
Opportunities in the New Bioeconomy
Mendel
BIOTECHNOLOGY

Crop Innovations for Renewable Energy

Energy security and environmental concerns are driving a transformation of the US economy from one based on hydrocarbons to one based on renewable energy.

We are in the very early stages of this transformation to a renewable economy. No single solution will completely meet US energy needs. Rather, multiple fuel sources are emerging based on regional climates, natural resource availability, and infrastructure. Biomass-based electricity and liquid fuel production are recognized as the most promising solutions for the eastern half of the country due to abundant arable land, sunlight, and sufficient rainfall.

The convergence of agriculture, energy, and biotechnology is providing the foundation for an entirely new bioeconomy in many rural areas in need of economic development. Total job creation from renewable fuel mandates alone is projected to exceed 100,000 by 2012 and 800,000 by 2022. Direct economic output is projected to rise to $5.5 billion by 2012 and $37 billion by 2022.[1] Additional markets, such as biomass power and bio-based chemicals would significantly add to these projections.

Estimates for biomass sourced from perennial energy crops range from 75 million dry tons to 125 million dry tons solely to meet liquid fuels mandates by the year 2022.[2] These requirements provide the opportunity to convert up to 15 million acres of underutilized agricultural land to energy crop production. Preliminary studies suggest that a portion of the 600 million acres of idle and pasture land in the country today could be converted to bioenergy production without impacting food acreage.[3]

At Mendel Biotechnology, we are developing high performing, non-food energy crops to serve these markets in an economically and environmentally sustainable manner.

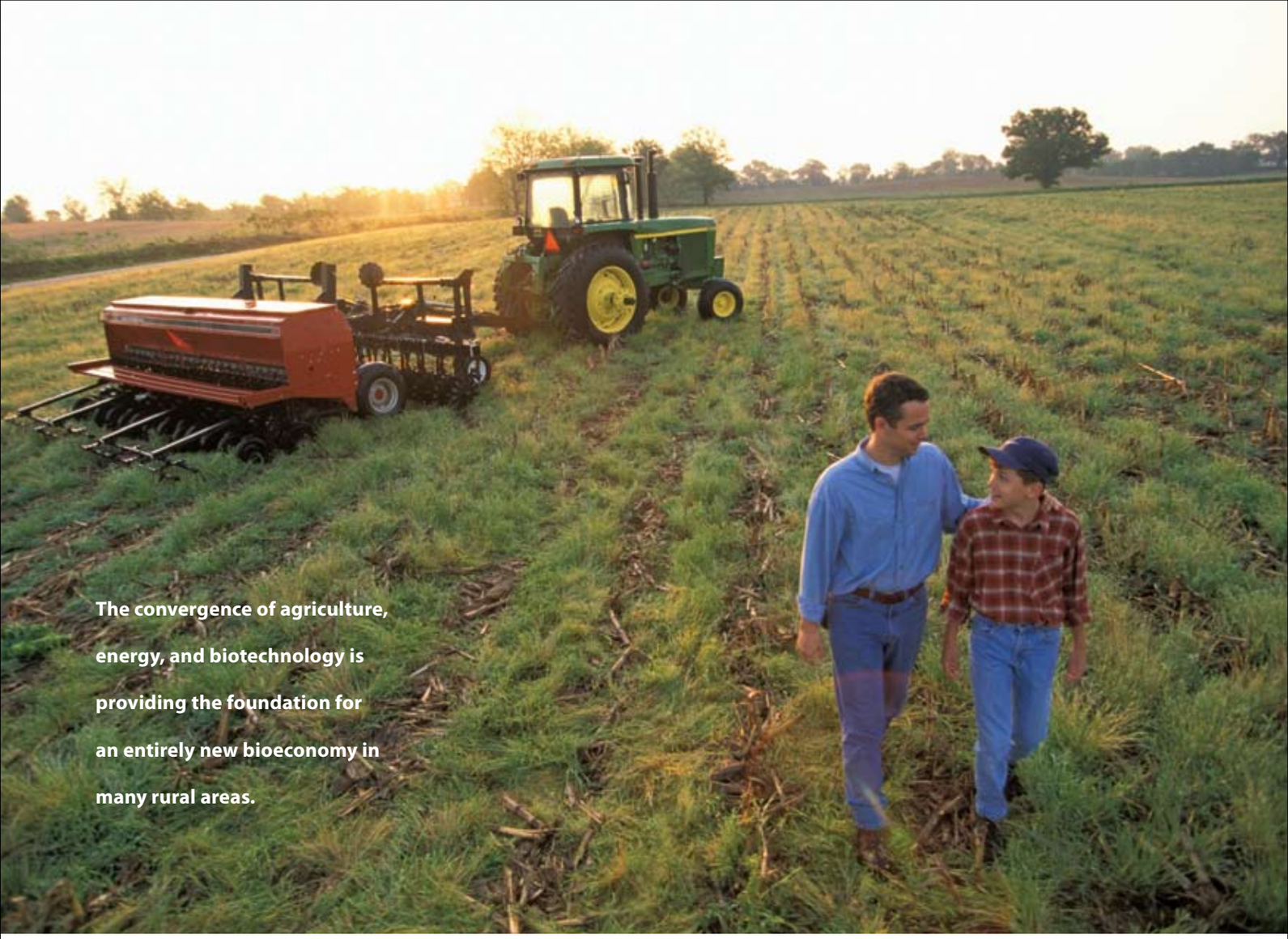
These crops include high-yielding perennial grasses adaptable to marginal lands, requiring fewer agricultural and energy inputs than existing biofuels crop species.

