THE GRAND CHALLENGE

BIG RED'S BIG GREEN INITIATIVES

CORNELL COLLEGE OF AGRICULTURE AND LIFE SCIENCE'S VISION for the BIOENERGY FUTURE

Executive Summary

The promise and potential of America's transition to a bioenergy economy provides a historic opportunity for government agencies, the private sector, and academic institutions to work together toward a common goal. In an earlier generation, America set its sights on space exploration and in less than 10 years traveled to the Moon and back, a previously unimaginable feat. Our generation has now taken on a project of similar dimension, difficulty and of even greater potential to revolutionize human existence on earth. As with the lunar missions, there will be inspirations, solutions, and set-backs. Today, we are gaining new understanding at a rapid pace about how the many different agricultural markets, the economy, and the environment are strongly interconnected and in delicate balance. National attention is focused on bioenergy as never before. Recent reports in mainstream media illustrate the growing importance of the public awareness, with some articles highlighting legitimate challenges while others have distorted the impact of the emerging bioenergy industry on commodity prices and global agricultural practices, and erroneously blamed biofuel crops, in particular, for a host of global ills.

These challenges underscore the importance of moving forward, through research and education, with the 25x'25 Alliance's *twin* goals of expanding *sustainable* bioenergy options while continuing "to produce safe, abundant, and affordable food, feed, and fiber." At Cornell University's College of Agriculture and Life Sciences (CALS), we are well on the way to finding solutions that by 2017 will bridge the considerable gap between promise and reality. We envision a vibrant agricultural production system that makes optimal use of regionally-produced biomass resources, utilizes a variety of conversion technologies, encourages conservation and rural development, and produces a mix of energy and bioproducts in a sustainable and holistic manner. We are:

- Building strong and competitive research, extension/outreach, and education programs focused on bioenergy, biofuels, and bioproducts development;
- Preparing the next generation to address the challenges of new biobased industries through whole-system thinking and industrial ecology engineering and science;
- Assessing environmental and economic impacts associated with bioenergy development, to help identify and communicate the most effective, efficient, and sustainable approaches to a bioenergy economy;
- Thinking "green" – with the smart design of products, processes, and systems to avoid environmental problems before they arise;
- Using sound assessments of economic and logistical impediments to the development of a New York and Northeast regional bioenergy economy;

- Recognizing that success in developing a sustainable bioenergy economy hinges on creating flexible, efficient systems and processes responsive to differing regional, consumer, and business opportunities. "One size fits all" will not work;
- Adopting a "Culture of Sustainability" within CALS and the Cornell University Agricultural Experiment Station, including spearheading the development and adoption of a major bioenergy commitment by Cornell University as part of Cornell's participation in the University Presidents' Climate Commitment.

Cornell University is in a unique position to meet the challenge. As New York's Land-Grant University, we have a long tradition of bringing applied and basic science to bear on problems of local, national, and international development. Cornell is one of very few institutions in the world that is able to bring together so many physical and life scientists, engineers, and social scientists with the motivation and expertise to create a sustainable, vital, bioenergy future.

We will make significant contributions to the bioenergy economy in 2017 and beyond by utilizing the concept of a "living, learning, laboratory," where faculty and students participate in world-class basic and applied research on issues of feedstock production, conversion technologies, and sustainable development. Discoveries will be extended to society through our extension networks and partnerships with public agencies and private industry participants. Students will gain an understanding of the fundamental knowledge required to be leaders in the field.

In this paper, we offer examples that reflect how Cornell's vision meets the four goals of increasing the production of renewable energy and alternative fuels, delivering that energy to consumers, meeting consumer demand, and enhancing sustainability, conservation, and energy efficiency. Listed in this paper are some – but by no means all -- of the more than a dozen projects, many multidisciplinary, in bioenergy research and extension that will be critical to the ultimate success of bioenergy as a secure, domestic source of energy and a viable replacement to a significant portion of fossil fuels. Our focus:

- **Developing Next Generation Bioenergy Crops:** Finding the right mix of lignocellulosic biomass given the Northeast's unique mix of resources and proximity to major energy-consuming markets, developing processing technology that will lead to lower costs and more efficient systems, and encouraging agriculture and forestry bioenergy development with minimal environmental impact;
- **Identifying and maximizing resources,** including business infrastructure, and economic, conservation, and public policy incentives to encourage sustainable development of biomass that is complementary to food production;
- **Creating flexible and responsive models** that will guide communities, emerging and existing energy businesses, policy makers, and agricultural producers in finding the right approach given their location, energy needs, and available resources;
- **Enhancing sustainability, conservation, and efficiency** with realistic and science-based solutions for bioenergy development, including conservation and best management practices for producers and consumers.

