Carbon Policy Impacts on Agriculture

Certified Crop Advisor Update
Paynesville American Legion
Paynesville, Minnesota
September 24, 2013
Douglas G. Tiffany
Assistant Extension Professor
TODAY’S TOPIC

- Discussion of Greenhouse Gas (GHG), ag energy use, GHG emissions from ag production
- Why is it important to study GHG emissions?
- GHG standards for biofuels and renewable electricity make GHG reductions valuable
- GHG types and rates of atmospheric forcing
- Estimates of GHG by ag activities and inputs
- Discussion of methods to improve carbon footprint of ag. and products from agriculture
- Your questions
IMPORTANCE OF CARBON POLICY TO
U.S. AND MN AGRICULTURE

- GHG emissions from ag are evident and some instances may be restricted.
- Likely Costs of Compliance
  - Carbon Taxes on Energy Sources
  - Potential Carbon Taxes on Ag Exports
  - Required Changes in Ag Practices
  - More Expensive Inputs
ACKNOWLEDGEMENTS

• This research was supported by the Initiative for Renewable Energy and the Environment at the University of Minnesota.
• Nalladurai Kaliyan and Vance Morey of BBE have collaborated on the engineering and life cycle analysis.
• Graduate students Carrie Johnson and Won Fy Lee have assisted me in business modeling of ethanol plants, power plants, and torrefaction plants.
SOURCES OF GREENHOUSE GAS EMISSIONS
THREE MAIN MOLECULAR CULPRITS AND THEIR ATMOSPHERIC FORCING POTENTIALS IN CO2 EQUIVALENTS

- Carbon Dioxide
- Methane
- Nitrous Oxide
GHG MOLECULES ARE CAUSED BY:

- Respiration and Combustion (CO2)
- Anaerobic fermentation—methane (CH4)
- Engine and Power plant emissions, soil bacterial action (NO2, CO2)
DYNAMIC FLUXES OF GHG

Source: Intergovernmental Panel on Climate Change, Climate Change 2001: The Scientific Basis (U.K., 2001)
U.S. GREENHOUSE GAS EMISSIONS

Figure 1. U.S. Greenhouse Gas Emissions by Gas, 1990–2010

GREENHOUSE GAS EMISSIONS

AG ENERGY USE LESS THAN 2% OF U.S. TOTAL

Total Energy Directly and Indirectly Consumed on U.S. Farms in 2002 was 1.7 Quadrillion Btu

- Diesel: 27.3%
- Fertilizers: 29.0%
- Natural Gas: 3.6%
- LP Gas: 4.5%
- Gasoline: 8.5%
- Electricity: 20.7%
- Pesticides: 6.3%

SHIFTS IN US AG ENERGY USE 1966-2000

The graph illustrates the shifts in energy use by different sources in the U.S. agriculture sector from 1966 to 2000. The x-axis represents the years from 1965 to 2000, while the y-axis indicates the use of energy measured in quadrillion BTUs (quadrillion British thermal units).

Energy sources include:
- Natural gas
- Electricity
- LP gas
- Diesel
- Gasoline
- Fertilizers and pesticides

The graph shows a decline in the use of diesel and gasoline over the years, with a slight increase in the use of electricity and a relative stability in the use of natural gas. The use of LP gas remains relatively stable throughout the period.

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BIOFUELS PRODUCTION—GHG IMPACTS
GHG STANDARDS FOR BIOFUELS VS. GASOLINE

- Renewable Ethanol ---- 20% reductions
- Advanced Biofuels ---- 50% reductions
- Cellulosic Ethanol ---- 60% reductions
- RINS certificates validate RFS compliance
- Carbon Taxes on Emissions or Credits for substitute low emissions fuels have value.
- Many ethanol plants are implementing GHG-reducing practices and are not being rewarded
SOURCES OF GREENHOUSE GAS EMISSIONS OF DRY-GRIND ETHANOL USING CORN: NOTE THE BIG 3

WHAT RESPONSES ARE POSSIBLE AND LIKELY TO BE REWARDED UNDER CO$_2$ TAXES?