1 "U.S. Economic Impact of Advanced Biofuels Production: Perspectives to 2030"; bio-era, 2009

2 "Increasing Feedstock Production for Biofuels"; BRDi, January 2009

3 Tyner, Taheripour, et al; "Preliminary Analysis of Land Use Impacts of Cellulosic Biofuels"; February 2009

Miscanthus can collect and store the sun's energy very efficiently.



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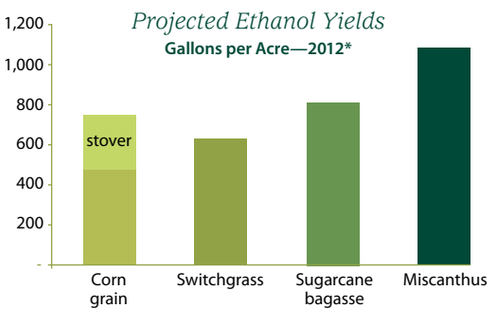
The Case for Energy Crops

While the solar radiation reaching the earth provides 10,000 times the energy consumed on this planet each year, the challenge has been capturing, storing, and distributing this energy **into a usable form.**

C4 perennial grasses, and, particularly Miscanthus, can collect and store that energy more efficiently than any other system. Domestication of commercial Miscanthus varieties in the US and breeding new varieties, combined with continued advances in fuel conversion technologies is an integral component of the country's renewable energy solution.

Biomass yield drives the economics of the bio-based economy. Specifically, for renewable energy to be commercially viable in a zero-subsidy world, biomass feedstock costs will need to be $55–$60 per dry ton ($0.55–$0.60 cents per gallon, or $3.50–$3.90 per MMBTU) to compete with hydrocarbon fuel sources. In order to achieve these cost targets, energy crop yields will need to be at least 10 dry tons per acre with minimal energy inputs.



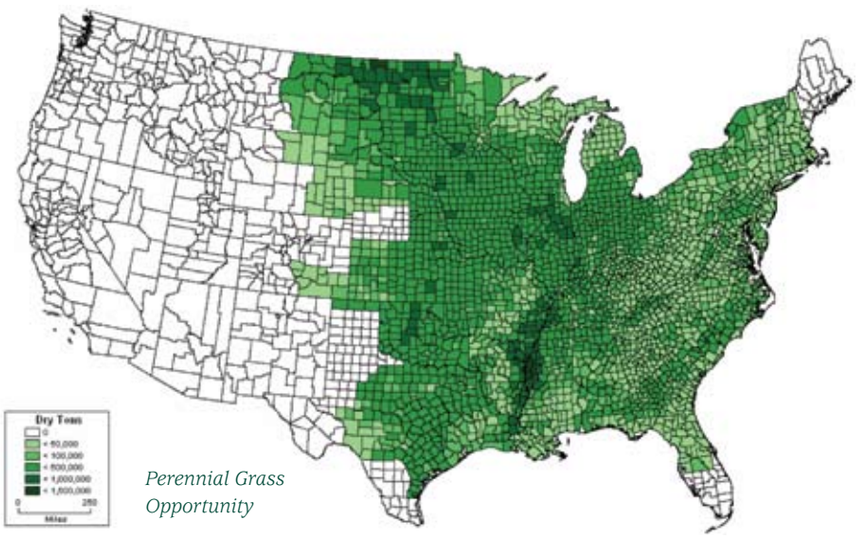
***Yield Assumptions**
- Corn grain: USDA reported yields, 2007 plus 3% improvement
- Corn stover: 3 dry tons per acre
- Switchgrass: 7 dry tons per acre
- Bagasse: 9 dry tons per acre
- Miscanthus: 12 dry tons per acre
- Conversion yield: 90 gallons per dry ton

