De-risking and scale-up of bio-based technologies

Addressing Biomass Supply Chain Challenges With AFEX™ Technology

DOE Biomass 2014

July 30, 2014

MBI: Mission and Capabilities

MBI personnel & facility, - Lansing, MI

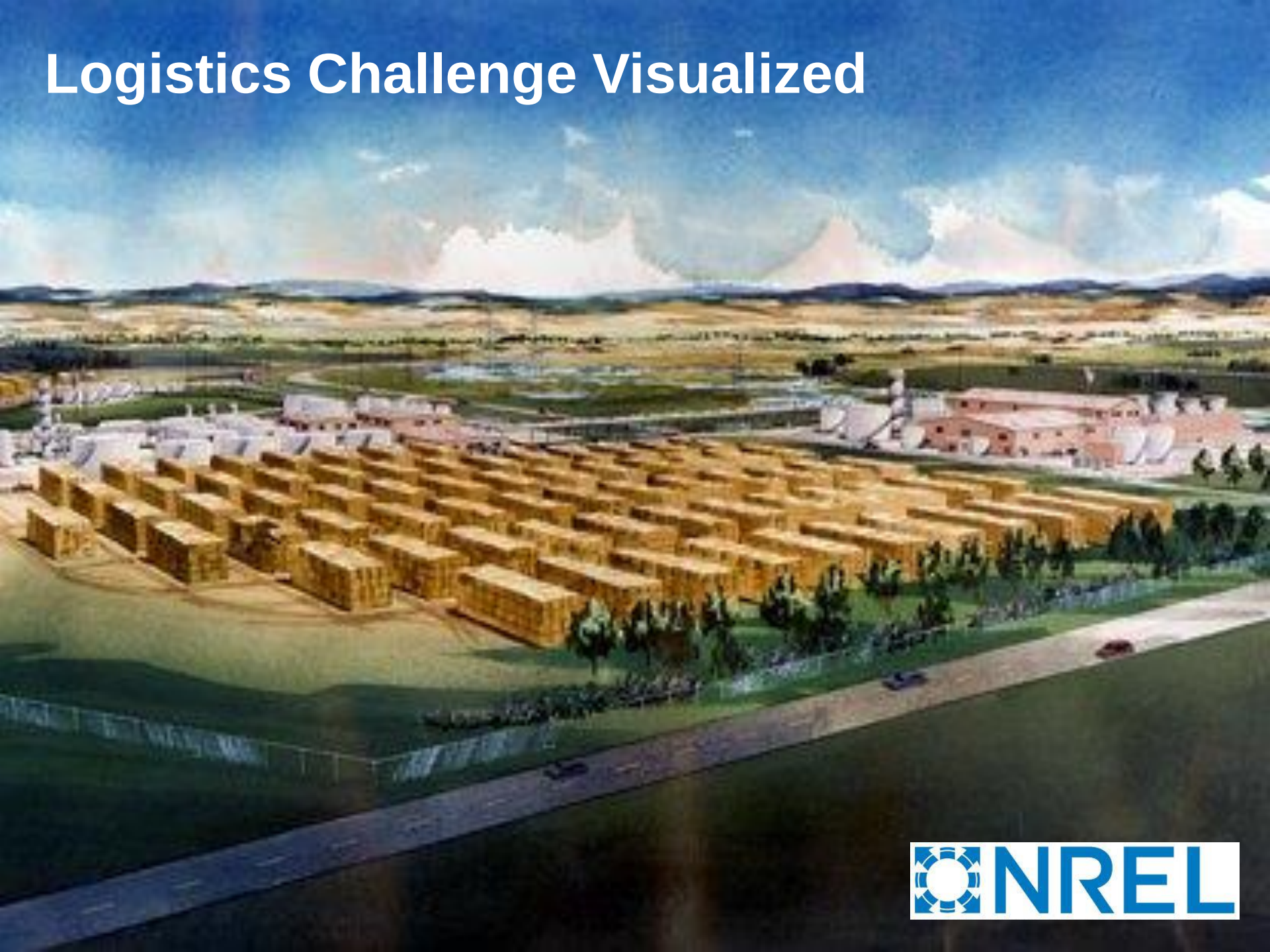
- **Who we are**: Not-for-profit, founded in 1981, subsidiary of MSU Foundation
- **Mission**: Create meaningful societal benefits by collaborating with universities, governments and companies to accelerate the commercialization of bio-based technologies.
- **What we do**: develop and derisk early stage bio-based technologies, demonstrate commercial viability, transition to commercial partners
- **Capabilities**: biomass processing, strain engineering, bench and pilot fermentation development, downstream processing

