

Acetone-Butanol-Ethanol (ABE) Production from Rice Wastes in China

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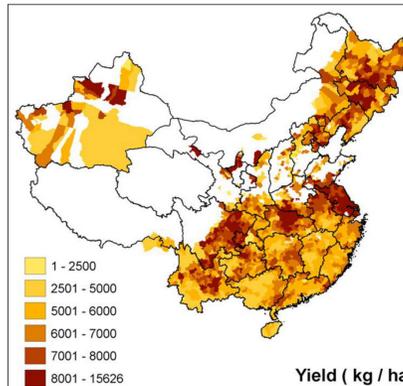


The Idea

- Overall process produces acetone, butanol, and ethanol (ABE) from rice straw and husk that is normally burned
- Ethanol and butanol are valuable products that will be used as biofuels in emerging markets, both locally and worldwide
- Acetone is valuable and will be sold as a solvent for commercial uses in local markets
- The idea to use rice waste has existed, but has been very difficult to make economical
- Very expensive to transport agricultural waste long distances
- Developed a method to increase scale of the process by increasing the range of waste collection

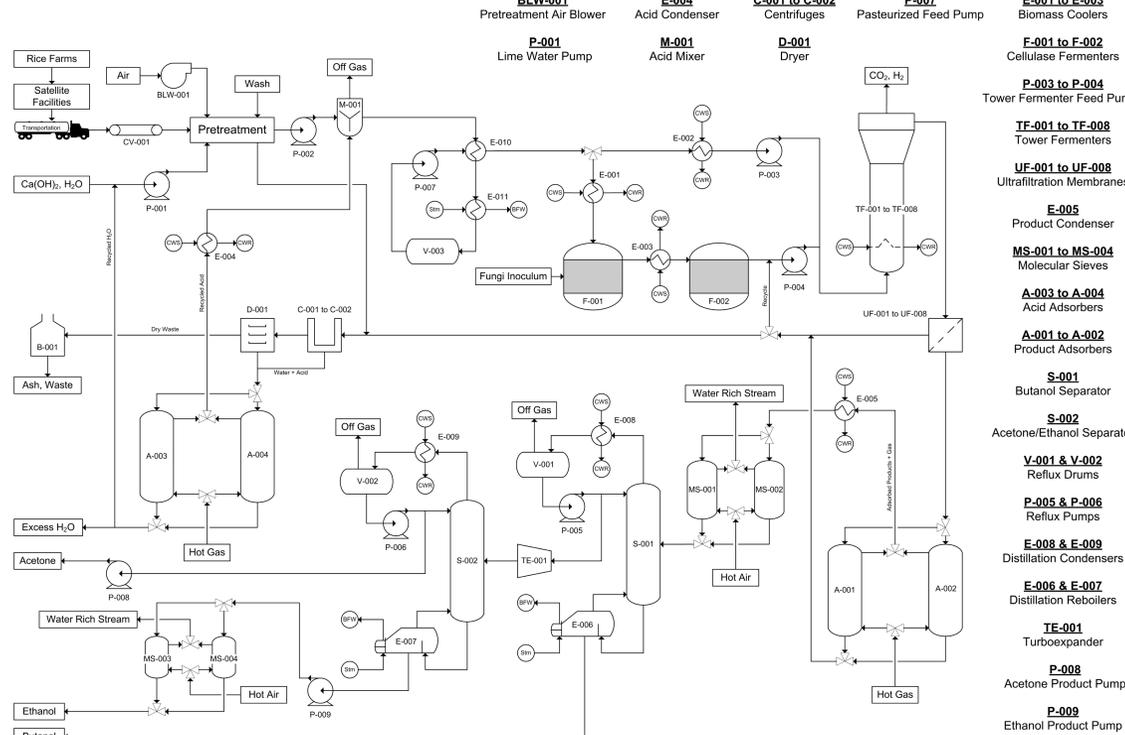
Why Rice Waste in China?

