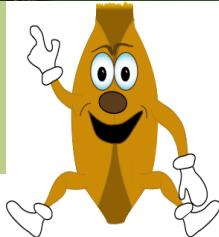




# The Winter Barley Ethanol Initiative



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**ARS, USDA**  
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# Number of Ethanol Plants, Locations, and Their Capacities as of 3/3/2011

## BIOREFINERY LOCATIONS



- Currently Operational
- Under Construction

Source: RFA

204 Plants with 14.1 Billion Gallons Capacity

5 Plants under Construction will Provide another 0.5 Billion Gallons

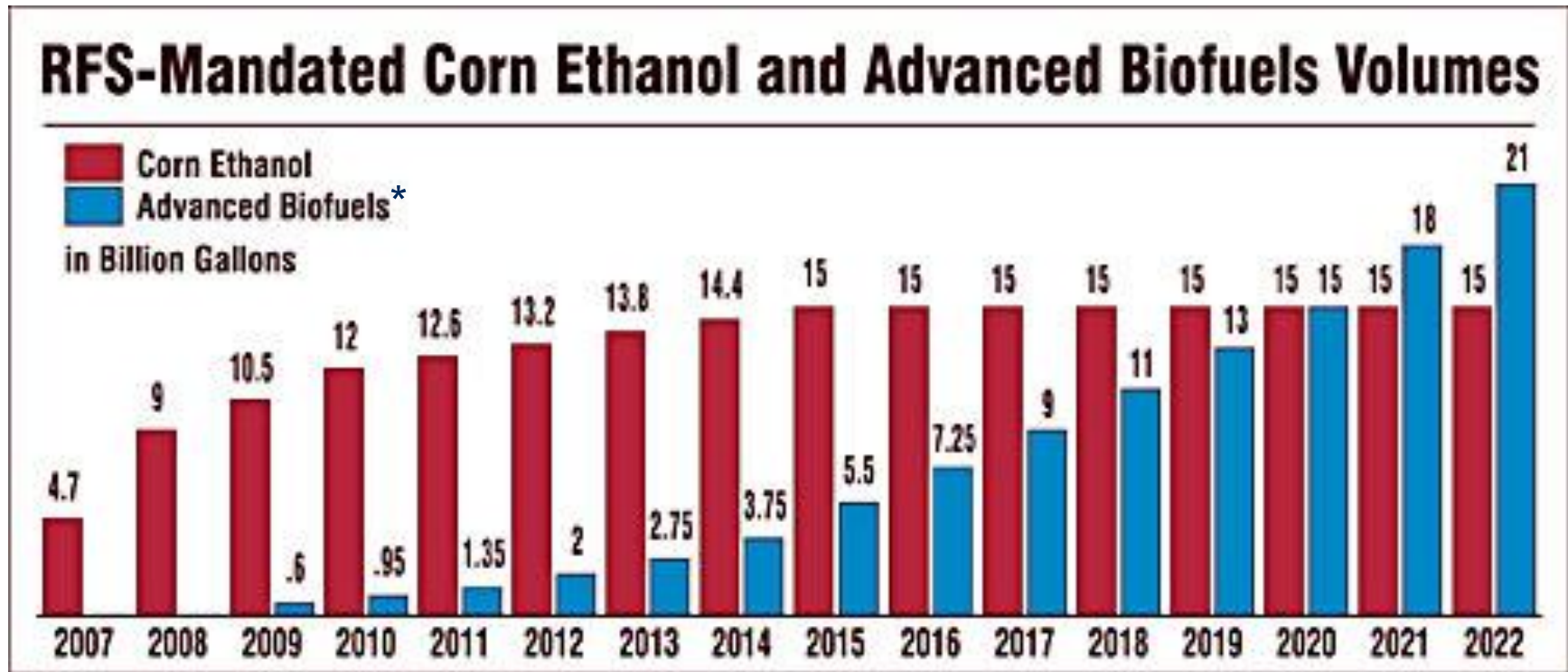
Total Capacity When Completed = 14.6 Bil. Gal.