In regions with annual rainfall in excess of 35 inches per year and a sufficient growing season, Miscanthus meets or exceeds this yield target.[4] As a C4 perennial grass, it has high water use efficiency and efficient photosynthesis, requires very little nitrogen, and sequesters carbon in the soil via abundant root and rhizome growth.

4 Heaton E., Voigt T. & Long S.P. (2004) A quantitative review comparing the yields of two candidate C-4 perennial biomass crops in relation to nitrogen, temperature and water. Biomass & Bioenergy, 27, 21-30

Rural Economic Development

Working with the DOE and other key opinion leaders, **Mendel has modeled the potential conversion of underutilized land to high yielding perennial crops** matching the profile of Mendel's lead product candidates. The map below summarizes the economically viable productive capacity potential at a county level for these crops.



Perennial Grass Opportunity

In order to meet the Renewable Fuel Standard (RFS) mandate, 320 commercial scale (50 M gal) lignocellulosic refineries will be required, needing over $80 billion in capital investment over the next thirteen years. Our analysis suggests that many counties on the map could support three or more refineries without converting acreage currently in food production. For each biorefinery, approximately 300 agriculture related jobs would be created, in addition to personnel required to build and operate each facility. Total economic impact of each biorefinery is projected to be $380 million.[5]

5 "U.S. Economic Impact of Advanced Biofuels Production: Perspectives to 2030"; bio-era, 2009

High yielding perennial grasses can improve both the soil quality and farming economics of marginal lands.

Mendel BioEnergy Seeds

Mendel's product portfolio includes the largest Miscanthus research and development program in the world.

Mendel is applying its validated trait technology and advanced breeding techniques to **develop superior, proprietary Miscanthus varieties** and other energy crop products. Additional crops in development include bioenergy sorghum and "Miscanes", a hybrid of Miscanthus and sugar cane.

Mendel Product Portfolio

		Sorghum	Energy Cane/ Miscane	M X Giganteus	Mendel Miscanthus
SUSTAINABILITY	Efficient photosynthesis	✔	✔	✔	✔
	Low inputs		✔	✔	✔
	Adopted to marginal lands	✔	✔	✔	✔
	↑ soil C Sequestration		✔	✔	✔
	Genetic diversity	✔	✔		✔
ECONOMICS	Yield > 10 dt per acre	✔	✔	✔	✔
	Low establishment costs	✔	✔		✔
	First year harvest	✔			
	Low production costs		✔	✔	✔

What is Miscanthus?

Miscanthus is a genus of about 15 species of C4 perennial grasses.

Miscanthus giganteus, a sterile species, has been used as a bioenergy feedstock source in Europe since the early 1980's. It can grow to heights of more than twelve feet and yield greater than 10 dry tons per acre per year in many climactic regions. Propagation of *Miscanthus giganteus* is through rhizome cuttings, and therefore, is slow and expensive. We are solving this problem through improved propagation methods and direct seeded technology.