Biomass Supply Chain & Pretreatment Challenges

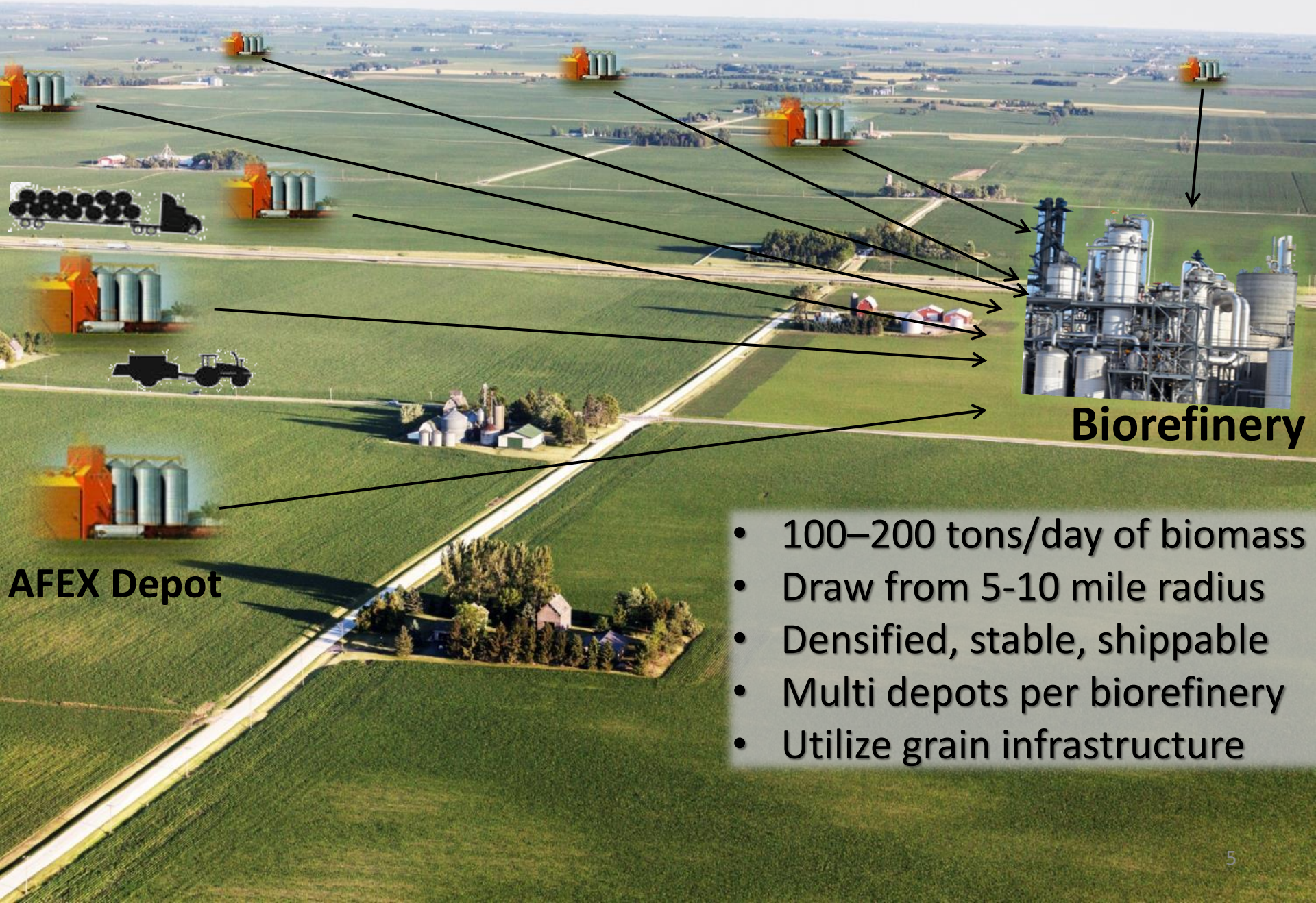
- Low density of Ag residue biomass
- Expensive to transport long distances
- Often not situated close to desired biorefinery locations
- Collection area may not be practical
- Potential for spoilage