14.6 Billion Gallons meets about 10% of our total transportation fuel needs!

Corn is Still the #1 Feedstock



# The 2007 Energy Independence and Security Act Requires Aggressive Increase in Advanced Biofuels!



Based on Energy Independence and Security Act of 2007

\* *Advanced biofuels* is renewable fuel other than ethanol derived from corn starch that is derived from renewable biomass, and achieves a 50 percent greenhouse gas (GHG) emissions reduction (compared to gasoline).

# How will we meet these goals?

## → **Cellulosic Ethanol by Biochemical Pathways**

- **Outstanding Potential**
- **Uses Non Food Feedstocks**
- **Still Major Research Challenges to Solve**
- **Still Several Years Away From Commercial Viability**

## → **Pyrolysis and Gasification-Based Bio-Fuels**

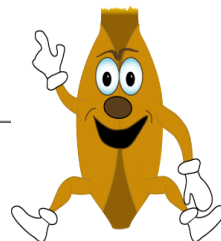
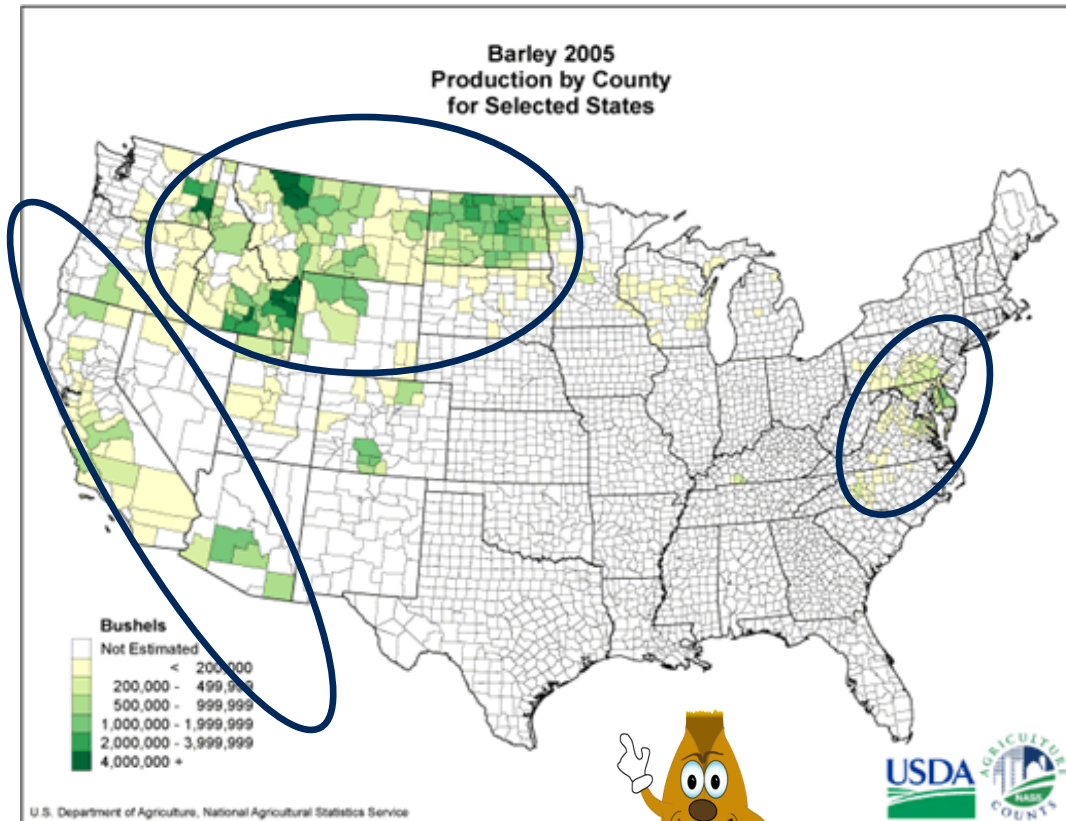
- **Outstanding Potential**
- **Uses Non Food Feedstocks**
- **Still Major Research Challenges to Solve**
- **Still Several Years Away From Commercial Viability**

# Is There a Simpler Way?

- Wouldn't it be great if there were a simpler feedstock to make Advanced Biofuels?
- One that we could convert to “low-carbon” fuel ethanol and valuable food and feed products
  - One that wouldn't compete with food crop production
  - One that wouldn't harm the environment



# There is Such a Crop and it is Winter Barley!



These “barley belts” can provide feedstock for ethanol plants outside the corn belt where transportation fuels and economic development are needed!