Next Generation Bioenergy Crops: A Vision for Cellulosic Biofuels and Bioproducts

The cellulosic biofuels program at the College of Agriculture and Life Sciences is a multidisciplinary team of scientists, engineers, economists, and educators working on a "systems approach," addressing the current challenges in the development of cellulosic ethanol and associated biobased industries, which include overcoming the physical, chemical and biological barriers to liberating sugars from energy crops such as switchgrass, cold tolerant sorghum, and woody biomass, and to biologically convert these sugars into biofuels such as ethanol, butanol, hydrogen, and methane. A new state-of-the-art Biofuels Research laboratory scheduled for operation in 2008 will strengthen CALS' capacity in pretreatment, enzymatic conversion of cellulose to glucose, and the co-fermentation of glucose and xylose to ethanol or butanol. These three activities are the core of the industrial biotechnology component of the biofuels sector.

As expanding biobased products, bioenergy, and biofuels markets are providing new opportunities for agriculture and forestry, people involved at all levels – from farm to processing plants, from research laboratories to government legislatures -- are stimulating a new vision of how research, development, and education must be organized to reach ambitious national goals. We believe the best approach is based on principles of industrial ecology. By examining methods tried and tested by nature in ecological systems, we can build a sustainable industrial ecology, where the waste products of one process are the resource inputs for another. This approach requires a new vision and higher level of integration of research, development, and education at all levels, identifying opportunities to exploit the breakthroughs of molecular biology, genetics, and nano-biotechnology along with advanced engineering research activities such as sophisticated reactor systems, biosensors, and advanced separation systems to imagine how sustainable bioindustries might be developed. To that end, Cornell is committed to a four-pronged approach for maximum impact in the next decade: *fundamental research*, which includes protein engineering and metabolic engineering to create more efficient cellulose enzymes; *advance biofuels engineering research*, including reactor systems, advance separation systems, bio-chips, fuel cells, and plant systems for energy production*; education activities*, including graduate student training, master of engineering bio-industries design projects, workshops and internships for students with industry partners; and *technology transfer and economic development activities*, including licensing and patents for Cornell technologies, economic forecasting, and biofuels systems strategy development.

Cornell's Cellulosic Biofuels Research Program will play a key role in research, development, and training within the industrial ecology of the bioeconomy in 2017. We will contribute to meeting the 25x'25goal through achievements in production of improved bioenergy crops and agricultural production methods, integration of research with industry infrastructure, integration of communities through Cornell Cooperative Extension (CCE), and enhancing sustainability through an industrial ecology systems approach. Another important element is the training of students, our future leaders, and extension educators so that the ripple effect of bioenergy industrial ecology does not stop at the university gates but expands exponentially into increased community and business awareness of opportunity.

Production of cellulosic biofuel on large scales will require new agroecosystems to produce crops with a *high* biomass yield per acre and *maximum* extractable energy per unit weight that have optimal performance under a variety of stresses, with minimal inputs (e.g. fertilizer and pesticides). There is

not a single biomass ideotype: the ideal biomass will be regionally-specific. The development of effective, environmentally-friendly, long-term agroenergy cropping systems requires the collaboration of many plant scientists, including breeders, agronomists, physiologists, pathologists, geneticists and biotechnologists. For example, one critical challenge in producing cellulosic ethanol competitively is the relatively expensive process of breaking down a plant's cell wall material and fermenting the released sugars. Working with environmental and biological engineers, CALS plant scientists have already made breakthroughs in cell wall science that will lead to increased efficiency and reduced processing costs.

Location
Because of the unique challenges in transporting bulky biomass materials, a successful biomass industry will include locally produced biomass, locally converted and locally consumed energy and products. Given the local nature of biomass systems, Cooperative Extension educators will play a critical role in advising communities about local bioindustries. A report from the National Renewable Energy Laboratory finds that the transport of bulky biomass materials beyond 20 miles becomes very costly, and that beyond 100-200 miles becomes cost prohibitive.[1] As communities in the Northeast begin to consider distributed biomass energy plants or distributed biomass-to-ethanol processing plants it is indeed possible that, based on current predictions, every one or two counties in the region might consider its own biomass processing center. Cornell Extension is uniquely positioned to advise community planners on the nature and optimization of county-level biomass, and help attract private investment dollars. Extension personnel will also play a role in developing a workforce to support this growing industry. In the Cornell vision, mega-plants will not be feasible for the Northeast. A more realistic scenario envisions smaller facilities, using a regionalized, tailored portfolio of renewable resources from a 30 to 40 mile radius.