- Use of natural gas for CHP at ethanol plants
- Extraction of Corn Oil from DDGS or Wet Stillage—(more energy recovered)
- Use of biomass to produce thermal energy and electricity at ethanol plants
- Use of torrefaction off-gasses for thermal energy at ethanol plants
- Use corn fertilizer produced with lower GHG
Conventional Natural Gas Fired Ethanol Process
Energy Balance

Energy Ratio: 1.7
Conventional Natural Gas Fired Ethanol Process
Energy Balance

MJ of energy per energy content of ethanol produced (MJ)

Input | Output
--- | ---
0.2 | 1.2

- Coproduct Credit
- Ethanol
- Fossil Electricity
- Natural Gas
- Corn Production

Renewable Energy Ratio 3.9
Corn Stover in CHP or Integrated CC can Replace Fossil Thermal and Electric Energy
Life-Cycle GHG Emissions of Fuels

10 g of CO$_2$e/MJ of dry corn stover
(includes combustion emission, but not SOC)
Combined Heat and Power (CHP) Concept

- Simultaneous production of two or more types of usable energy from a single energy source (also called “Cogeneration”)
- Use of waste heat from power generation equipment
BIOMASS TECHNOLOGY OPTIONS

- Process heat for the ethanol plant
- Combined heat and power (CHP) – process heat plus generate electricity with a back pressure turbine
- CHP plus grid – process heat plus generate electricity with an extraction turbine and condensing turbine
- Biomass integrated gasification combined cycle (BIGCC) – process heat plus generate electricity with gas turbine and steam turbine.
Steam Tube Dryers

Used for drying co-products and biomass fuel

Corn Stover Combustion: CHP + Grid

- Ammonia
- Limestone
- Corn Stover

Fluidized Bed Boiler

- Lime Slurry
- Flue Gas

Semi-Dry Scrubber

- Baghouse
  - To Stack
  - Ash

Extraction Turbine

- Low Pressure Steam

Process Steam

Dryer

- VOC

Steam Tube Dryer

- DDGS

Conventional Dry Grind Ethanol Process

- DWG
- Syrup

Condenser

- Ethanol
Biomass Integrated Gasification Combined Cycle
System Comparisons

- CHP, CHP + Grid, and BIGCC with corn stover and syrup and corn stover as biomass fuels
- Life-cycle GHG analysis for fuel ethanol based on Liska et al. (2009), Plevin (2009), and GREET (2009)
- Life-cycle GHG analysis excludes indirect land use change effects
GHG EMISSIONS COMPARED: CORN ETHANOL VS. GASOLINE

U.S. Midwest average corn ethanol (Liska et al., 2009; Plevin, 2009)
CHP, CHP+Gr, and BIGCC GHG Reductions vs. Gasoline

- Natural Gas Plant (Liska)
- CHP Syrup & Stover
- CHP Corn Syrup & Stover
- CHP+G Syrup & Stover
- CHP+G Corn Syrup & Stover
- BIGCC Syrup & Stover
- BIGCC Corn Stover

GHG Reduction (%)

- 38.9%
- 66.3%
- 79.1%
- 80.4%
- 91.8%
- 116.5%
- 124.1%
GHG REDUCTIONS VS. GASOLINE OF CONVENTIONAL, BIGCC AND NATGAS CC

GHG Reduction (%)