# How Did This Idea Begin?

- At a Stakeholders Workshop held at ERRC on August 31, 2001 a Virginia Tech Extension Professor, Dr. Dan Brann convinced me that winter barley could be a major biofuels feedstock for the East Coast and that sales from this crop could help save farmers and farms and improve the rural economy of the Mid Atlantic States.
- Over the next 9 years, we worked with many partners to solve the major problems that existed at that time, with using barley for making fuel ethanol.
- This is a short synopsis of that success story.

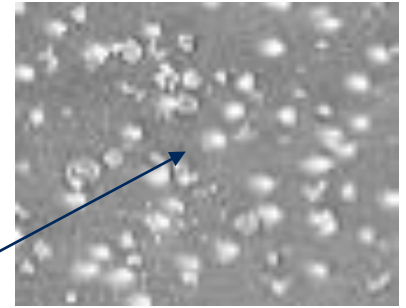
# Why Winter Barley For Fuel Ethanol ?

- Provides feedstock for ethanol plants outside the Corn Belt
- Farmers on the East Coast and other areas with mild winters can grow barley as a winter crop, allowing double cropping with soy. More grain on same acreage.
- Winter barley is grown on “fallow ground” and doesn’t compete with food production thus there are no Indirect Land Use Change effects in LC-GHG emissions according to the RFS2.
- Winter barley acts as a cover crop, preventing soil and nutrient losses to the environment- this is critical for sustainability of soil and water. Especially important for the Delaware and Chesapeake Bays.
- Higher protein and digestible amino acids than corn, especially lysine means that barley DDGS should sell at a premium relative to other grain DDGS.



# Major Challenges with Barley for Ethanol Production in 2001

Phytoliths



- **Abrasive nature of hull – destructive to grain handling and grinding equipment**
- **Low starch content (~50-55%) compared to corn's (~70%) – results in low ethanol yields plus too much fiber**
- **High viscosity of mash due to beta-glucans – makes ethanol production difficult and expensive and limits the feed use of the ethanol co-products, DDGS to primarily ruminant animals**

## ERRC/ARS Created A Barley Research Program to Solve These Technical Issues

- Working with breeders at Virginia Tech to develop better hull-less and hulled barley with high starch content for fuel ethanol production
- Developing dry fractionation and other processes to separate barley grain into fermentable and non-fermentable fractions and coproducts
- Working with Genencor, A Danisco Division to develop new enzymes to reduce viscosity, increase ethanol yield, and develop energy saving fuel ethanol processes

# Breeding Improved Barley was Conducted at Virginia Tech



Griffey, C., Brooks, W., Kurantz, M., Thomason, W., Taylor, F., Obert, D., Moreau, R., Flores, R., Sohn, M., and Hicks, K. *Grain composition of Virginia winter barley and implications for use in feed, food, and biofuels production.* Journal of Cereal Science. 51: 41–49. 2010.

# What about those Abrasive Hulls?

- Many of the barley varieties developed were hull-less varieties
- We also developed methods to remove the abrasive hulls and to produce starch-enriched fractions for ethanol production.



Flores, R.A., Hicks, K.B., Eustace, D.W., and Phillips, J.G. *High-starch and high- $\beta$ -glucan barley fractions milled with experimental mills*. Cereal Chem. 82(6):727-733. 2005.

# How Did We Solve the $\beta$ -Glucan Viscosity Issue?

## → With Better Enzymes and Processes

- Combinations of  $\beta$ -glucanases and  $\beta$ -glucosidases convert viscous  $\beta$ -glucans into fermentable glucose
- This lowers viscosity and increases ethanol yield because now both starch and  $\beta$ -glucan are converted to ethanol.
- Barley containing 65% starch and 5%  $\beta$ -glucan should be equivalent to corn's 70% starch!