Identifying and Maximizing Resources

Feedstock Production: A Vision for Feeding a Fuel-hungry Nation
In the Northeast, an array of diverse bioenergy feedstocks will be necessary to produce enough biomass to meet the region's energy needs. To reach national goals it is estimated that one billion tons of dry biomass will be needed to produce approximately 60 billion gallons of ethanol per year. To attain this level of production, we will need approximately 446 million dry tons of crop residues (e.g. corn stover and grain straw) and 377 million dry tons of perennial grasses and woody crops, in addition to other supply streams (e.g. grain, manure and agricultural wastes), to reach an estimated annual production of 1.3 billion metric tons of sustainably produced biomass by the mid-21st century. At this level, biomass would then have the potential to produce roughly 130 billion gallons of liquid fuel per year.

One project currently underway at Cornell designed to help the region assume a larger role in the biofuels industry, is a multi-year, multi-site study to identify perennial grass and legume feedstocks that have the best potential to provide the quantity and quality of biomass needed to support the emerging biofuel industry in New York Through data collected from these multi-site trials, researchers will be able to deliver species recommendations and management advice to current and potential producers of dedicated bioenergy feedstock crops. The trials, funded in part by a grower-

[1] (*Wiltsee, G. (2000) Lessons learned from existing biomass power plants,* NREL Report #NREL/SR-570-26946).

led organization, the New York Farm Viability Institute and the Northern New York Agricultural Development Program, will also provide data for economic analyses of production costs and value of different feedstocks for use in conversion to biofuels or for direct combustion. Information on management practices that influence yield and plant compositional characteristics associated with bioenergy conversion, along with data on the incidence and severity of plant diseases and insects, and seed quality of the perennial grasses are also being collected.

This research has already resulted in preliminary recommendations for optimal seeding times, spacing and pest management, meeting demand by regional growers who are hungry for information about entering the bioenergy market. Cornell researchers have identified approximately 1.5 million acres in New York that is currently underutilized and available for biofuel production *without* interfering with current agricultural operations or replacing food crops. Close proximity to major population and transportation centers gives the state, and region, a logistical advantage for development of bioenergy crops and industrial bioproducts from energy conversion processes. Production of warm season perennial grass field crops for dedicated use as bioenergy crops has the potential to increase revenue for the agricultural industry and transportation sectors, make use of idle farmland, and expand options to the livestock industry for manure management. By 2017, the results of these trials will help establish a base of sustainable, viable feedstock production to keep pace with demand and keep the state on track to meet 25x'25 goals.

Organic Waste

Livestock production is an important component of the agricultural economy in the Northeast and livestock waste, particularly from dairy farms, presents a potentially large source of renewable energy. New York's 700,000 cows alone produce millions of tons of waste each year. Implementing a waste-to-energy solution is a double plus for agricultural producers because it generally results in improved waste treatment, thereby reducing the environmental impacts associated with livestock operations, particularly impacts on water quality. Cornell researchers are working on many aspects of conversion technologies, including system design and implementation, establishing economic policy recommendations aimed at market development, and economic analysis for livestock operators and system developers.

Anaerobic digestion technology is one promising way to convert waste streams to heat and power. It can fulfill an important and complementary part of a bioenergy future, which must include both large and small-scale development models. In Cornell's vision for a bioenergy future, farm and other organic waste would meet a significant portion of community energy needs, reducing the demand on industrial-scale systems. A coordinated effort implemented by Cornell Cooperative Extension (CCE) and supported by bioengineers and rural economic development specialists is intended to revolutionize waste stream utilization on a grand scale with many positive environmental and economic benefits.

