grant States. The list is not intended to be all-inclusive, but is intended to promote discussion and collaboration in determining the best policy options for the Northeast Region.

FEEDSTOCKS

Sustainable Feedstocks Inventory: Support a rigorous inventory and analysis of sustainable biomass feedstock production technology including determination of amounts of biomass that should be left in the soils for adequate soil conditioning and replenishment of nutrients.



Regional Definition and Labeling of Biomass: Support increased dialogue between Northeast region policy makers and stake holders to facilitate 1) a more uniform definition of biomass feedstocks; 2) a more uniform definition of renewable energy that includes biomass; and 3) a uniform regional labeling program for biomass feedstocks to facilitate interstate biomass feedstock commerce.

Feedstock Infrastructure: Support state and regional analysis and development of improved rural infrastructure (road and rail) to facilitate the transport of biomass feedstocks to conversion facilities.

CONVERSION

Benefits to existing facilities for conversion: Provide economic incentives to existing power and fuel producers to incorporate innovative biomass conversion technology into existing fuel production facilities.

Advanced Technology Risk Sharing: Provide financial risk-sharing incentives for advanced conversion technologies such as gasification and pyrolysis, including technology improvements and commercial scale demonstrations.

SYSTEMS INTEGRATION

Identification of Barriers: Support state and regional research/analysis to identify technological, economic, and public policy barriers to the development of an environmentally sound sustainable biobased economy

Distributed Energy Resources (DER) incentives: Support development of small biomass generators and policy that includes eligibility of small biomass generators in DER incentives.

Permitting/location challenges: Support analysis and identification of optimal locations for potential biorefineries in Northeastern rural areas, including analysis of permitting challenges and environmental impact analysis.

Combined Heat and Power (CHP) emissions incentives: Support incentives that reward biomass energy for increased efficiencies and reduced emissions in combined heat and power systems.

ENVIRONMENTAL BENEFITS AND EMISSIONS

Comprehensive emissions policy: Support revisions of current emissions policies that penalize biomass energy for certain emissions (CO and NO_x) but do not reward biomass for positive attributes (reduced greenhouse gas emissions, i.e., CH_4, CO_2, and reduced SO_2, emissions reduction relative to coal and oil emissions).

Cost of new environmental controls: Support incentives to existing conversion facilities to reduce the capital cost of installing environmental controls (particulate matter reduction, CO and NO_x emissions reduction) for the increased use of biomass power generation.

RURAL ECONOMIC DEVELOPMENT

Economic Analysis: Perform an economic analysis of energy and agricultural policies, incentives, and programs that promote commercialization of environmentally sound biobased technologies in rural communities of the Northeast region.

Small Business Technology Transfer (STTR) Program: Provide a Northeast Regional STTR program to support the commercialization of Sun Grant biomass technologies developed through Land Grant Universities.

Research, Education, and Outreach Priorities for the Northeast Sun Grant Competitive Grants Program

A regional workshop was held on April 25-27, 2004 in Buffalo, New York. Meeting participants at the *Northeast Sun Grant Regional Workshop* represented each of the 14 states and the District of Columbia in the Northeast Sun Grant region. In addition to hearing presentations from biobased industries, nine working group sessions enabled participants to meet, discuss and define specific research, education and outreach priorities for the region's competitive grants program. Moderators for the nine working group sessions presented each group's conclusions, comments and recommendations for the region's program priorities. The funding level for the program was unknown at the time of the workshop and also is unknown at this writing. Meeting participants focused on 3 strategic areas: BioPower, BioFuels, and BioProducts. Participants identified specific enabling activities in the areas of feedstock development, conversion processes, systems integration, and marketing, economics & policy. The national Sun Grant Initiative goals of promoting energy security (energy self-sufficiency), homeland security, rural development, human capital enhancement, and capacity building were strongly supported by Northeast Sun Grant Initiative (NESGI) region participants. The following summarizes the collective outcome of the working group sessions; these are adopted as the Northeast Sun Grant Initiative regional priorities for research, education, and outreach activities.