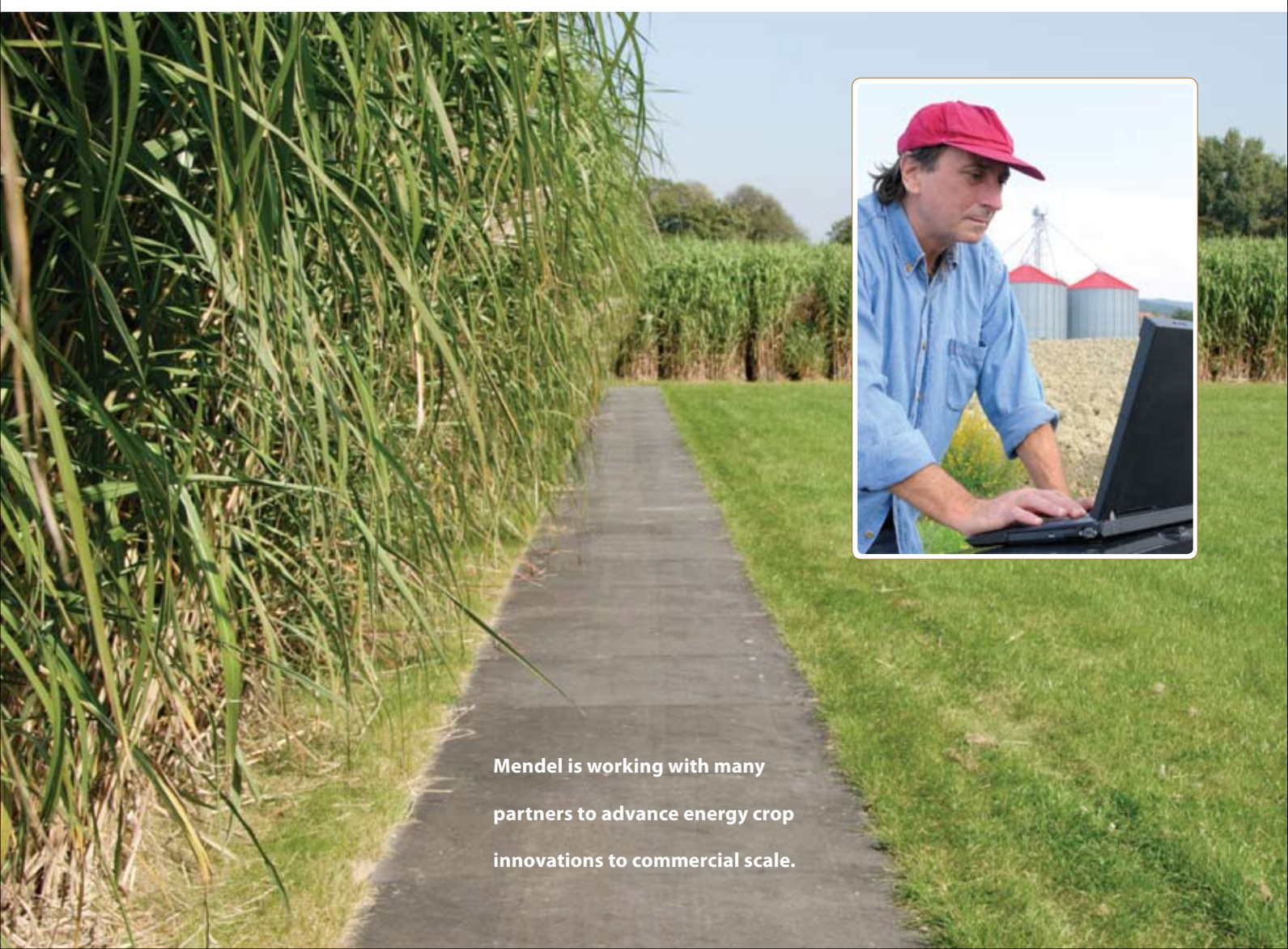
Mendel has developed high-performing elite varieties of Miscanthus that are competitive in yield with giganteus but which can be propagated much more efficiently. With these varieties, Mendel offers a genetically diverse set of varieties that provide increased reliability of feedstock production. The genetic diversity of our product offerings will continue to increase substantially over the next several years.

Opportunity for Innovation and Economic Development

Learn more about the potential development opportunity **in your region.**

Mendel is working with the private sector, state and federal agencies, and leading academic institutions to accelerate the research and development and commercial scale-up of more efficient feedstock systems for the LC biofuels and biomass power markets.

Please email us at **bizdev@mendelbio.com** if you would like to learn more about the potential development opportunity in your region.



Mendel is working with many partners to advance energy crop innovations to commercial scale.

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Seeding a Sustainable Future

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