- 38.9%
- 116.5%
- 124.1%
- 93.4%
Carbon Taxes around the World

<table>
<thead>
<tr>
<th>Country</th>
<th>Carbon Tax (USD/ton)</th>
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<tr>
<td>Sweden</td>
<td>$150</td>
</tr>
<tr>
<td>British Columbia, Canada</td>
<td>$30</td>
</tr>
<tr>
<td>Finland</td>
<td>$26</td>
</tr>
<tr>
<td>Australia</td>
<td>$23</td>
</tr>
<tr>
<td>Ireland</td>
<td>$20</td>
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<tr>
<td>Denmark</td>
<td>$18</td>
</tr>
<tr>
<td>California</td>
<td>$10</td>
</tr>
<tr>
<td>Quebec, Canada</td>
<td>$4</td>
</tr>
<tr>
<td>Japan</td>
<td>$3</td>
</tr>
<tr>
<td>India</td>
<td>$1</td>
</tr>
</tbody>
</table>
2012 Corn Ethanol: Emerging Plant Energy and Environmental Technologies

http://ethanolrfa.org/page/-/PDFs/2012%20Corn%20Ethanol%20FINAL.pdf?nocdn=1

Steffen Mueller, PhD
University of Illinois at Chicago
John Kwik, PE
Dominion Energy Services, LLC

Midwestern Ethanol Innovation
Maximizing Process Efficiency and Carbon Reduction

by
Amanda Bilek and Dane McFarlane

Advantage per Gallon of Ethanol Produced by Alternative Plants over Gasoline for Carbon Permit Fees of $10, $20, $30 and $40 per Ton CO2 e
TORREFACTION INTEGRATION

- Torrefaction Plant
- Biocoal to Power Plant
- Volatile Off-Gasses
- Steam
- Coal Power Plant
- Ethanol Plant

Inputs:
- Corn Stover
- Wood

Outputs:
- Biocoal
- Steam
TORREFACTION FOR WOODY OR HERBACEOUS BIOMASS

- Like coffee roasting (in absence of oxygen)
- Roast biomass at (250-320° C) at near zero oxygen to drive off water and VOCs while degrading hemicelluloses to release the heat needed to drive the reaction
- Depending upon initial moisture of biomass, there may be steam available after pre-drying for other purposes or sales.
- Use of inert gases (like CO2), prevents combustion from occurring during roasting phase (15 to 20 minutes)
- Hydrophobic, will not rot or harbor pests like wood pellets, integrates with coal infrastructure, increases energy density
- Brittleness of densified torrefied biomass facilitates grinding at power plants.
- Torrefied biomass can replace coal in combustion or be used as a feedstock for further pyrolysis or gasification.
Mass and Energy Balances of Torrefied Corn Stover

Mass & Energy Balance of Torrefied Corn Stover

- **biocoal**
- **Lost as off-gas volatiles**

<table>
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<tr>
<th>Dry Matter</th>
<th>Energy Content</th>
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<tr>
<td>65.6</td>
<td>74.5</td>
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</table>

<table>
<thead>
<tr>
<th>%</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>34.4</td>
<td>22.5</td>
</tr>
</tbody>
</table>

0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%
Schematic of Torrefaction Unit by Agri-Tech
Steps in the Analysis

• Develop spreadsheets to determine costs of converting biomass to biocoal, ethanol plants, coal-fired power plants
• Collect data on delivered biomass and coal costs
• Determine GHG emissions from pulverized coal power plants using various blends of “biocoal”
• Determine ROE of torrefaction plants and plants using products to comply with environmental regulations
• Determine if existing power plants will gradually reduce their GHG emissions by blending torrefied biomass in order to extend their economic lives
Co-located Advantage for Torrefaction

• After cost of biomass, independent torrre. plant may have costs of production of $42 per finished ton.
• With sales of steam, costs of process, $17 per finished T. of biocoal, a $25/T. advantage.
  ▪ Co-located torrefaction plants can enjoy a 16% ROE vs. 6% ROE over independent plants.
• Require 1.7 tons of 17% biomass to yield 1.0 T. of biocoal D.M.
Life Cycle Assessment (LCA)

- Determination of GHG emissions associated with the production and use....

