Driving Value to Agriculture Through Low Carbon Solutions for Corn Biorefineries
Matt Durler
VP of Feed Development
Our Vision for Corn Biorefining

Increased efficiency
Value-added products
Lower carbon and a focus on sustainability
Our Mission Serves The Environment

Provide innovative solutions that sustain agriculture.

Develop feed technologies that increase the world's protein supply.

Advance renewable energy.

*SMT™ and FST™ are protected by US Patent Number 9012191. SMT V2™ and FST Next Gen™ are protected by US Patent Numbers 10774303 and 9376504. TS4™ is protected by US Patent Numbers 10260031, 10093891, 8986551 and is patent pending. FOT™ is patent pending. Rotary Press Methods and MZSA are protected by US Patent Numbers 10260031 and 9718006. Screens and Flingers are patent pending. © 2022 ICM, Inc.*
Sitting at the intersection of fuel, feed, and farming, bioethanol plants play an important role in optimizing the carbon footprint.
How Can a Biorefinery Reduce Its CI Score?

• 2/3 of the CI score is out of the control of the plant
  • Corn
  • Indirect land use

Values calculated from ICM finance assumptions for a typical base plant performance. LCFS impact calculated assuming 1.2 cents per gallon per CI point. Actual values will vary based on individual plant parameters.
Farming
Variables in Farming CI Score

Farm-level operations account for 36% of overall ethanol greenhouse gas (GHG) emissions and can be impacted by:

- Tillage Practices
- Nitrogen Efficiency
- Cover Crop Usage
- Seed Variety

Liu et al. 2020
Opportunities for CI Improvements in Farming Through Biorefineries

Using gasification technology, biorefineries can provide opportunities to reduce emissions in the following variables:

- Tillage Practices
- Nitrogen Efficiency
- Cover Crop Usage
- Seed Variety
Long-term studies have shown that systematic stalk and stover removal bring agricultural benefits:

• Enables no-till option
• Better nitrogen efficiency
• Improves corn yields

Aller et al. 2018
ICM’s Advanced Gasification Technology (AGT) for Biorefineries

• Utilizes gasification to produce a substitute for natural gas in biorefineries
• Capable of utilizing corn stover as a feedstock
• Produces biochar for soil benefits
Potential to reduce nitrogen leaching up to 20% while improving water holding capacity when applied to soil
Corn Stover as an AGT Feedstock:
Potential Impact on Farming Emissions

• Reduces the need for tillage
• Improves nitrogen efficiency in fields
• Improves corn yield potential
• Biochar returns nitrogen and minerals to the soil

Mangalassery, et al. 2014;
Aller et al. 2018;
Laird, farm-energy.extension.org 2019
Fuel
Other Low-Carbon Fuels

California Alternative Fuel Volumes

Renewable diesel, biodiesel, and biomethane are growing

- Ethanol
- Biodiesel
- Renewable Diesel
- Fossil Natural Gas
- Biomethane
- Electricity

California Air Resources Board LCFS
How Can a Biorefinery Reduce Its CI Score?

- Natural gas is the largest source of carbon intensity within the ethanol process
  - 1/3 drying
  - 2/3 for steam

Values calculated from ICM finance assumptions for a typical base plant performance. LCFS impact calculated assuming 1.2 cents per gallon per CI point. Actual values will vary based on individual plant parameters.
Baseline Biorefinery

Fossil & Gas Power Plant

Natural Gas

Medium

Medium

Boiler

Ethanol Plant

High

CO₂

Fossil & Gas Power Plant

Natural Gas

Medium

Medium

Boiler

Ethanol Plant

High

CO₂

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Reducing CI with Carbon Capture and Sequestration (CCS)

Fossil & Gas Power Plant

Natural Gas

Boiler

Compressor

Ethanol Plant

CO₂

Low

Medium

High

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Reducing CI with CCS

CCS brings a massive reduction in CO₂ emissions, but incurs additional costs from clean up and compression.

Relative CI change over base case: ~34
LCFS impact: 41 cents/gal

Values calculated from ICM finance assumptions for a typical base plant performance. LCFS impact calculated assuming 1.2 cents per gallon per CI point. Actual values will vary based on individual plant parameters.
Offsetting Electricity with Combined Heat & Power (CHP)

- Fossil & Gas Power Plant
- Natural Gas

Low

- Compressor
- Medium

Electricity

- Turbine Generator
- Steam

- Ethanol Plant
- Boiler

CO₂
A natural gas turbine-driven generator produces electricity for the facility.

Waste heat from the turbine is used in steam generation for the plant.

A duct burner installation can also provide more heat for steam generation.
Powering a Midwest Biorefinery with CHP

• ICM installed the system, which produces +/- 7MW of electricity, (approximately half of the facility’s overall electrical needs).

• The complete installation produced all of the steam needed by the biorefinery.