The Northeast – Forest Assets

Forested lands are by far the biggest potential source of biomass in the Northeast. In New York alone there are 15.4 million acres of forestland with adequate growth rates for commercial timber production with a potential annual yield of biomass residues from timber stand improvement cuts estimated to be 0.8 tons per acre on 5 million acres, according to researchers. Cornell researchers are examining options that use wood from existing mixed-species forests. Many forests could benefit

from a timber stand improvement cut, which would remove low-value cull wood for bioenergy, and leave high value timber species to grow and produce future high-value products. This is a "win-win" opportunity, because there is a greenhouse gas reduction benefit gained from the cull wood, and the forest is left in better shape for future production of high value wood products. With a timber stand improvement cut, forests will also continue to sequester carbon, providing an ongoing greenhouse gas benefit. The best forest strategy for maximal greenhouse gas mitigation potential is timber stand improvement cuts for either heat (replacing fuel oil) or electricity (co-fired with coal). Together, these strategies could reduce total New York State emissions by 3.7%, which exceeds the total predicted emissions from the agricultural sector. These options provide 30-fold greater greenhouse gas mitigation than using corn to generate ethanol and 24-fold greater than using soybean for biodiesel.

Technologies are being tested and developed at Cornell to assess the viability of woody biomass, including technologies to burn wood chips, wood pellets, and grass pellets at very high efficiency, meeting EPA's air quality requirements, at home, farm, commercial, and industrial scales. Pyrolysis – or burning in the absence of oxygen – also has potential because it produces energy, is carbon negative, and creates "biochar," which is a valuable soil amendment. These approaches are being researched as well.

Flexible and Responsive Models: Deliverables for the Future

The Triple Bottom Line of a Biomass Boom

Consumers, policy makers and citizens are demanding a biomass energy industry that is economically, environmentally, and socially sustainable -- the "triple bottom line". There are multiple dimensions or elements of sustainability, including soil, water, and air quality, greenhouse gas emissions, and energy inputs and outputs. Because many of these elements are interrelated, they must be analyzed using an integrated approach. In the next decade, analysis that is spatially-explicit will be particularly critical since biomass will be produced and consumed in specific locations depending on local biophysical, infrastructure, economic, and social factors. Because no "one size fits all," analyses are being conducted at multiple spatial and temporal scales in an integrated fashion using agronomic, ecological, economic, and other expertise within the region, integrating existing information, and identifying strengths, weaknesses, opportunities, threats (SWOT), and research needs.

Better understanding of feedstock production potential based on existing data and spatially explicit biophysical data on soils, elevation, and relevant derivative variables, land use, and transportation networks will help stakeholders make informed decisions, rather than encouraging a pell-mell rush into biofuel/bioenergy production that could in the long run do more harm than good. Cornell researchers, working hand-in-hand with stakeholders, are addressing a range ofsystemic barriers – information gaps that must be filled with sound research and science so that informed decision making will guide industry development. Among other things, scientists are conducting improved biomass feedstock production capacity analysis taking into account the potential effects on food, feed, and fiber production. Recommended land use for multiple biomass crops will be modeled on a regional scale, providing necessary infrastructure information for businesses at all stages of the pipeline, from farm or forest, to the fuel pump. The research will also highlight energy inputs and outputs, including separate tracking of inputs and outputs of transportation fuels and other fossil

fuels,[2] which will vary among locations. For example, marginal farmland will produce lower yields of some biomass crops as compared to prime farmland. Environmental considerations, such as soil and water quality will also be considered, as well as analysis of transportation options.

The information gathered will support industry development by 2017, based on proven feedstock production potential, and social and economic factors throughout the region, to encourage the creation and sustainability of a "safe and abundant" supply. By the year 2017, regional SWOT analyses will be conducted by incorporating results from bio-refinery scale analysis, model comparisons, and economic analyses. The goal is to identify the most sustainable technology options for different portions of the region that will optimize the triple bottom line of environmental, economic, and social value for current and future generations. The results will guide community planners, public officials and private industry in directing investment dollars for maximum energy impact and minimal environmental risk.

Transitioning to Cellulosic Ethanol

Ethanol production (primarily from corn) in the United States reached nearly 5 billion gallons in 2006, up nearly 1 billion gallons from 2005, with production expected to top 10 billion gallons by 2009[3]. The U.S. Department of Energy (DOE) expects technological developments will reduce the cost of cellulosic ethanol and make it competitive with corn ethanol by as early as 2012[4] . There is general recognition that it will take time to deploy cellulosic technology through new plant construction and expected retrofitting of existing grain ethanol plants. In the interim, there are also other issues that must be addressed. Chief among the challenges in the Northeast is the need to view the industry as an integrated system to produce, harvest, transport, store, and process the biomass and other critical inputs in ethanol production, and to market ethanol and valuable byproducts. The required infrastructure and/or markets either do not currently exist, or they are in their infancy. As the production technologies and processes evolve, it is critical to determine how best to organize the system from a spatial and logistical perspective, as well as in terms of the appropriate business model. To create an efficient cellulosic system, we must understand how incentives influence the industry's development and efficiency, particularly in terms of the optimal location and size of cellulosic ethanol production facilities. Decisions about size and location of ethanol facilities depend in large part on the extent to which a biorefinery can take advantage of economies of size in ethanol production. The supply of biomass will also depend on farmers' willingness to commit land to the production of biomass. [5]