- Three Businesses:
  - 150,000 ton/year torrefaction plant
  - 100 MM gpy eth plant co-located w/torref. plant
  - Coal power plant co-firing biocoal

- Sources
  - Bepex
  - USDA, ERS model, Aspen Plus
  - Greet Model, Argonne National Lab
Life-Cycle GHG Emissions of Biocoal vs. Coal

Life-Cycle GHG emission of Biocoal compared to Coal

<table>
<thead>
<tr>
<th>g/MJ</th>
<th>biocoal</th>
<th>coal</th>
</tr>
</thead>
<tbody>
<tr>
<td>110.6</td>
<td></td>
<td>11.4</td>
</tr>
</tbody>
</table>
Torrefaction + Ethanol Plant Co-location

A 150,000 ton/year torrefaction plant can produce excess heat in the torrefaction off-gas volatiles, which can meet 42.8% of process energy needs in the ethanol plants.

<table>
<thead>
<tr>
<th>GHG emission of gasoline</th>
<th>GHG emission of conventional ethanol plant relative to Gasoline(%)</th>
<th>GHG emission of ethanol plant with 42.8% energy from Torref.Plant relative to Gasoline(%)</th>
<th>GHG emission of ethanol plant with 100% energy from Torref.Plant relative to Gasoline(%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>100%</td>
<td>65.90%</td>
<td>60.0%</td>
<td>52.10%</td>
</tr>
</tbody>
</table>
GHG Reductions of Coal PP Co-firing Biocoal

- 8.50% at 10%
- 17.10% at 20%
- 25.60% at 30%
- 85.50% at 100%

Biocoal co-firing percentage
NITROGEN FERTILIZER IN CORN PRODUCTION

- Dominant Source of Imbedded Energy
- Largest Source of GHG Emissions in Corn Production
- Fertilizer on Corn costs $149/ A. was less than rent ($225) and more than seed ($115) in 2012 on cash rented land reported by SWMFMA. (Staff Paper P13-2)

Source: www.countrysidefarmsimplements.com

Annual Prices of Anhydrous Ammonia and Corn Per Ton from 1984-2012

Sources: National Ag. Statistical Service and Economic Research Service

Corn Price ($ per Ton)
Ammonia ($/Ton)
Cost of Natural Gas & Gross Margin in Sale Price of Anhydrous Ammonia

Derived by using Citygate natural gas prices and assuming 32.7 decatherms per ton of ammonia

Douglas G. Tiffany, University of Minnesota Extension

Gross Margin per Ton of Ammonia

Natural Gas Cost per Ton of Ammonia
ECONOMIC EVALUATION OF DEPLOYING SMALL- TO MODERATE-SCALE AMMONIA PRODUCTION PLANTS IN MINNESOTA USING WIND AND GRID-BASED ELECTRICAL ENERGY SOURCES
PROJECT ECONOMICS TASKS

- Cost of Production of Current Unit
  - Energy Required for Stages of Production
  - Water Deionizing
  - Hydrogen Extraction from Water Hydrolysis
  - Nitrogen Extraction from Air
  - Ammonia Synthesis
  - Storage and Transportation
ADDITIONAL TASKS

- Consider Impact of Carbon Taxes on Ammonia
- Consider Economic Scale or Production
- Consider Effects of Improved Catalyst Performance
# NITROGEN FERTILIZER MARKET IN MINNESOTA

<table>
<thead>
<tr>
<th>Crop</th>
<th>Statewide Acres*</th>
<th>Avg. Yield/Ac (bu.)*</th>
<th>Statewide Yield (bu.)</th>
<th>Estimated N Required (lbs NH3)**</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corn</td>
<td>8,234,507</td>
<td>146.0</td>
<td>1,201,898,815</td>
<td>901,424,111</td>
</tr>
<tr>
<td>Barley</td>
<td>108,268</td>
<td>53.6</td>
<td>5,801,418</td>
<td>4,351,063</td>
</tr>
<tr>
<td>Wheat</td>
<td>1,718,565</td>
<td>48.1</td>
<td>82,554,282</td>
<td>61,915,712</td>
</tr>
</tbody>
</table>