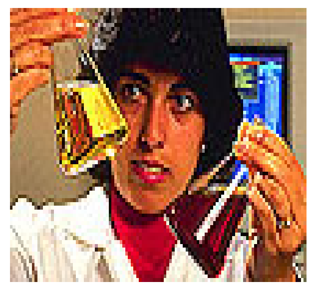
The Northeast Sun Grant Regional Planning Workshop convened in Buffalo, NY on April 25-27, 2004. Participants from the northeast region met to set the priorities for the Northeast Sun Grant region's competitive grants program. Participants represented land grant colleges and universities, biobased industries & biofuel companies, students, government representatives, and not-for-profit bioeconomy development organizations.

Student participation at the Northeast Sun Grant Regional Planning Workshop

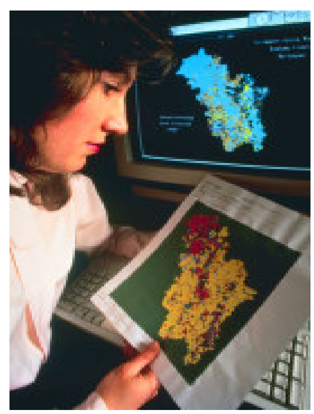
Research priorities for the region

Moving new technologies, products and discoveries to the public market place is strongly supported by NESGI. Workshop participants recommend that the NESGI research portfolio should include a mixture of projects with short term and long-term commercialization potential. The possibility of requesting matching funds in research proposal applications was raised. One approach identified may be to attach the level of matching funds to a particular project's potential for marketability. This must be balanced with the need for "high impact" products to get the attention of policy makers and other potential investors. The working groups voiced the need for broad "Request for Applications" (RFA) topic areas, because it is difficult to select or de-select commercially viable concepts at the basic science stage of the development pipeline. A broadly written RFA increases the chance of finding "winning" concepts and also affords this pioneering effort greater ability to evolve to meet the needs of the region and the nation.

Research Priorities for the region's will address issues relating to: 1) Feedstock development; 2) Conversion Processes; 3) Systems Integration; and 4) Marketing, Economics and Public Policy Issues.



(Photos are courtesy of USDA ARS Image Gallery)



The working groups recommend the ideas of sustainability be integrated into the program themes. Technology exchange beyond the region and the nation and working across state and regional boundaries could be encouraged through multi-institutional as well as university-industry joint proposals, particularly for large projects involving mature concepts. Smaller projects, especially for concept development, should be available for single or small teams of investigators. The following chart lists specific research priorities identified by the region for the strategic areas of BioPower, BioFuels, and BioProducts.

BIOPOWER RESEARCH PRIORITIES

ENABLING ACTIVITIES	TASKS
FEEDSTOCK DEVELOPMENT	- Identify and characterize biomass feedstocks. - Develop desirable traits in biomass to improve energy yield. - Improve biomass production systems to optimize resource and land use.
CONVERSION PROCESSES	- Improve efficiency of conversion processes. - Improve conversion efficiency of biomass to electricity and heat using fuel cells. - Examine scalability for technical workability and economic viability. - Place research emphasis on small farm or home use.
SYSTEMS INTEGRATION	- Perform strengths, weaknesses, opportunities, and threats (SWOT) analysis on the region's biobased power production. - Use process integration and synergy to optimize economic, social, and environmental returns (triple bottom line). - Address reliability and reduncy issues in subsystems and whole-system design.
MARKETING, ECONOMICS and POLICY ANALYSIS	- Test small scale as a market entry strategy. - Study the impact of variability of law and regulation on biopower (e.g., current and potential incentives). - Model the natural and agricultural production of biomass in terms of ecological impacts, sustainability, and cost effectiveness.

