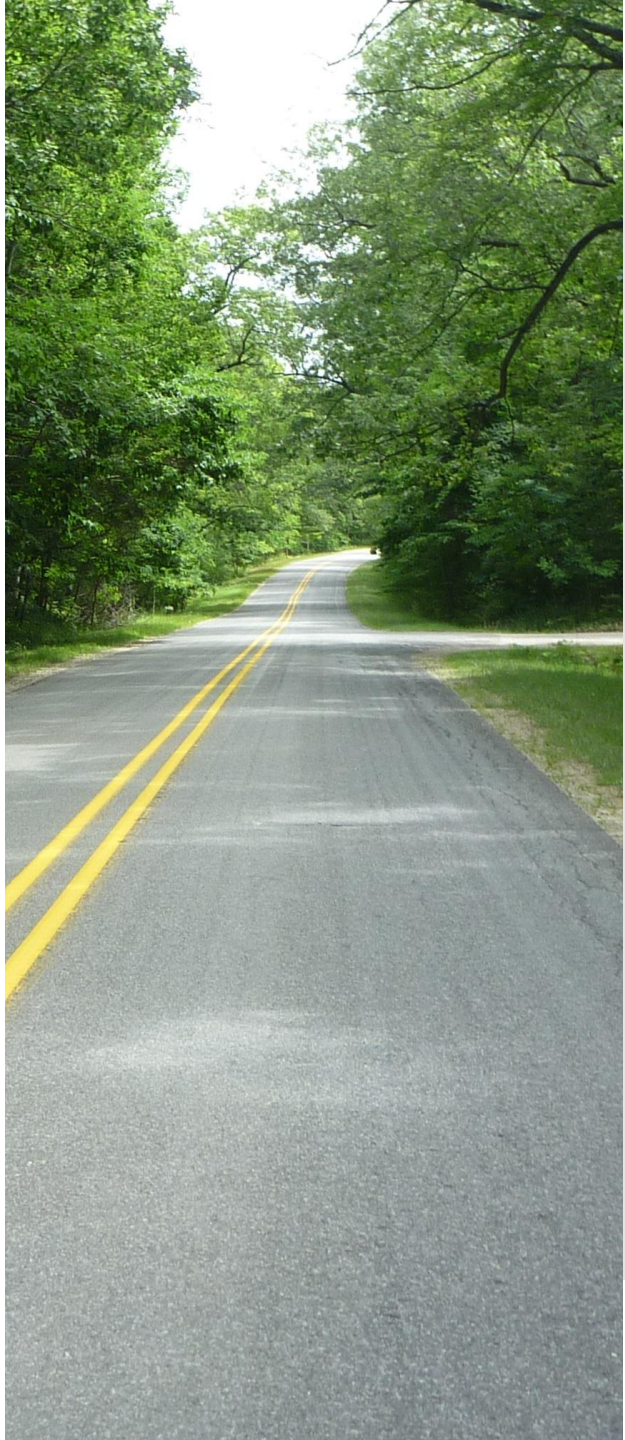
Capturing the Value of Low Carbon Intensity Practices in Low Carbon Fuel Markets

Ron Alverson:

Corn Producer, Board of Directors Dakota Ethanol



Topics

- Low Carbon Fuel Markets
- Fuel Life Cycle Carbon Intensity
  - Calculation
  - Importance
- Carbon Intensity
  - Various Fuels
  - Midwest Corn Ethanol
- Low Carbon Pathways
- Opportunities

Low Carbon Fuel Markets

- U.S. EISA-RFS2 - 2007
- California LCFS – 2007
- British Columbia – 2008
- European Union – 2008
- United Kingdom
- Under consideration:
  - Oregon
  - Washington State
  - 11 Northeast and Mid-Atlantic States

EISA-RFS2

- U.S. EPA evaluates CI of biofuels for GHG reductions
- Biofuels qualify for several categories
  - D3 thru D6
  - RINs signify market value
- New ethanol production must meet GHG reduction standards to receive RINs

California Low Carbon Fuel Standard (LCFS)

Administered by the California Air Resource Board (CARB)

Goal to reduce CI by 10% by 2020.

Established a Carbon Trading Market

*incentivizes reductions from fuel producers

LCFS Carbon Credits have traded for $20 to $85 per metric ton CO_2 over the past 12 months.