Total NH3 Req. (lbs) 967,690,886
Total NH3 Req. (tons) 483,845
Retail Value ($800 / ton) $387,076,354

*Production Data from USDA NASS (2007)
**Based on a requirement of 0.75 lbs of NH3 per bushel of yield
Production Capacity of 27 U.S. Ammonia Plants

Source: U.S. EPA, Office of Air and Radiation, 2009

Tons

Ammonia Plants
SCALE-UP METHODOLOGY

- Start with known capital cost for a capacity
- Determine Scale Factor of Increase
- Raise to appropriate exponent (.75, .7, .67)
- Determine project cost per unit of capacity

Example: A 50 Million Gallon per year ethanol plant can be built for $2.25 per gallon of capacity. What will be the estimated cost of a 100 million gallon plant?

- $112.5 \text{MM} \times (2.0)^{.7} = $182,756,789 for plant
- Ans: $182,756.789 /100\text{MM} = $1.8275/ \text{gal.}
SCALE ECONOMIES

Source: http://pinterest.com/pin/55943220341431594/
Estimated Installed Capital Cost per Ton of Capacity for Ammonia Production Using Electrolyzed Water and Scale up Exponent of .75, Excluding Wind Turbines

Morris Facility

$98,714

$17,554

$9,871

$0

$20,000

$40,000

$60,000

$80,000

$100,000

$120,000

Tons of Annual Capacity

$17,554

$9,871

$0

26 263 2,628 26,280 262,800 500,000 1,000,000
Percent of Installed Capital Cost per Ton of Ammonia Capacity for Scale-up Multiples

- 0% - 10%
- 10% - 20%
- 20% - 30%
- 30% - 40%
- 40% - 50%
- 50% - 60%
- 60% - 70%
- 70% - 80%
- 80% - 90%
- 90% - 100%

Multiples of Expansion

- 1
- 10
- 100
- 1,000
- 10,000
- 19,026
- 38,052
## Ammonia Synthesis and Storage Pro forma

<table>
<thead>
<tr>
<th>Capital Cost/Ton of Ann. Cap.</th>
<th>$ 9,871.40</th>
<th>per Ton</th>
<th>$ 259,420</th>
</tr>
</thead>
<tbody>
<tr>
<td>Percent equity</td>
<td>0.60</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Percent debt</td>
<td>0.40</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Interest Rate on Debt</td>
<td>0.06</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### NH3 Production

- **Capacity Factor**: 1.0
- **Nameplate Cap.**: 26.28 Ton/yr
- **NH3 Price and Annual Revenue**: $ 700.00

### Operating Expenses

- **Electricity Purchase Price**
- **Water Treatment and Deionization**
- **Water Electrolyzed per hour**: 1.42 gal/hr.
- **Hydrogen Produced by Electrolyzer**: 1.19 lb./hr.
- **Nitrogen Gas Production**: 6.75 lb/hr
- **Ammonia Production**: 6.00 lb/hr
- **Electricity Purchased**: $ 0.071
- **Efficiency of NH3 Production**: 0.15%
- **Catalyst Replacement for Ammonia Skid**: 5 yr
- **Operator Labor**: $ 120,000
- **Maintenance Labor**: 0.050 % Cap Cost
- **Repairs to Equipment**: 0.050 % Cap Cost
- **Depreciation**: 20 Yr.
- **Interest**: 10 Yr.
- **Fees, Licenses, Insurance**: 0.01
- **Real Estate Taxes**: 0.005

### Production Cost of Anhydrous Ammonia for Facility

- **Total**: $ 185,774.01
- **Cost per Ton of Anhydrous Ammonia**: $ 7,069
- **Cost per lb. of N in product**: $ 4.31