BIOPRODUCTS RESEARCH PRIORITIES

ENABLING ACTIVITIES	TASKS
FEEDSTOCK DEVELOPMENT	- Identify alternate uses of existing feedstocks. - Study biomass residue composition and use after energy extraction. - Identify value-added products in bioenergy biomass utilization. - Update inventory of feedstocks available in the Northeast. - Explore potential residue streams vs new agricultural/forest products. - Explore opportunities for reviving USA specialty chemical industry.
CONVERSION PROCESSES	- Optimize microbial fermentation. - Refine and develop separation technologies. *NOTE: The area of Conversion Processes was selected as the highest priority for Bioproducts Research.*
SYSTEMS INTEGRATION	- Itegrate bioproducts production into biorefineries. - Perform life cycle analysis with emphasis on quantification.
MARKETING, ECONOMICS and POLICY ANALYSIS	- Analyze bioproducts industry's regional and environmental impacts. - Analyze bioproducts industry's influence on job creation.

BIOFUELS RESEARCH PRIORITIES

ENABLING ACTIVITIES	TASKS
FEEDSTOCK DEVELOPMENT	- Demonstrate combinations of crops and crop residues with conversion processes capable of providing sugar at a new cost of $0.06/lb. - Update inventory of existing and potential organic residues. - Breed new crops for enhancing biofuels production and minimizing environmental impact.
CONVERSION PROCESSES	- Determine the most efficient methods for converti ng biomass into biofuels. - Analyze additional co-product opportunities from processes. - Analyze most efficient combination of scale and scope economies. - Develop rapid and cost-effective test procedures for quality assurance. - Analyze and develop distributive conversion systems.
SYSTEMS INTEGRATION	- Develop efficient harvesting, storage, transporation methods and equipment. - Perform a least cost assessment with focus on the northeast area for crops common to this area and with a view of enhancing and maintaining environmental resources. - Conduct GIS analysis to combine feedstocks for optimization of material and energy flows. - Model with large-scale systems thinking for inputs and outputs (beyond state boundaries). - Analyze fuel utilization issues with integration between the fuel and the conversion technology. - Integrate farm-scale conversion systems - reintegrating waste into the farm operation. - Develop specific models for analyzing system interactions: Agro-eco-industrial integration. - Develop close coupling of biogas and bio-oil to energy converters (i.e., fuel cells and advanced energy conversion systems.
MARKETING, ECONOMICS and POLICY ANALYSIS	- Review policies for current land use preservation and for utilization of marginal lands. - Develop models of the circulation of dollars in the local bioeconomy. - Develop least cost methods for greenhouse gas (GHG) reduction and assessment of greenhouse gas reduction attributed to biofuels. - Perform cost and benefit analysis for time and space accounting of biofuels options. - Analyze market drivers for biofuels. - Assess balance of capital markets, financing options, relation to final products, including influence of funding sources.

Education Priorities for the Region

Pioneering the transition to a biobased economy includes a strong commitment to educating the future workforce.

Potential audiences served

(Photos are courtesy of USDA ARS Image Gallery)

Education priorities for the region include a suite of programs supporting Kindergarten through graduate school education (K through PhD).

The Northeast Sun Grant Initiative's investment in education should include a suite of programs for the kindergarten through graduate school (K-Ph.D.) education community. The education community includes students, teachers, guidance counselors, education researchers, and education administrators.

Methods of education

The participants of the Northeast Sun Grant Regional Workshop advise that the educational programs should include an emphasis on industry involvement, business management, and the integration of disciplines. Preference should be given for courses with a "northeast regional" focus. Education should train the leaders of tomorrow; therefore a survey of biobased industry needs is desired to focus areas for training and course/module development. Members of the region also recommend topical meetings, capacity development and web-access training programs. Educational activities should include scholarships for students, as well as development of training materials.

Expected Impacts

The Northeast Sun Grant educational programs expect to impact the future of education and industry in many positive ways. The science modules, innovation competitions, will help educate today's youth in the basics of science and math while simultaneously instilling an appreciation for the environment, the importance of renewable energy sources, and the importance of strong communities. The support of scholarships, fellowships and internships for students and teachers will help build a strong core of future researchers and engineers working in the area of biobased industries. The involvement of industry partners with the educational programs will improve the communications between industry and universities, and will increase the function of universities to solve real-world problems.