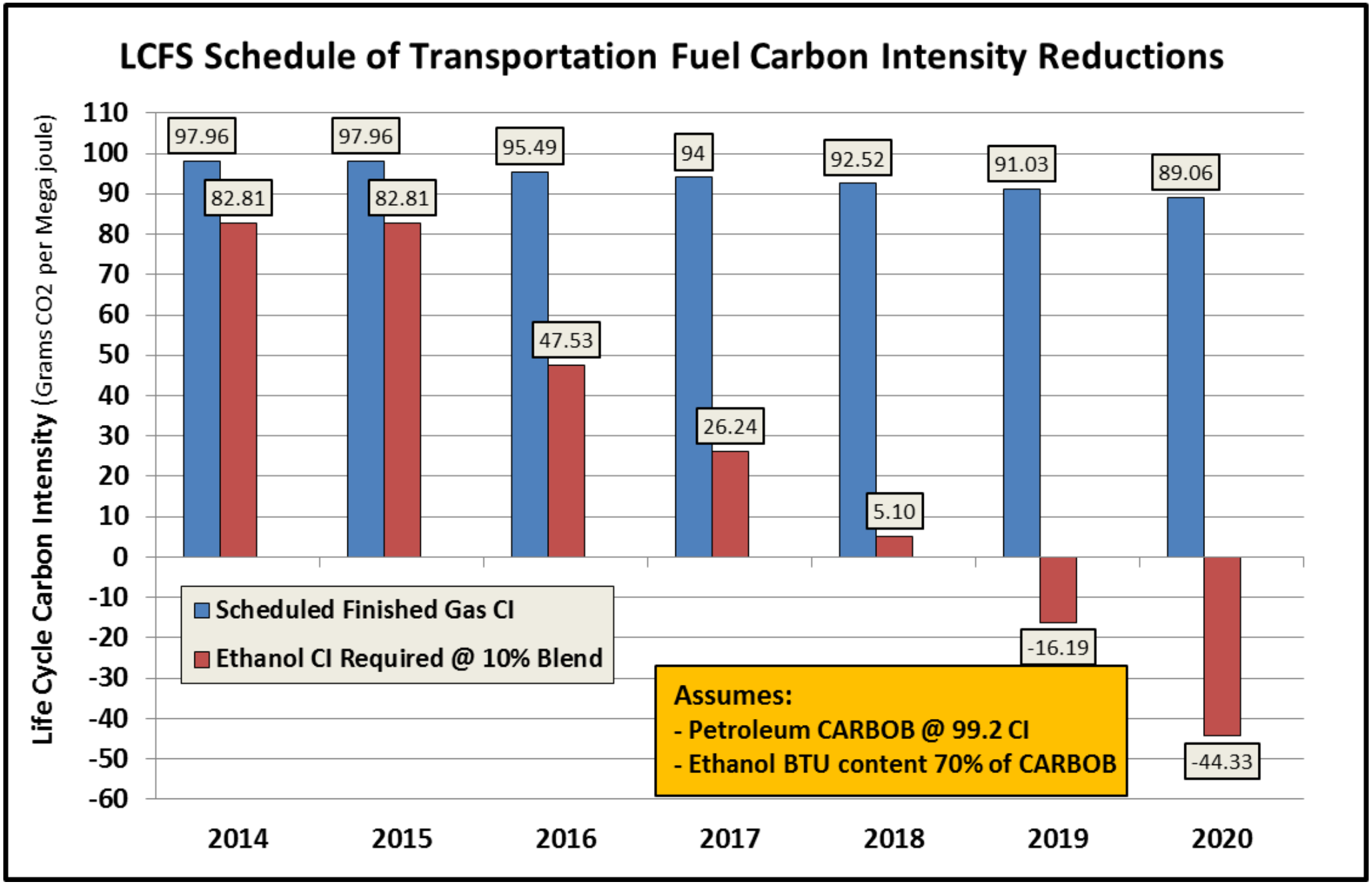
LIFE **C**YCLE **A**NALYSIS – "**C**ARBON **I**NTENSITY"