• The plant was able to take advantage of a new lower CI Score.
Offsetting Electricity with (CHP)

CHP displaces some or all of the electricity added by CCS, with only a nominal increase in natural gas.

Relative CI change over base case: ~40
LCFS impact: 48 cents/gal

Values calculated from ICM finance assumptions for a typical base plant performance. LCFS impact calculated assuming 1.2 cents per gallon per CI point. Actual values will vary based on individual plant parameters.
Using AGT to Offset Natural Gas

Fossil & Gas Power Plant

Natural Gas

Biomass

Gasifier

Producer Gas

Biochar

Boiler

Steam

Ethanol Plant

Turbine Generator

Steam

Ethanol Plant

Electricity

CO₂

Lower

Compressor

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ICM’s AGT

- Internally augured, air-blown, atmospheric gasifier
- Uses extremely high heat to convert biomass into a usable producer gas and biochar
- Accepts a wide variety of feedstock including wood, corn stover, corn bran + syrup, and other materials
- Patented
Making Producer Gas at Colwich Facility with AGT

• Provides up to 85% natural gas offset in the boiler
• Co-Generates 7 Megawatts Electric (MWe)
• Provides 135,000+ pounds per hour of medium and low pressure steam to the plant
• Produces a high-carbon biochar for other applications
Using AGT to Offset Natural Gas

- AGT converts biomass into producer gas and biochar through gasification
- Producer gas can replace natural gas in the boiler
- By utilizing CCS with CHP and producer gas, the CI score is reduced from a baseline plant by almost 70%

Relative CI change over base case: ~52
LCFS impact: 62 cents/gal

Values calculated from ICM finance assumptions for a typical base plant performance. LCFS impact calculated assuming 1.2 cents per gallon per CI point. Actual values will vary based on individual plant parameters.
Efficient Separation with the Advanced Processing Package™ (APP™)

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Baseline Ethanol Process

GRAIN ✢ HAMMER MILL ✢ SLURRY TANK(S) ✢ LIQUEFACTION TANKS ✢ CO₂

ETHANOL ✢ DEHYDRATION ✢ DISTILLATION ✢ FERMENTATION

SOLIDS ✢ WHOLE STILLAGE DECANTERS ✢ LIQUIDS

DISTILLERS CORN OIL ✢ EVAPORATORS ✢ SOLUBLES

DRYER ✢ DRIED DISTILLERS GRAINS WITH SOLUBLES

PRODUCTS ✢ EXISTING PROCESS
The APP™ Process

GRAIN >>>>>>>> MILLING >>>>>>>> SLURRY TANK(S) >>>>>>>> LIQUEFACTION TANKS

CO₂

DEHYDRATION >>>>>>>> DISTILLATION >>>>>>>> FERMENTATION

PROTEIN

FST

TS4

DRYER

FOT

DISTILLERS CORN OIL

EVAPORATORS

ETHANOL

SOLBRAN OR DDGS

YEAST-ENRICHED 50% PROTEIN

APP™ ADDITIONS

PRODUCTS

EXISTING PROCESS

ADVANCED PROCESSING PACKAGE

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Selective Milling Technology™/SMT V2™

SMT™/SMT V2™ can reduce a plant’s connected horsepower while right-sizing particles for efficient separation downstream.
Fiber Separation Technology™/FST Next Gen™

FST™/FST Next Gen™ increases efficiency by removing fiber before fermentation. It reduces electrical demand and the load on the dryers.
Feed Optimization Technology™ (FOT™)

FOT™ dewateres the protein cake for further dryer load reduction.
Thin Stillage Solids Separation System™ (TS4™)

TS4™ separates solids from the thin stillage, driving more liquids to the evaporators and solids to the dryer for added efficiency.
Combined Efficiencies from ICM’s Advanced Processing Package™

Reduce natural gas usage up to 12%
Total reduction of 2,181 BTU/gallon of ethanol*

Reduction in electrical consumption up to 5% on each gallon produced

*Calculations using Industry Standard of 37% solids on the decanter cake and 40% solids on the syrup
The Impact of Low-Carbon Technologies

Values calculated from ICM finance assumptions for a typical base plant performance. LCFS impact calculated assuming 1.2 cents per gallon per CI point. Actual values will vary based on individual plant parameters.
Feed
Efficient Product Diversification

ICM’s Advanced Processing Package™ separates “clean piles” of feed components:

- Fiber
- Protein
- Enhanced Protein with Yeast
- Solubles
- Distillers Corn Oil

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The Opportunity for Feed

Oil
Fiber
Yeast
Protein
Oil
Fiber
Protein
Yeast
Oil
Fiber
Protein
Yeast
Oil
Fiber
Protein
Yeast
Oil

DDGS
Optimizing Feed for Tailored Nutrition

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Creating Feed Products from Separated Components