Although current ethanol producers have gained valuable experience in the procurement, transportation, and storage of large amounts of corn, they have little experience handling the volumes of materials required to produce meaningful amounts of cellulosic ethanol. Whereas the distance to ethanol markets remains an issue for both corn- and cellulosic-based ethanol producers, the disposal and use of byproducts differ significantly depending on the feedstock.

Primary to success of Cornell's vision of a bioenergy future will be the development of models that can be used to examine the potential impacts of altering a wide variety of biosystem inputs for New York and the Northeast region. These models will serve as a base that can be broadened both in

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2 Farrell et al. 2006
3 Wescott, 2007
4 ERS, 2007
5 Jensen, et al. 2007

geographic scope and detail as future issues arise in the development of the biofuels industry. This framework will allow policy makers and industry participants to have a better understanding of how the entire biomass-to-ethanol production system may develop and will support a wide variety of public policy analyses.

Corn: Improving Practices

In the Northeast, corn is expected to fill an interim role as a feedstock crop until sufficient alternative biomass production can be developed. However, relatively high nitrogen loss and other environmental issues need to be continually assessed and addressed to minimize environmental impact. Nitrate leaching associated with corn production can also impair surface and ground water resources. Research into sustainable, high-productivity corn cropping systems for the Northeast will directly benefit the economic viability of agriculture and will reduce the environmental 'footprint' of production. For each cropping system, environmental impacts will be quantified in terms of energy inputs and outputs, greenhouse gas emissions, and both soil and water quality. Using modeling tools, data from field experiments, and data from the literature, Cornell researchers will provide producers with reliable estimates of the impact of different corn cropping systems on greenhouse gas emissions, release of reactive nitrogen to the environment, soil carbon and nitrogen stocks, and capacity for carbon sequestration to enable sustainable growing practices to be widely used by the year 2017.

Enhancing Sustainability, Conservation and Efficiency

Science-based Solutions for Consumers, Producers, and Communities

Energy initiatives are an opportunity for economic growth. Local production keeps energy money inside the community rather than exporting it to outside entities. This money can fuel new business opportunities leading to lower taxes and increased jobs. Farmers and other landowners benefit from revenue generated from renewable energy production on their land. Local energy production can provide a source of low-cost energy with stable long-term prices and can decrease costs for businesses, residents, and government, but only if it is the right mix in the right location to attract investment dollars and business growth.

What profit margins will encourage businesses to get in or out of biofuels? Evaluating processing investment and operating costs, input and output prices, and profitability are giving Cornell economists greater understanding of private business entry and exit decisions, given current and expected market conditions. Economists are estimating the spread between ethanol output prices and gross margins that would cause a firm to exit and that would encourage new entrants. Providing models for differing investment and cost structures of firms based on size, technology, feedstocks, and location will help drive effective public policy and resource use – all critical to biofuels making marked inroads by 2017 to be on track to achieve 25x'25 goals.

With the aid of CCE several municipalities in upstate New York are pursuing pioneering initiatives to implement community energy plans, develop local renewable sources, and encourage conservation and increased efficiency among residents, businesses, and municipal government entities. CCE is well positioned to disseminate information from the experience of these forward-looking communities. Identifying common barriers and challenges will save other communities valuable time and resources when considering similar strategies. Several important points that could be helpful to other communities have already been identified. Generally, these include activities and planning to maximize the level of community involvement and effectively address group dynamics, procedures to develop and maintain good working relationships with local municipal officials, taking advantage of existing educational and technical resources, utilizing other community models while recognizing differences in initiative objectives, scope, resources, and time horizons, and understanding that renewable energy, energy conservation, and increased energy efficiency are closely linked. Understanding the commitments needed up front and the potential pitfalls to avoid will improve the efficiency of municipal planning efforts in addressing energy initiatives.