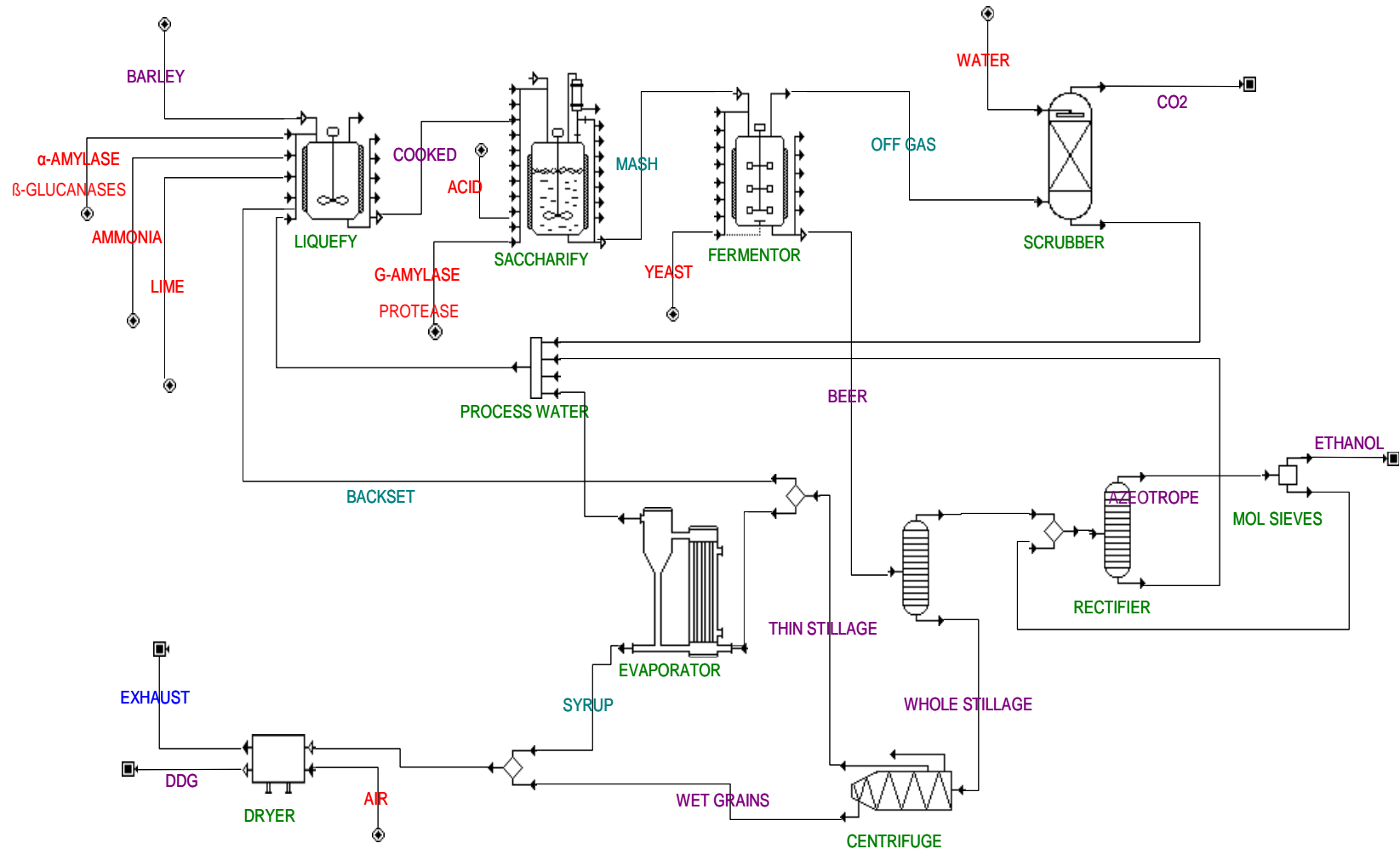
Nghiem , N.P., Hicks, K.B., Johnston, D.B., Senske, G., Kurantz, M., Li, M., Shetty, J., and Konieczny-Janda, G. *Production of ethanol from winter barley by the EDGE (enhanced dry grind enzymatic) process.* Biotechnology for Biofuels 3:8. 2010.