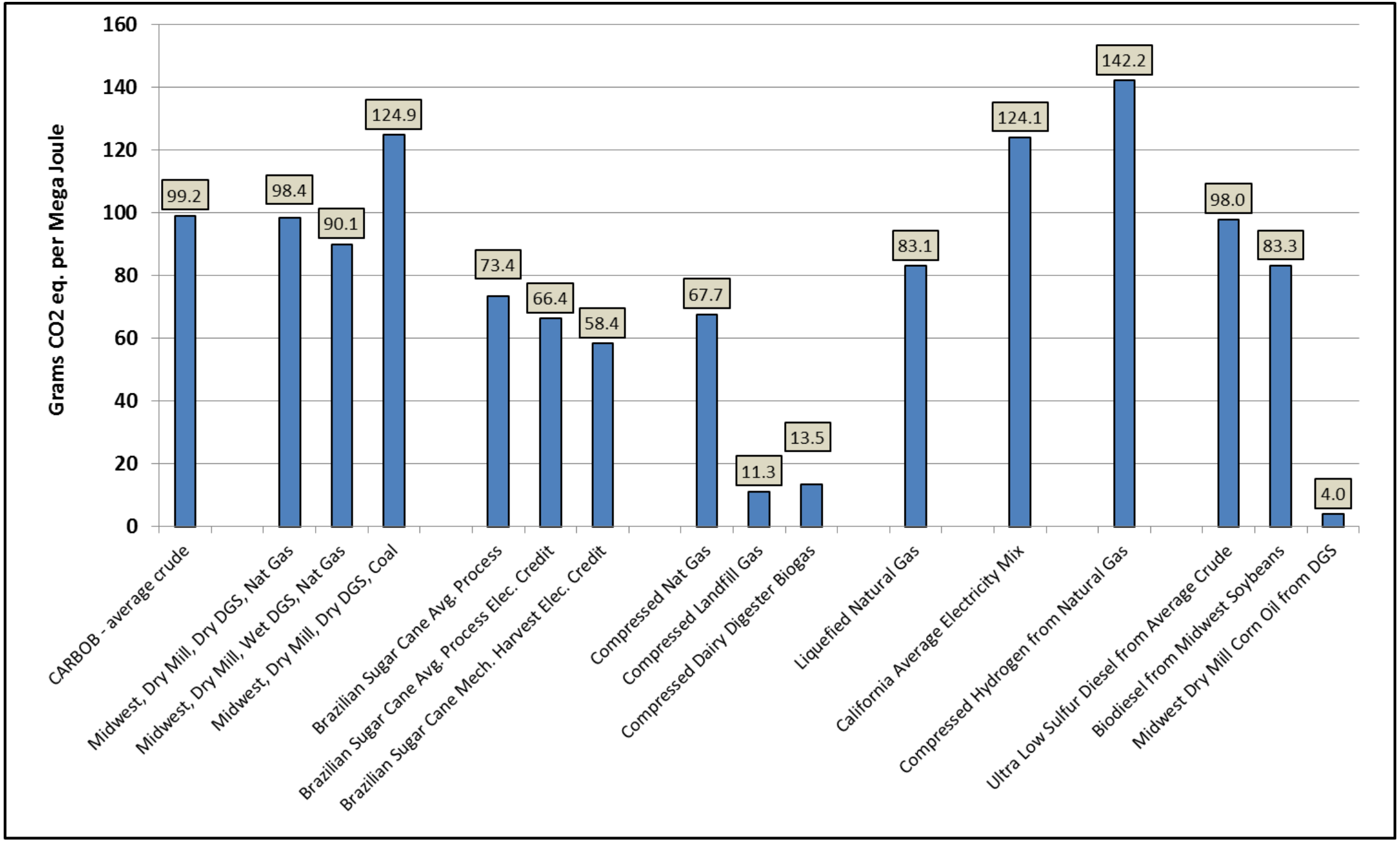
GREET model (**G**reenhouse gasses, **R**egulated **E**missions and **E**nergy use in **T**ransportation)

- GREET developed at Argonne National Energy Lab by a team led by Dr. Michael Wang
- calculates GHG emissions from all energy used in a fuel's production life cycle
- reported in grams CO_2 equivalent emissions per mega joule of energy produced
  - a.k.a. the "**Carbon Intensity**" of a fuel

Importance of Life Cycle Carbon Intensity Analysis

- Growing Low Carbon Fuel Markets present opportunities:
  - **Economic** – rewards Low Carbon Fuel Producers.
  - **Political** – Old data and ILUC in calculations negatively impacted political support after 2007, now opportunity to make positive impact
- New data = significant potential for CI reductions, renewed support
- The trend is our friend – Fossil fuel carbon intensity is going up, and biofuel carbon intensity is going down