### Net Margin for Facility

- **(167,378.01)**
### Ammonia Synthesis and Storage Pro forma

<table>
<thead>
<tr>
<th>Capital Cost/Ton of Ann. Cap.</th>
<th>$ 1,480.65 per Ton</th>
<th>26.28 T/yr</th>
<th>$ 38,911</th>
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<tbody>
<tr>
<td>Percent equity</td>
<td>0.60</td>
<td></td>
<td></td>
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<tr>
<td>NH3 Production</td>
<td>1.0</td>
<td>Capacity Factor</td>
<td>Nameplate Cap.</td>
</tr>
<tr>
<td>NH3 Price and Annual Revenue</td>
<td>Price per Ton $ 700.00</td>
<td>Price/ lb. N. $ 0.427</td>
<td>$ 18,396.00</td>
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<tr>
<td>Operating Expenses</td>
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<tr>
<td>Electricity Purchase Price</td>
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<tr>
<td>Water Treatment and Deionization</td>
<td></td>
<td>22.454 gal/hr.</td>
<td>85 l/hr</td>
</tr>
<tr>
<td>Water Electrolyzed per hour</td>
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<td>1.42 gal/hr.</td>
<td></td>
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<tr>
<td>Hydrogen Produced by Electrolyzer</td>
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<td>1.19 lb./ hr.</td>
<td>H2</td>
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<tr>
<td>Nitrogen Gas Production</td>
<td></td>
<td>6.75 lb/ hr</td>
<td>N2</td>
</tr>
<tr>
<td>Ammonia Production</td>
<td></td>
<td>6.00 lb/hr</td>
<td>NH3</td>
</tr>
<tr>
<td>Electricity Purchased</td>
<td>$ 0.071</td>
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<tr>
<td>Efficiency of NH3 Production</td>
<td>0.15 %</td>
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<tr>
<td>Catalyst Replacement for Ammonia Skid</td>
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<td>5 yr</td>
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<td>Maintenance Labor</td>
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<td>0.050 % Cap Cost</td>
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<td>Depreciation</td>
<td>20 Yr.</td>
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<td>Interest</td>
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<td>$ 933.88</td>
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<td>Fees, Licenses, Insurance</td>
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<td>$ 389.11</td>
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<td>Real Estate Taxes</td>
<td>0.005</td>
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<td>$ 194.56</td>
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<tr>
<td>Total Production Cost of Anhydrous Ammonia for Facility</td>
<td>$ 144,097.82</td>
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<td></td>
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<tr>
<td>Cost per Ton of Anhydrous Ammonia</td>
<td>$ 5,483</td>
<td></td>
<td></td>
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<tr>
<td>Cost per lb. of N in product</td>
<td>$ 3.34</td>
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<td></td>
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<tr>
<td>Net Margin for Facility</td>
<td>(125,701.82)</td>
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</table>
Carbon Taxes Applied Per Ton of Anhydrous Ammonia Based on Alternative Carbon Permit Fees Based on GHG Emissions of 1.2 Ton CO2e per Ton
Production of Low GHG Ammonia at West Central Research and Outreach Center from Wind, Water and Air
Conclusions

- Well-documented studies confirm that dry-grind ethanol continues to reduce energy, water, and GHG in production. (S. Mueller, A. Liska)
- EPA is documenting additional pathways for advanced biofuels
- Use of biomass to produce CHP at ethanol plants has been documented to reduce GHG of ethanol, but natural gas is very cheap.
- Oil Extraction practices at ethanol plants improve energy yield per bushel and per acre and lower the GHG of all fuels produced.
- Anhydrous ammonia may be produced from renewable sources such as wind and biomass and will reduce GHG further.
- As more heavy crude oils are utilized, the GHG emissions of petroleum fuels will rise.
- Low rates of CO2 taxes on fuels offer an economic incentive for production of biofuels because of the GHG emissions these fuels can displace from fossil fuels left unmined and unburned.
FLOYD NEEDS TO COME HOME FROM IOWA
Thanks!

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- (612) 625-6715

http://www.apec.umn.edu/staff/dtiffany/