Conservation

Energy conservation and increased energy efficiency are essential strategies for decreasing energy costs and environmental impact. It has been estimated that residential energy consumption in New York alone could be cut by as much as two-thirds, utilizing existing technology and conservation practices. As the issue of global climate change becomes more prominent, citizens are demanding action of their local governments. Because local governments interact directly with community members, they can be influential in changing energy usage patterns and encouraging local energy development.

Educating community developers has already resulted in measurable impact; fifteen community agencies/organizations have adopted appropriate alternative energy sources and/or energy conservation practices; fourteen communities assessed local energy development proposals and/or the relationships between current policies and regulations and energy conservation; four community agencies/organizations reported savings on energy costs attributable to adopting alternative energy sources and/or energy conservation measures; fourteen communities have established or modified land use and development policies to promote energy conservation.

CCE has implemented a five-year statewide plan of work related to energy conservation and renewable energy that will contribute to the sustainability and economic vitality of New York communities. The Renewable/Alternative Energy and Conservation Program is a multi-emphasis, multi-audience effort aimed at agricultural and natural resource producers, community decision makers, and individual consumers. This outreach effort is vital to Cornell's vision in contributing to the sustainability of New York communities, including environmental quality, health, and economic vitality. One joint program with the New York State Energy Research and Development Authority (NYSERDA) educates New Yorkers about ways to reduce energy expenses in the home. Since 2003, 815,500 New Yorkers attended a sponsored event. The average New York residential energy bill is $2,616. If each person applied what is taught and reduced his/her energy bill by 30%, the savings amount to over $640 million.

Farmers who are considering becoming energy independent will face particular need in coming years for sound information on various types of energy systems. CCE is helping farmers, agribusinesses, and communities identify and implement energy conservation measures in order to save energy and reduce cost of alternative energy systems installed on properties. CCE educators encourage the private sector to conduct farm energy audits targeted at the physical plant, mainly dairies, but also cash grain operations. To date, more than 200 agricultural producers/horticulture businesses/natural resource managers have documented improved economic returns to agricultural/horticultural business profitability and vitality resulting from adopting alternative energy sources and/or energy

conservation.

Cornell is active in New York City as well. In NYC, extension experts have recruited several large and medium-sized apartment buildings to use a biofuel blend of B20 (20% from soydiesel) and are collecting performance data to enable other big municipalities with multi-family housing units to consider alternative-fuel systems.

Practicing What We Preach: Renewable Energy on Campus; A Community Vision

The Cornell University Agricultural Experiment Station is currently assessing the feasibility of an onsite-bioenergy facility that will be both production oriented – contributing to Cornell's heating and electrical needs – while also providing a "living, learning, laboratory" for research, extension, and education to develop workable, mixed-waste bioenergy systems, including anaerobic digestion, direct combustion, and pyrolysis, a form of burning biomass and other inputs in the absence of oxygen that produces heat, syngas, and also produces biochar, a beneficial soil amendment. Pyrolysis is the one renewable energy technology that is "carbon" negative and deserves further research and development related to its market and environmental potential. This is one example of the "Culture of Sustainability" that is being adopted and nurtured throughout the Cornell University Agricultural Experiment Station in its office practices as well as its management of the college's farms, forest, and field stations. With successful change in culture and implementation of a multiple bioenergy technology approach, Cornell will be a model for other agricultural experiment stations across the country, land grant universities, small businesses, community leaders and others interested in farm, forest and agricultural - waste technologies and rural economic development. The University views this as a major contribution to its participation in the University Presidents' Climate Commitment, to which Cornell is a signatory.

Conclusion

America's energy economy of 2017 can be – and should be – radically different than it is today, with a growing bioenergy sector in the Northeast based on new and existing energy crops, grown, harvested and processed in a sustainable manner, workable storage technologies, efficient and profitable processing plants, multiple distribution channels, environmental sensitivity and widespread conservation efforts. Such a strong platform will provide the base from which the Northeast can expand to meet ambitious national goals and contribute to Cornell's commitment to fueling the greening of America's energy economy through cutting-edge, problem-solving research, education and extension. We are building strong and competitive research, outreach, and education programs focused on bioenergy, biofuels, and bioproducts development. These programs are core to Cornell's sustainable human development focus that cuts across multiple colleges and centers. The challenge is to exploit major breakthroughs in engineering and science to create novel sustainable bioindustries, whether from crops, organic waste, or forest products, adding measurably to rural development, a thriving agricultural economy, and national energy security.

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