- **Corn Bran (Fiber)** + **CDS (Syrup)** = **SOLBRAN**
  - High-energy feed

- **Protein** + **CDS (Syrup)** = **Protein Enhanced Protein with Yeast**
  - Yeast-enriched 50% protein

- **Corn Bran (Fiber)** + **Protein** + **CDS (Syrup)** = **DDGS**
DDGS Have Too Much Protein for Some Cattle

80% fed to cattle

40+ mil tons
distillers grains
made annually
in the US

4 mil tons
protein wasted
The animal eats crude protein (a mixture of natural protein and urea)

The crude protein is broken down into ammonia and amino acids

Unutilized nitrogen becomes waste nitrogen and exits with digested microbial protein
Right-Sizing Protein in Ruminant Diets

Microbial Protein on Ammonia and Amino Acids

- Feedlot/Dairy
- Range Cow
- Deficient

Ammonia and Amino Acids
Optimizing Feed for CI Reduction

<table>
<thead>
<tr>
<th>Nutrient Content</th>
<th>Corn</th>
<th>Corn + WDGS</th>
<th>*Corn + SOLBRAN™</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crude Protein</td>
<td>13.00</td>
<td>15.00</td>
<td>14.00</td>
</tr>
<tr>
<td>ME, Mcal/kg</td>
<td>2.91</td>
<td>2.99</td>
<td>3.22</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Animal Performance</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Gain:Feed</td>
<td>0.14</td>
<td>0.15</td>
<td>0.15</td>
</tr>
<tr>
<td>Methane, L per lb of Intake</td>
<td>13.70</td>
<td>13.42</td>
<td>11.42</td>
</tr>
<tr>
<td>Total CO2 Equivalent*</td>
<td>1309.00</td>
<td>1212.00</td>
<td>1110.00</td>
</tr>
<tr>
<td>kg of CO₂e / kg BW Gain</td>
<td>1.45</td>
<td>1.31</td>
<td>1.20</td>
</tr>
</tbody>
</table>

| Total CI Reduction  |          | -17%        |

- Dr. Andy Cole, USDA Ag Research Service in Bushland, TX, evaluated Corn and WDGS feed rations on the carbon footprint of feeding cattle.
- ICM hypothesized the CI reduction in a SOLBRAN™ ration by applying his equations for GHG and assuming the same performance as WDGS.*

* Cole et al. 2020
Too Much Fiber in Swine Diets is Costly

Each additional percentage point of neutral detergent fiber (NDF) in a swine finishing diet is estimated to cost swine producers $2 per pig.

+1% NDF COSTS $2/

Kline, 2017 Midwest ASAS meeting
Study: DDGS in Swine Diets

- DDGS replaced 75% of the protein from soybean meal (SBM)
- Diets were balanced for essential amino acids
- Animal performance was depressed:

<table>
<thead>
<tr>
<th></th>
<th>Corn + SBM</th>
<th>Corn + DDGS + SBM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Daily feed intake, lbs</td>
<td>5.72</td>
<td>5.94</td>
</tr>
<tr>
<td>Daily gain, lbs</td>
<td>2.02</td>
<td>1.96</td>
</tr>
<tr>
<td>Feed efficiency</td>
<td>0.35</td>
<td>0.33</td>
</tr>
<tr>
<td>Dietary NDF, %</td>
<td>8.7</td>
<td>16.1</td>
</tr>
</tbody>
</table>

- The 7% decrease in feed efficiency can be attributed to the higher fiber content of the DDGS

Tolosa et al., 2022
### Designing Feed for Target Markets

<table>
<thead>
<tr>
<th>Animal Group</th>
<th>PROTOMAX Yeast-Enriched 50% Protein</th>
<th>SOLBRAN High-Energy Feed</th>
<th>DDGS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beef</td>
<td><img src="http://example.com/beef.png" alt="Beef" /></td>
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<tr>
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<tr>
<td>Swine</td>
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<tr>
<td>Poultry</td>
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</tr>
<tr>
<td>Tilapia, Carp, Catfish</td>
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<td><img src="http://example.com/tilapia.png" alt="Tilapia, Carp, Catfish" /></td>
</tr>
<tr>
<td>Salmon, Shrimp</td>
<td><img src="http://example.com/salmon.png" alt="Salmon, Shrimp" /></td>
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</tr>
<tr>
<td>Pets</td>
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<td><img src="http://example.com/pets.png" alt="Pets" /></td>
</tr>
</tbody>
</table>

- **Beneficial**
- **Most Beneficial"
Conclusion

• At the intersection of fuel, feed, and farming, biorefineries are uniquely positioned to do more with less.

• Benefits can be realized across all three sections when optimized to work together.
THANK YOU
Matt Durler
VP of Feed Development
Matthew.Durler@icminc.com
Appendix