Logistics Challenge Visualized

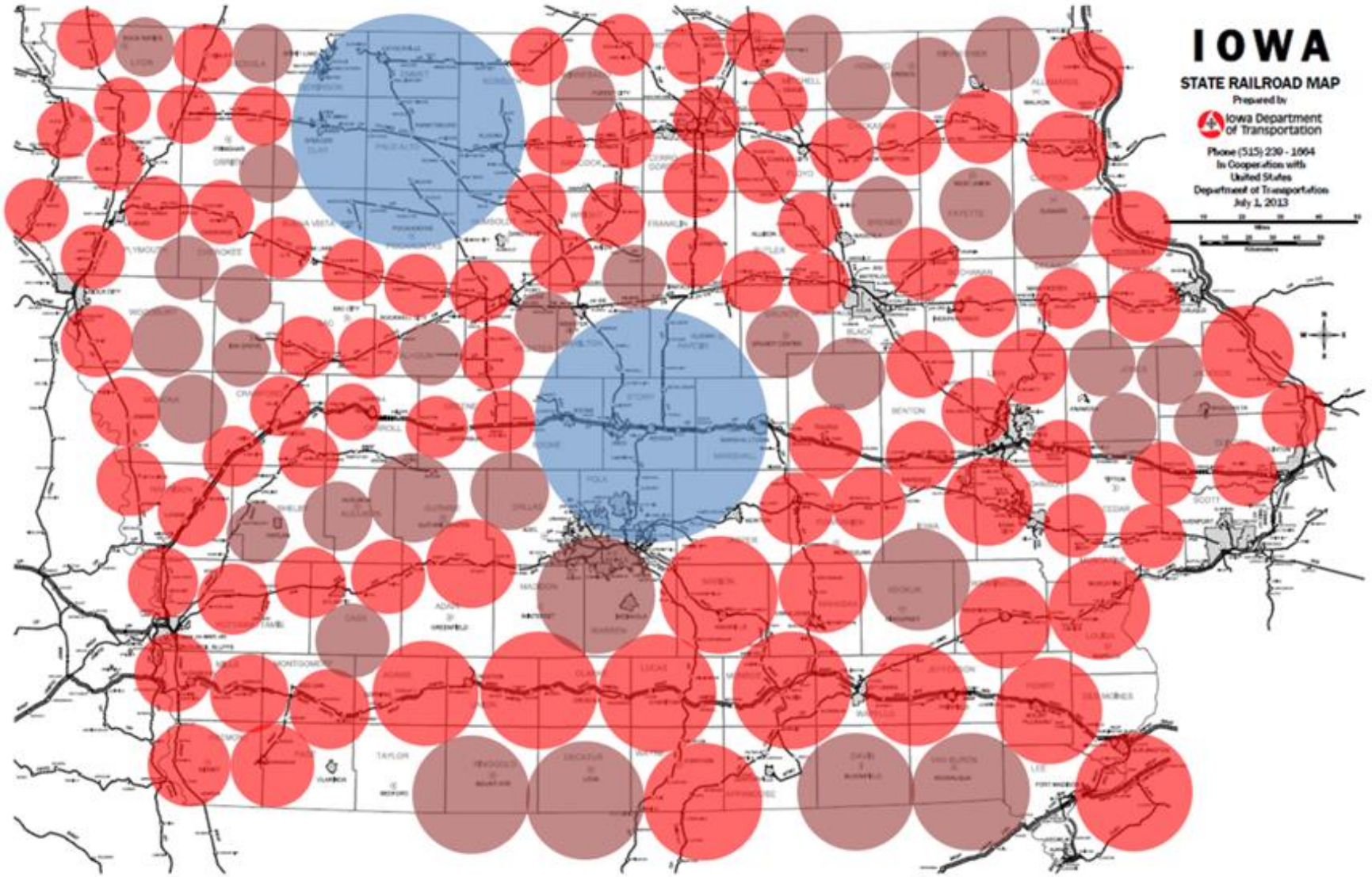


Decentralized Biomass Processing



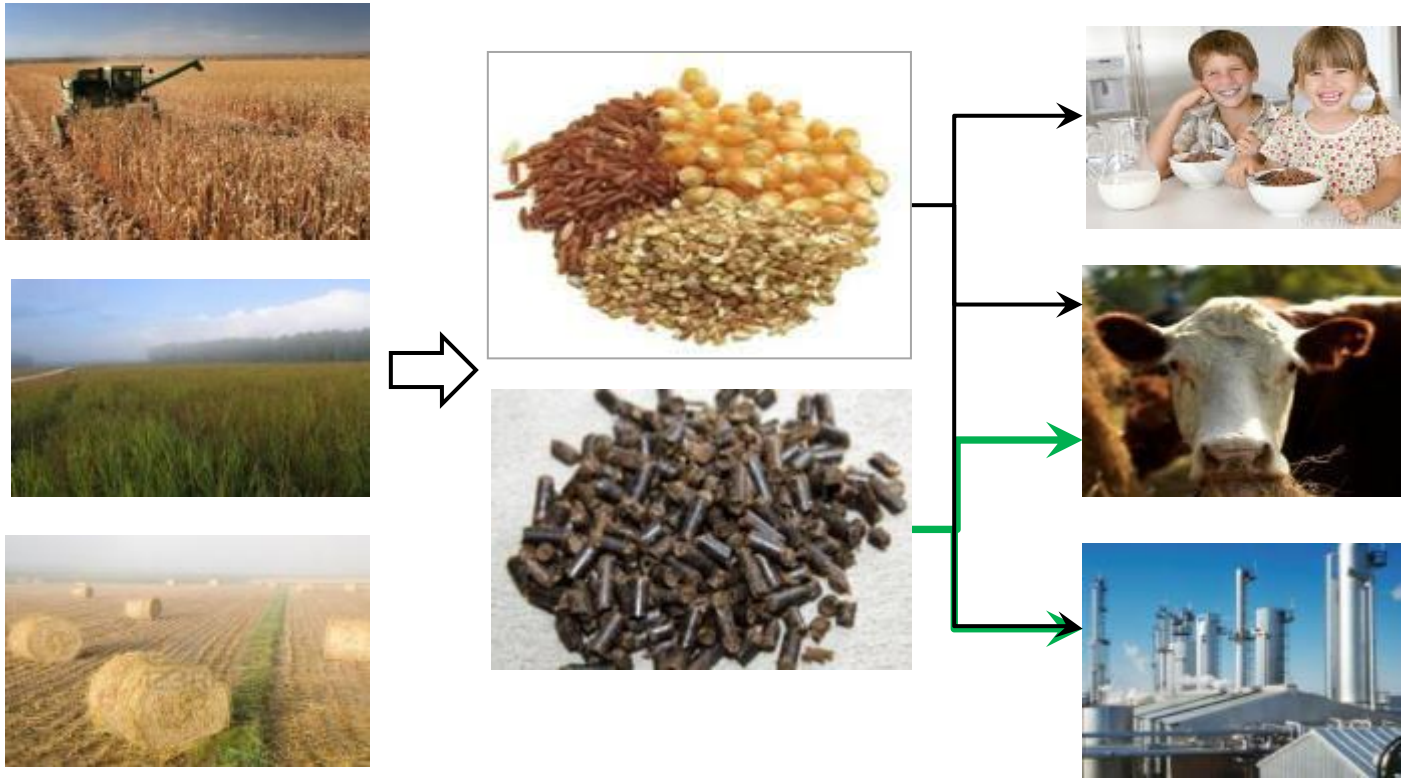
- 100–200 tons/day of biomass
- Draw from 5-10 mile radius
- Densified, stable, shippable
- Multi depots per biorefinery
- Utilize grain infrastructure

Potential AFEX Depots in Iowa



Red circles represent potential 200 DMT/day (70,000DMT/year) depots with rail access
Burgundy circles represent potential 200 DMT/day depots on major highways