Specific Activities

During the Northeast Sun Grant Regional Workshop (April 2004 in Buffalo, NY), the workshop participants identified education program priorities for the Northeast Region. These priorities are shown in the following chart.

EDUCATION PRIORITIES

<table>
<tr><th>WHO</th><th>K-12</th><th>UNDERGRADUATE</th><th>GRADUATE</th></tr>
<tr><td>WHAT</td><td>- Strengthen mastery of the "basics".

- Provide support for teacher summer sabbaticals.

- Introduce concepts of biobased industries through local, state, and regional activities.</td><td colspan="2">- Train the leaders of tomorrow.

- Encourage exposure to biobased industries and sustainability concepts.

-Encourage integration of diciplines

-Enable university student and industry interaction and involvement.</td></tr>
<tr><td>HOW</td><td>- Develop Sun Grant teaching modules for existing K-12 math and science courses.

- Design and hold competitions for K-12 innovations in bio-based technologies and products.

- Maintain an inventory of class modules at the Center of Excellence.</td><td>- Develop new courses in bioindustry-related topics.

- Develop teaching modules and seminars for existing courses.

-Provide undergraduate scholarships and internships.

- Create undergraduate bioindustries major/minor programs in existing related departments.

- Support the formation of student clubs and incubator space.

- Support field trips to bio-based industry sites.

- Encourage competitions for innovations in biobased industry technologies.</td><td>- Develop new courses in bioindustry-related topics.

- Develop teaching modules and seminars for existing courses.

- Offer graduate fellowships and internships.

- Offer intra-institutional seminar series.

- Support the formation of student clubs, incubator space, and field trips to biobased industry sites.

- Encourage competitions for innovations in biobased industry technologies and business plan competitions.

- Develop training and certification progrmas.

- Support traveling scholars.</td></tr>
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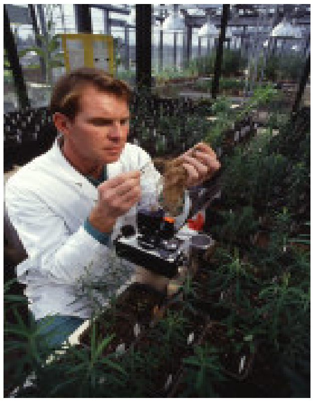
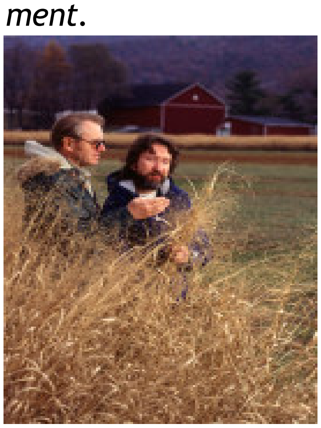
Outreach Priorities for the Region



Outreach Priorities include enhancing public familiarity and exposure to biobased industries and sustainability concepts to create more informed producers, processors, consumers and decision makers. Outreach information should be research-based and coordinated with the most current state of technology development.



(Photos are courtesy of USDA ARS Image Gallery)

The Northeast Sun Grant Regional Workshop participants identified potential audiences, methods, and specific outreach activities.

Potential audiences served

Potential audiences served by the Northeast Sun Grant Initiative (NESGI) activities include the public, consumers, users, farmers, landowners, industry (CEO's), processors, policy makers, regulators, decision makers, stakeholders, and advocacy groups. Outreach also should be provided in the form of professional development (i.e., train the trainers). Early adopters should be targeted (i.e., pioneers, e.g., hybrid car owners) for feedback on early outreach efforts.