## \*Enhanced Dry Grind Enzymatic

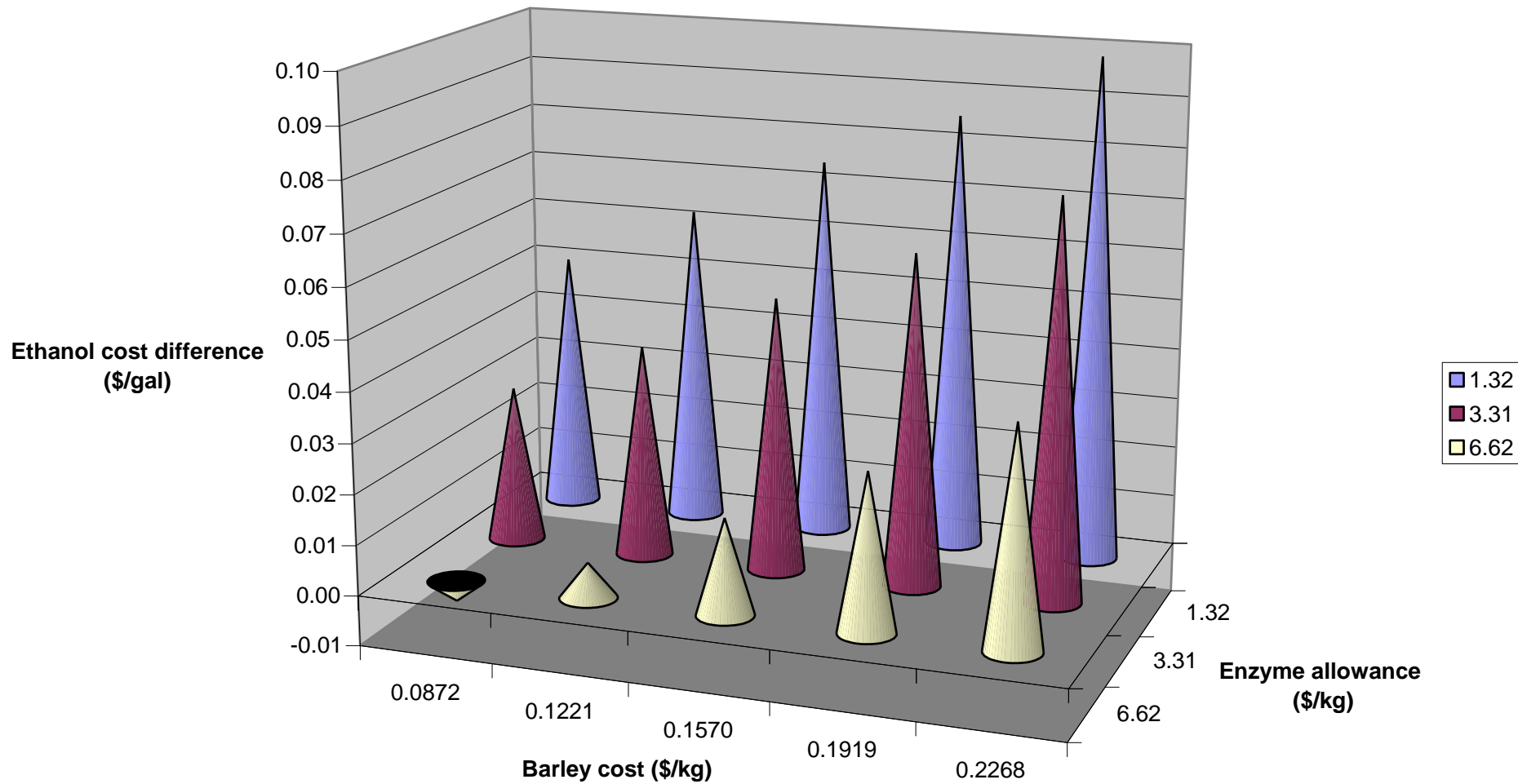




# Techno-Economic Model Of Fuel Ethanol Production From Barley Using The EDGE Process.



# Differences In Ethanol Production Costs Using The EDGE Process With Hulled Barley Feedstock.



# Looking for Commercialization Partners

- Between 2001 and 2007 we met with many different groups who were interested in building barley ethanol plants in the US and in Canada. None of those groups were successful in completing their projects.
- In February 2007 we met with the Management Team of **Osage Bio Energy (OBE)**, a new company wanting to build ethanol plants in Virginia and surrounding states. We provided technical and cost information and discussed our vision for barley ethanol. OBE took their business plan to First Reserve Corporation and received \$300,000,000 for building the first barley ethanol plants in the US.