AFEX Can Double Output From Existing Grain Production

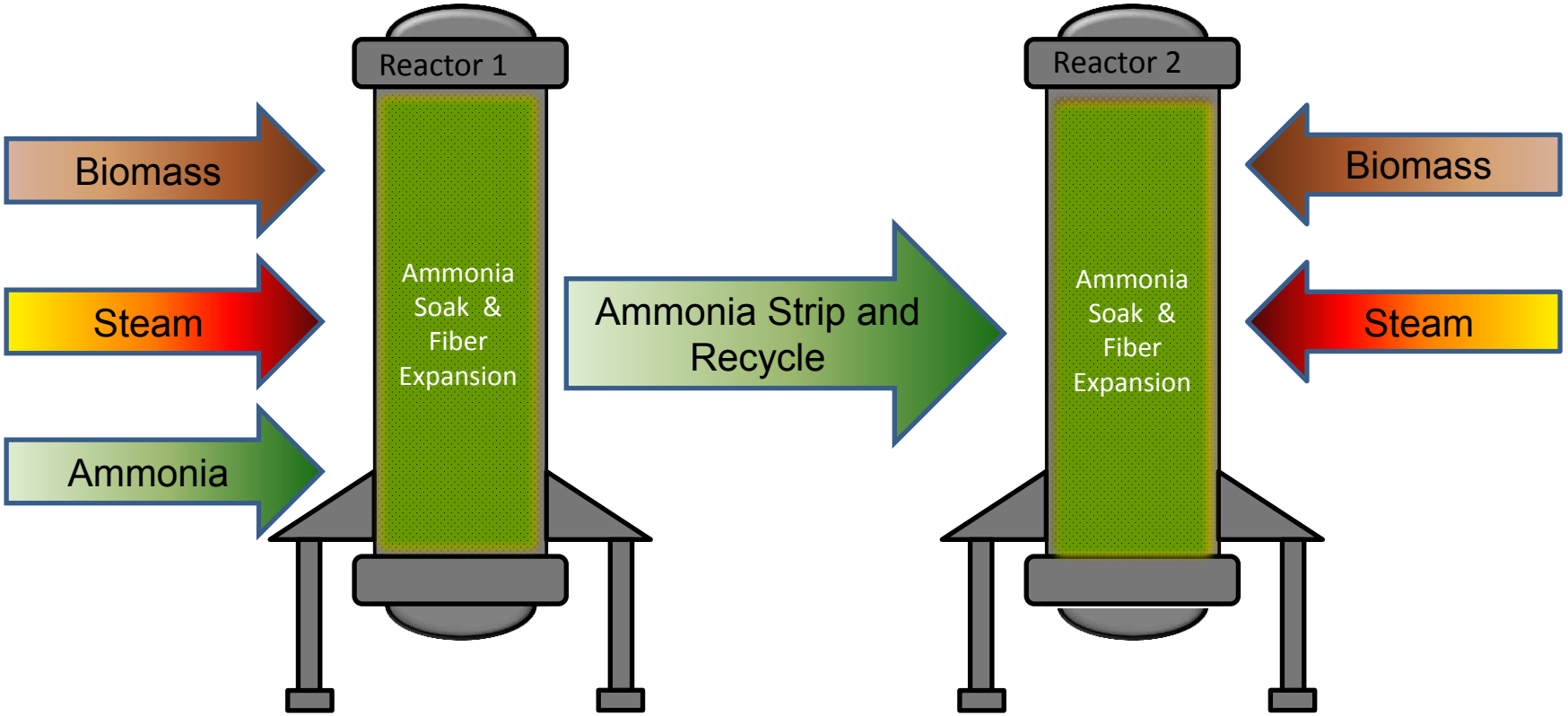


By 2030:

- Global population will grow from 7 Bn to 8 Bn
- Middle-class to grow by staggering 3 Bn (1.8 Bn to 4.8 Bn)
- Per-capita caloric intake to increase by 20% in India
- Per-capita meat consumption to increase by 40% in China
- Number of vehicles doubles (1 Bn to 2 Bn)

Source: 2011 McKinsey Global Survey

AFEX Process Description



After AFEX treatment:

Drying → Pelletizing →

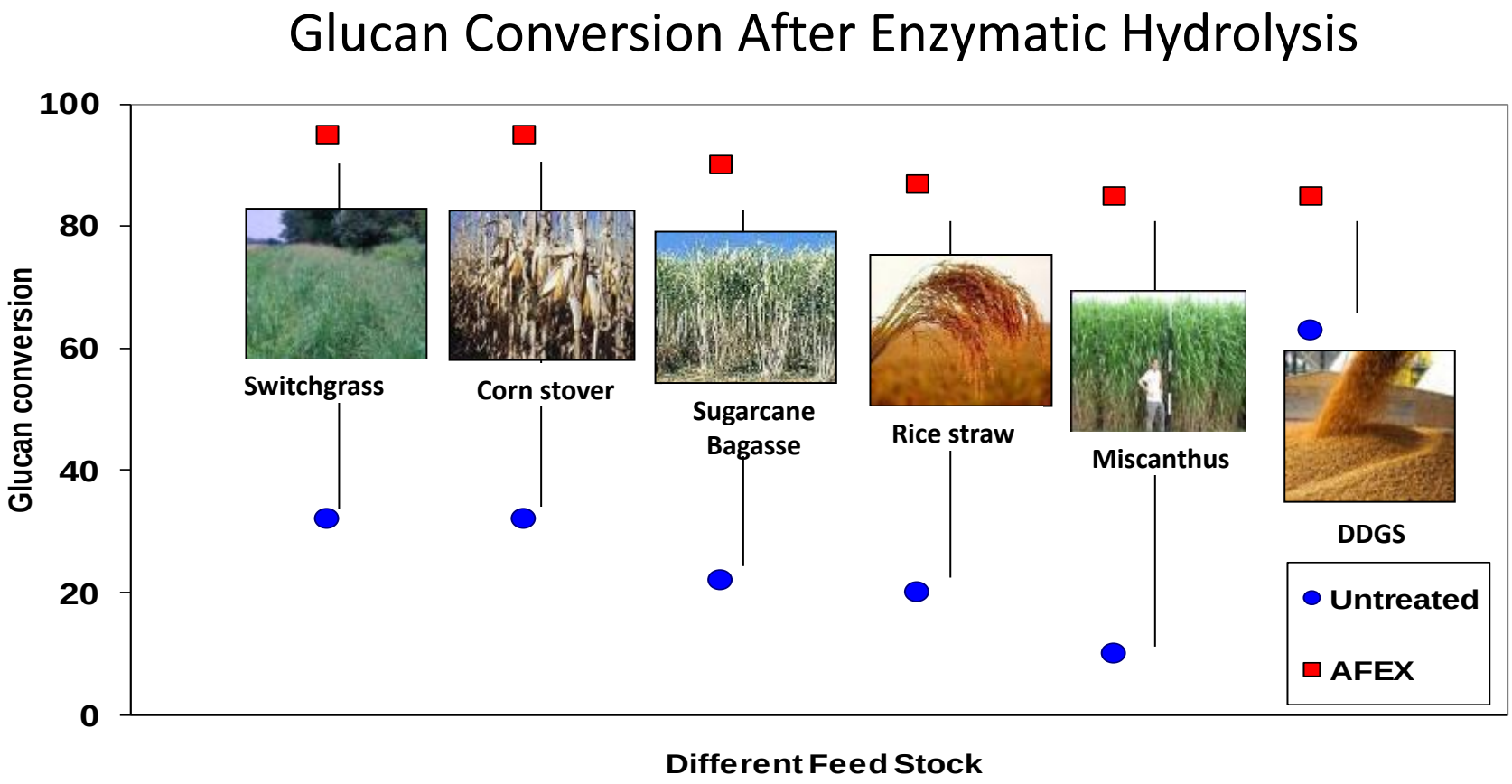
Treated biomass

AFEX pellets

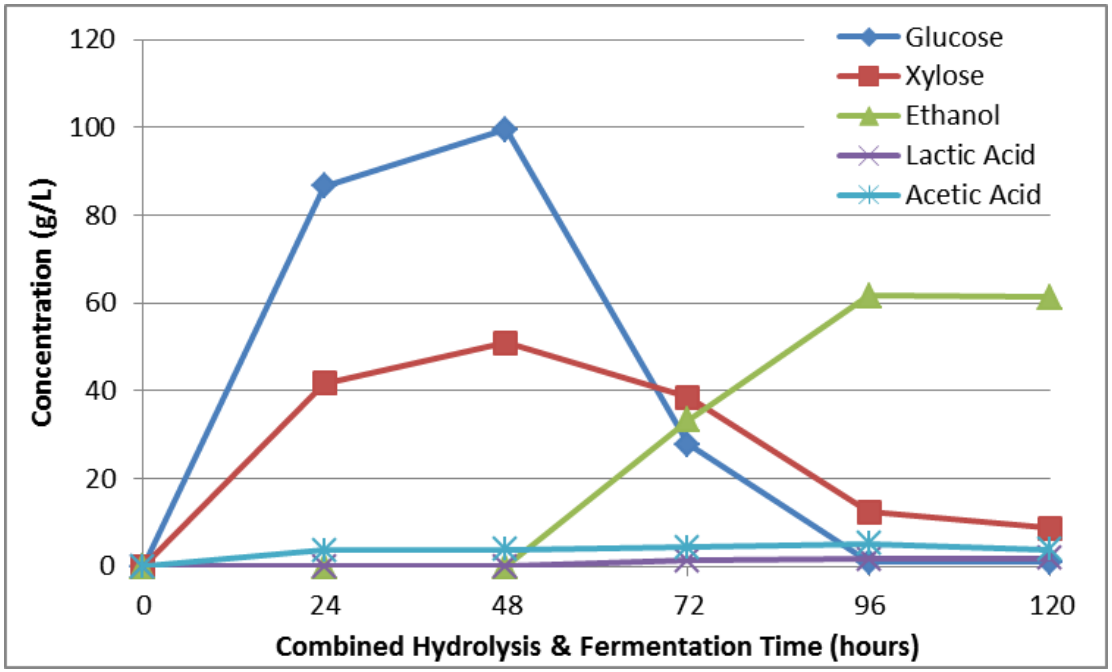
AFEX Pilot Reactor Operations

Corn stover being processed in MBI's AFEX pilot-scale reactor

Effective With Multiple Biomass Sources



Production of Cellulosic Ethanol From AFEX Pellets



- 20-25% solids loading of AFEX pellets
- Saccharification using Novozymes CTec3, HTec3 enzymes, 48 hrs @ 50° C. (7mg/g biomass)
- Did not remove unhydrolyzed residue prior to inoculation
- SHF fermentation using public domain Z. mobilis strain
- Glucose completely consumed, xylose 80% consumed within 48 hours of inoculation