Methods of outreach

The transition to a biobased economy is a potentially "disruptive" process. Methods of outreach could be through the use of innovative communication systems for selling disruptive technologies (e.g., websites, mass media, meetings, educational materials, and demonstrations). Effective methods are needed to survey public knowledge and preferences in order to optimize the usefulness of information provided in outreach efforts. Multi-state outreach efforts should be given preference. International applications of outreach also should be supported. Bioenergy/bioproducts outreach centers are needed and should combine both industry and land grant institution efforts. Outreach information should be research-based and must be coordinated with the state of technology development so that the most current, most accurate information is provided. All projects would be required to perform outcome evaluation and impact assessment reports to the region. The following chart summarizes the priorities.

OUTREACH PRIORITIES

WHO	Public, consumers, users, stakeholders	Farmers, landowners, industry (CEO's), processors	Policy makers, regulators, decision makers, and advocacy groups
WHAT	- Enhance public familiarity and exposure to biobased industries and sustainability concepts, to create more informed producers, processors, consumers, and decision makers.. - Optimize transfer of information by first surveying public knowledge to gauge outreach materials and methods. -Coordinate efforts across the region through outreach centers, website development, meetings, and educational demonstrations.		
HOW	- Demonstrate the economic benefits, environmental benefits, and social benefits of biobased power through providing a comparative analysis of integrated biopower systems (home heat, fuel cells, co-generation of electricity). - Facilitate bringing together the scientific community to address specific issues. - Organize conferences to bring stakeholders together. - Show the sustainability and applicability of recycling and reuse for biobased products after first use.	-Communicate the best management practices (BMP) for crops and crop residues including handling, harvesting and storage. -Communicate the benefits of taking feedstocks out of the waste stream for use in biobased industries. -Provide technical information on the sustainable production of new crops. -Communicate information on the energy values and economic values of various feedstocks for fuel and co-products. -Develop strong collaborative relationships between universities and industry through joint proposals, industry internships, and meetings. -Increase awareness of new technology, economic impact, and environmental impact of the bio industries.	- Provide information for standards for certifications and labeling. - Demonstrate and showcase application case studies. - Provide credible criteria and data to policy makers.

CROSSCUTTING AREAS and ENABLING ACTIVITIES

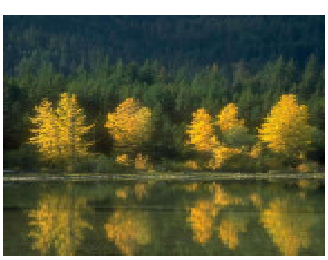
The three strategic areas pertaining to the United States biomass industry development (i.e., *1) BioPower, 2) BioFuels and 3) BioProducts*) each have strong relevance to the Northeast Sun Grant states. In the previous sections, we have identified within each of these three strategic areas four enabling activities: (i.e., *1) Feedstock Development, 2) Conversion Processes, 3) Systems Integration, and 4) Public Policy*) to move the United States through the transition to a biobased economy and to reduce dependence on foreign oil. Cross-cutting themes within the enabling activities are graduate education, economic development, and environmental sustainability.

Graduate Education

A strong multidiciplinary graduate education program is critical to the success of the Sun Grant Initiative. Training the "Green Industries" leaders of the future is a crosscutting priority, enabling the advancement of all aspects of the Initiative's purpose. It is important for the future leaders to be trained in multiple disciplines to develop strong, critical "systems thinking" abilities.

Economic Development

As with graduate education, economic development activities cut across all strategic areas and all enabling activities. The region envisions investment in economic development through partnering with industry for competitive STTR program grants.



Environmental Sustainability

Another crosscutting area for consideration within all enabling activities are the issues of sustainability. Technologies and processes that are developed must be environmentally sound practices that will improve and not deplete rural environments, maintaining our lands as a valuable, sustainable, national resource.