# Assistance with Commercialization

- During 2007 and 2008 we assisted **OBE** with information as they designed the plant with **Katzen Intl.**
- During 2008 we assisted **OBE** as they scaled up our EDGE process at the **National Corn to Ethanol Research Center (NCERC)** at SIU Edwardsville.
- During 2009-2010 construction on the first plant in Hopewell Virginia occurred.
- During this time ERRC and OBE partnered with Prof. Sabrina Spatari at **Drexel University** to conduct a Life Cycle Analysis of the GHG emissions for winter barley ethanol from the OBE plant. To qualify as an Advanced Biofuel, the ethanol's GHG emissions must be at least 50% less than gasoline.



# **A LIFE CYCLE GREENHOUSE GAS EMISSIONS MODEL OF OSAGE BIO ENERGY'S WINTER BARLEY-TO-ETHANOL PROCESS**

SABRINA SPATARI, ALEXANDER STADEL  
Kevin Hicks, Andrew McAloon, Winnie Yee, and  
Paul Adler



# In January 2011, OBE Submitted Their Petition to EPA for Evaluation of Winter Barley Ethanol as an Advanced Biofuel!



DD: 804.888.8350  
mark.beemer@osagebioenergy.com

**Mark Beemer**  
Chief Commercial Officer

January 21, 2011

U.S. Environmental Protection Agency  
Fuels Programs Registration  
Room 647C; 202-343-9038  
1310 L Street, NW  
Washington, DC 20005

**RE:    Petition for Evaluation of Winter Barley Pathway under 40 CFR 80.1416**





# First US Winter Barley Ethanol Facility



**Re-Start and Plant Validation Scheduled to Begin Next Week!**

# IMPACT

- Over 500 construction jobs over the last year and one half
- Over \$150 million in procurement, labor, utilities, etc.
- 50 new permanent jobs created to staff the biorefining plant
- \$1-2 million of new annual tax revenue for the City of Hopewell, VA
- Six new or existing companies, including Praxair, Perdue Farms, Land-O-Lakes/Purina, Verenium, and Genencor, all directly benefitting from new business from the plant.
- Local farmers able to grow an additional \$100 million of barley each year
- Cover crop effect of winter barley will help clean the Chesapeake Bay.
- Over 240,000 tons of high protein barley meal produced for animal feeds each year.
- 450 tons of CO<sub>2</sub> per day coming from a renewable source
- Barley hull fuel pellets produced for industrial boilers with 7400 btu/lb

# ISSUES

- Convincing local farmers to grow barley – and increasing the amount of seed each year to increase total production. Its expected to take 4-5 years to get up to maximum production for the region.
- Grain prices are significantly higher than when the plant was planned
- The plant is designed to also run on corn and wheat as alternative feedstocks, but these feedstocks are currently prohibitively expensive
- EPA will decide if winter barley ethanol is an Advanced Biofuel or not and this will effect its marketing and value

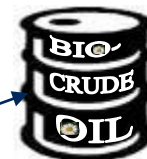


# The Winter Barley BioRefinery Vision



**ethanol**  
Fuel For Clean Air

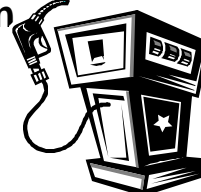
High fiber (hulls) and straw from barley can be used to make cellulosic ethanol and pyrolysis oil for producing “green” transportation fuels.



**FRACTIONATION PROCESSES**

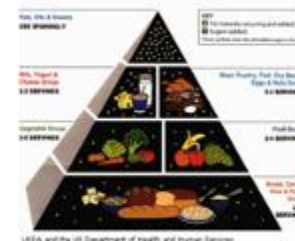
High starch fractions are used for fermentation and Fuel Ethanol Production plus Premium DDGS

**ethanol**  
Fuel For Clean Air



Growing winter barley for ethanol feedstock does not compete with food production and it actually improves soil and water quality!

Low starch fractions (high-protein, high-Tocol, high- $\beta$ -glucan) for health-promoting, obesity-fighting, foods and nutraceuticals



Contact: [kevin.hicks@ars.usda.gov](mailto:kevin.hicks@ars.usda.gov)



# Partners

- **ARS**
- **Virginia Tech**
- **Genencor, a Danisco Division**
- **Osage Bio Energy**
- **Katzen International**
- **Drexel University**
- **NCERC**