AFEX Beef Cattle Trial Results

Results of study of 24 Holstein steers (12 AFEX modified diet, 12 control diet) fed for 168 days from September 2013 – February 2014

- ✓ AFEX pellets palatable to steers
- ✓ Data confirms that AFEX pellets have utility as a partial substitute for corn grain in cattle diets
- ✓ No significant health difference between AFEX and control steers
- ✓ No significant difference in carcass quality properties
- ✓ No change in nitrogenous compounds in the meat
- ✓ Comparable weight gain observed

AFEX-Fed Ribeye

Control Diet Ribeye

AFEX Technology Highlights

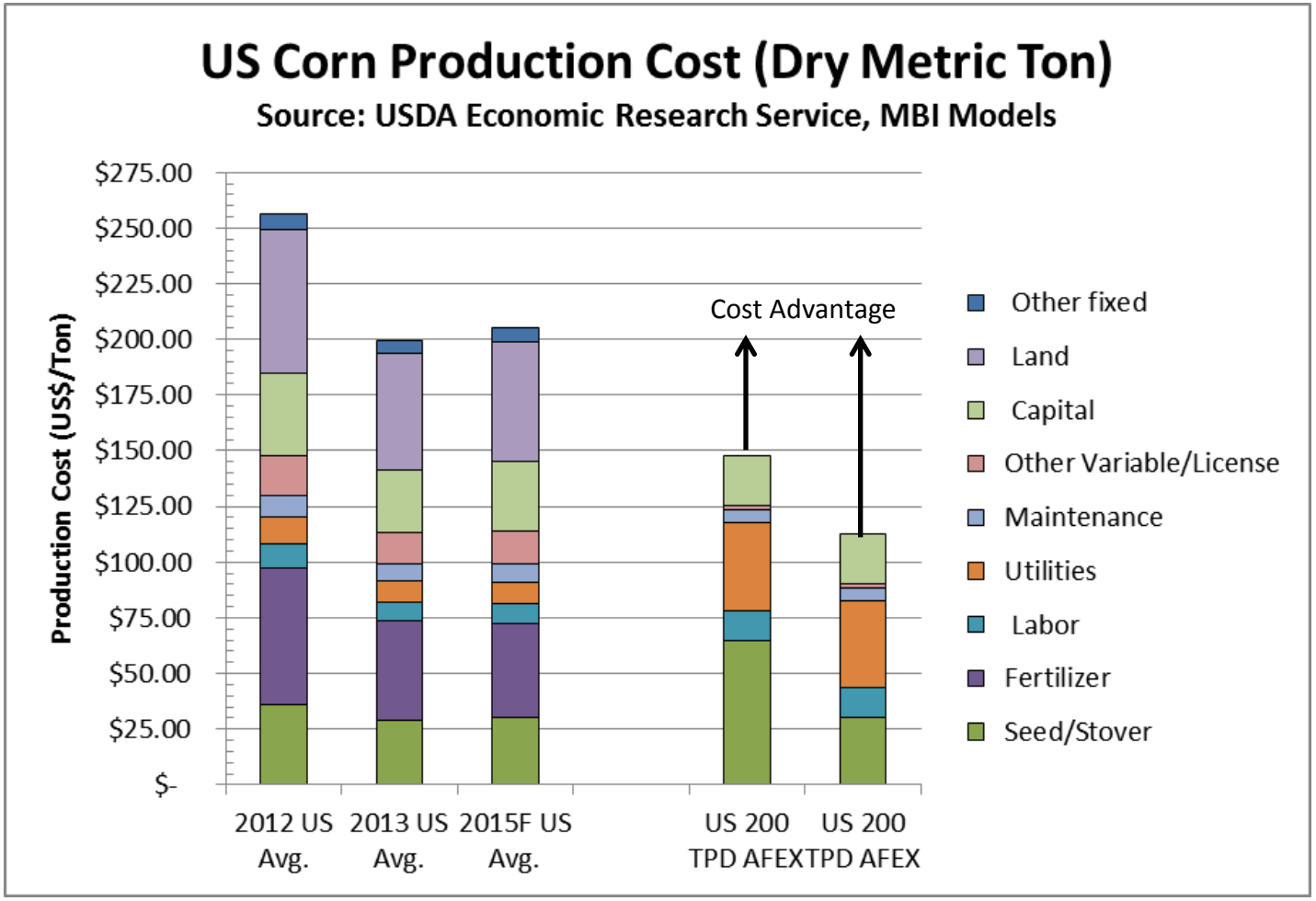
Reactors & Process:

- Simple low-cost reactor design
- >95% Ammonia recycle
- Dry-in, dry-out – no waste streams
- Can be scaled between 5 and 200 tons/day

Results:

- Enables recovery of >70% of cellulosic sugars
- Pellets 9x more dense than raw biomass
- Produces stable, shippable, pellets
- Enables “hub and spoke” system of local biomass depots
- No detoxification of sugar streams before fermentation
- Successful fermentation at high solids loading (>20%)

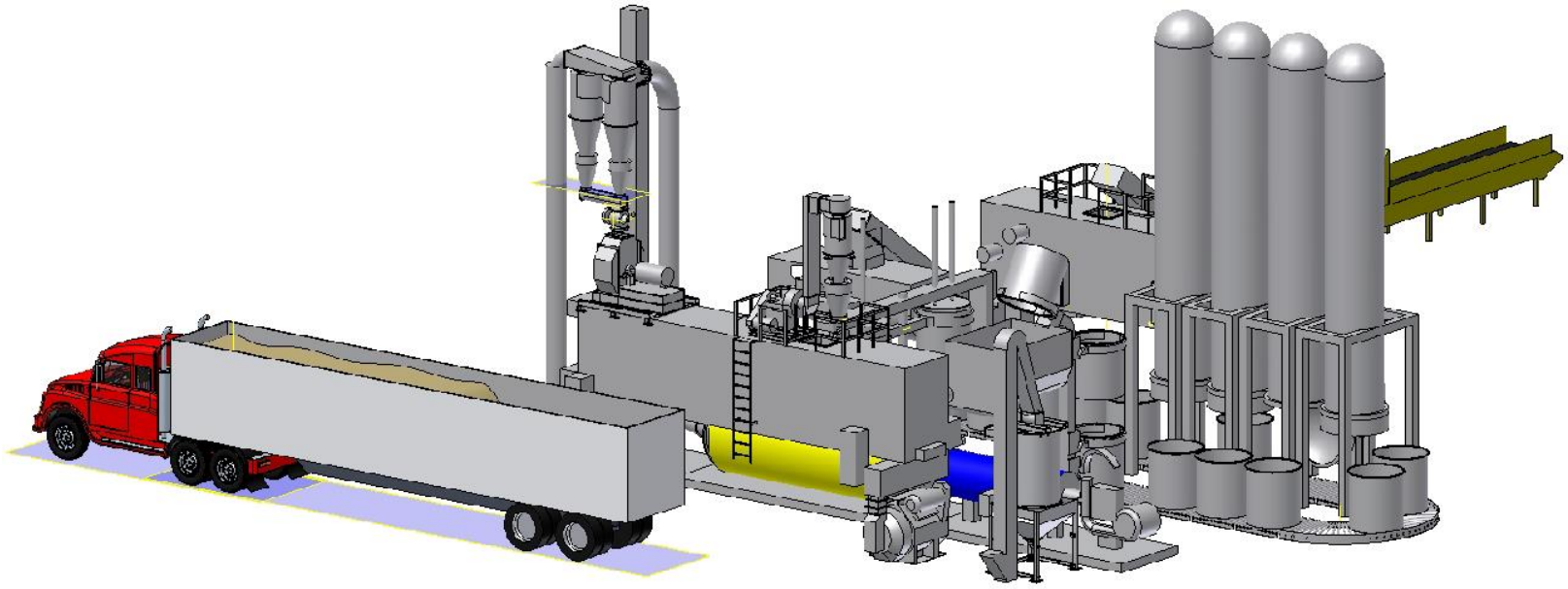
AFEX Cost Advantage vs. Corn



- 200 TPD USA based AFEX depot projected to have $50 - $100/metric ton cost advantage , depending upon raw biomass cost

AFEX Path to Commercialization

- Commercialization will require:
  - Validation of scale-up and economics through design, construction & operation of 100 TPD depot
  - Large scale animal and biorefinery trials
- MBI objectives: 1) Complete derisking at 100 TPD scale, 2) maximize societal benefit through non-exclusive, readily accessible licenses
- MBI Strategy: seek government and philanthropic support in order to retain opportunity to license broadly and inexpensively



AFEX depot CAD drawing by Corrie Nichol, INL

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Thank-you for your time and interest

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Successful Scale-up Attracts High-level Interest

President Obama and U.S. Agriculture Secretary Vilsack visit MBI Feb 7, 2014