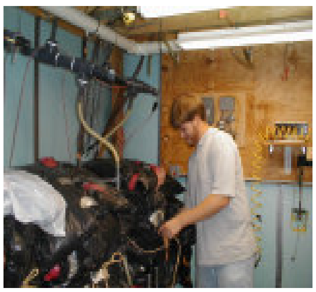
Feedstock Development Enabling Activities

In addition to traditional plant breeding and agricultural practices, new dedicated crops with specific properties or compounds may be engineered through genetic engineering approaches. One critical area of research is to determine the environmental impacts of introducing and harvesting a specific feedstock. If crop residues are to be utilized, the amount of residue to return to the field must be determined to provide a sustainable system. New crop-specific technologies and equipment are needed that can simultaneously harvest the crop and return the optimal amount of residue to the field to replenish the soil. A rigorous inventory of potential biomass resources in the Northeast Region is needed, including waste streams from food processing, municipal solid wastes, animal wastes, and source-separated solid wastes. Existing databases might be combined with GIS mapping technologies to develop an updated and rigorous biomass resource audit for the Northeast Sun Grant States.

Fermentation research and enzyme reactor engineering. Photo source: Erin Krause.

Conversion Processes Enabling Activities

The conversion of biomass to energy and useful products can be accomplished through thermochemical conversion processes, or bioconversion processes such as enzymatic and microbial conversion. Thermochemical conversion process research is needed to optimize the efficiency of co-firing, gasification, pyrolysis and thermal depolymerization process systems. Enzymatic conversion issues include prospecting for novel enzymes with useful properties, protein engineering and enzyme reactor engineering. Microbial conversion process research can address issues at the microbial-community level, such as anaerobic digestion issues, or at the microbial monoculture-level for the development of biocontrol products or hydrogen production. Metabolic engineering of organisms may lead to more efficient production of microbial products, or increased microbial activity under challenging thermal environments. Research is needed in bioreactor engineering, microbial ecology engineering, ecological engineering and proteomics.



Digestor research. Photo source: Cornell Biological and Environmental Engineering.

Systems Integration Enabling Activities

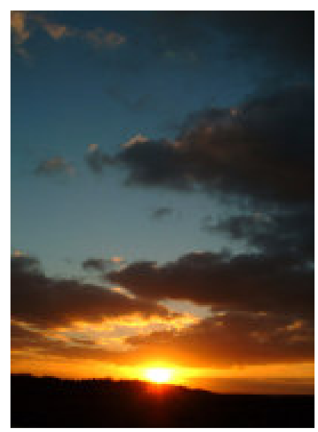
Research at the Systems level should identify and address aspects of an industrial ecology. Modeling tools are needed for systems optimization. Databases for system modeling and analysis are needed as tools for researchers. A cost database is needed to provide reliable estimates of the cost of various parts of the production system, and values of various products produced by the system. An analysis is needed of energy use or "energy audit" of the system and its products. The flow of labor requirements and job creation estimates for the various technology improvements are needed, linking economic development issues to systems integration. Environmental impact and life cycle analyses are needed for the various feedstocks, conversion processes, and systems.

Marketing, Economic and Policy Analysis Enabling Activities

A "Markets" database for the Northeast Region is needed so that researchers can focus technology development in areas with the greatest market demand. For example, databases on the northeast power market, transportation fuels market, industrial chemicals and enzyme markets, including domestic and foreign markets are important. Economic analysis on the availability of capital, the influence of interest rates, the influence of bond initiatives to finance biorefineries in the northeast, are important to the Sun Grant Initiative. Economic analyses are needed for potential or case-study job creation from new energy technologies. Another issue needing study is the cost and benefit (economic and social) of the development of infrastructure to support distributed energy technologies. Scale economy issues need to be addressed to determine the limiting resources of a rural "industrial ecology" model in the northeast region.

The Northeast Sun Grant Initiative

The priorities set forth by the Northeast region and summarized within this Roadmap set the stage for a strong competitive grants program. As the program research, education and outreach priorities are undertaken, new priorities may emerge and the Northeast region Sun Grant Initiative program will evolve to meet new challenges for addressing issues of national energy security, economic diversification in rural areas, and environmental sustainability. With this collective vision and set of priorities in hand and the resources of our great land grant institutions on board, we are prepared to forge ahead, fueling America's future with the rich resources of our homeland.



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