- Using agricultural waste doesn't take land for new energy crops and doesn't compete with food
- Rice is the single largest use of land for food and produces considerable waste
- China is the largest producer of rice, representing about 32% of world production
- Chinese rice farms are relatively high yielding and produce on average 6.2 tons rice/ha
- As seen in the figure, there are several high density rice production regions near urban centers
- Urban centers will provide a market for acetone, butanol, and ethanol products



The Process

ABE Production PFD



1. Pretreatment:

- $\text{Ca}(\text{OH})_2$ liberates cellulose from lignin
- Requires 400 tons lime/day
- Run at 55°C and requires little energy
- Requires constant mixing for adequate conversion

2. Cellulase Production:

- Fungus *T. Reesei* produces cellulase from feed material
- Flowrate of 615 tons/day
- Requires reactor volume of 1080 m³
- Requires 4.7 x 10⁵ m³/day of air

3. Simultaneous Saccharification and Co-Fermentation (SSCF):

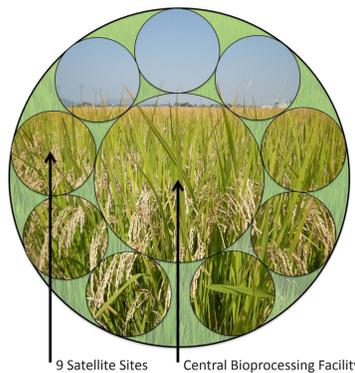
- Cellulase breaks down cellulose and hemicellulose into hexoses and pentoses
- *C. Beijeirinkii* converts sugars into ABE
- Requires reactor volume of 2200 m³

4. Separations and Distillation:

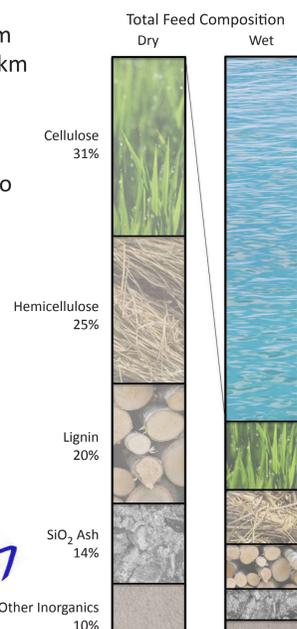
- Adsorption of ABE onto silicalite, desorption with hot air
- Centrifugal separation of waste from water
- Distillation of ABE and water
- Combustion of waste biomass for energy

Feedstock

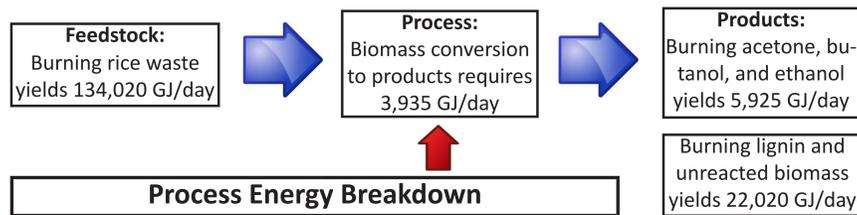
- Inlet feed consists of rice straw and husk, which would normally be left on fields to decompose and produce methane
- Have 1 central facility that collects within a radius of 50 km
- Have 9 satellite facilities that collect within a radius of 25 km
- Local farmers bring in waste and we pay them \$22.18/ton for husk and \$4.83/ton for straw
- Assume 10% cooperative rice farmland
- Grind rice waste at each facility, and transport feedstock to the central process
- Requires 45 trucks that make 5 trips per facility per day



Inlet Feed
8,580 tons/day
rice waste inlet feed



Energy Balance



Process Energy Breakdown	
Process Step	Energy Required (MJ/ton)
Grinding	100.9
Transportation	52.4
Pasteurization	87.5
Pretreatment	4.0
Mixing	13.7
Cellulase Production	0.6
SSCF	2.1
Adsorption (Products)	51.4
Molecular Sieve (Products)	7.4
Molecular Sieve (Ethanol)	11.7
Distillation	11.2
Centrifugation	34.1
Dryer	45.8
Adsorption (Acid)	36.0
Total Energy Needed	458.7

Net Energy Efficiency:
20.3%

Net Energy Ratio:
6.39

The Payoff

Product Summary

Acetone	45.1 tons/day
Butanol	148.4 tons/day
Ethanol	11.1 tons/day

Economic Summary

Total Capital Cost	177.4M \$USD
Daily Operating Cost	261.0k \$USD/day
Expected Daily Revenue	354.6k \$USD/day
Expected Annual Profit	34.2M \$USD/year
Break Even Point (i = 12%)	17 years
Net Present Value (lifespan = 30 years)	26.6M \$USD

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