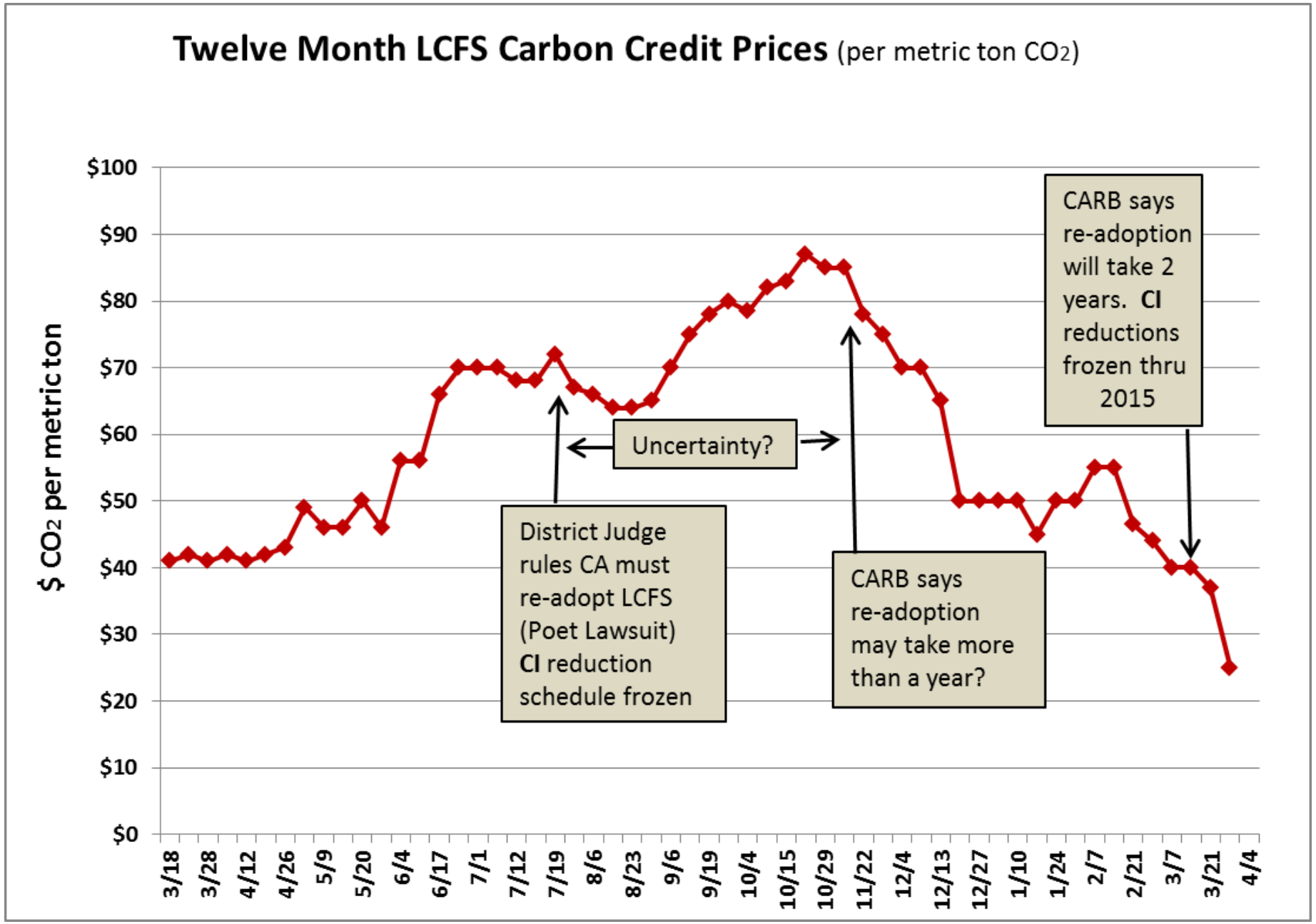

LCFS Schedule of Transportation Fuel Carbon Intensity Reductions
Life Cycle Carbon Intensity (Grams CO2 per Mega joule)
110
100
90
80
70
60
50
40
30
20
10
0
-10
-20
-30
-40
-50
-60
97.96
82.81
97.96
82.81
95.49
47.53
94
26.24
92.52
5.10
91.03
-16.19
89.06
-44.33
2014
2015
2016
2017
2018
2019
2020
Scheduled Finished Gas CI
Ethanol CI Required @ 10% Blend
Assumes:
- Petroleum CARBOB @ 99.2 CI
- Ethanol BTU content 70% of CARBOB


Grams CO2 eq. per Mega Joule
160
140
120
100
80
60
40
20
0
99.2
98.4
90.1
124.9
73.4
66.4
58.4
67.7
11.3
13.5
83.1
124.1
142.2
98.0
83.3
4.0
CARBOB - average crude
Midwest, Dry Mill, Dry DGS, Nat Gas
Midwest, Dry Mill, Wet DGS, Nat Gas
Midwest, Dry Mill, Dry DGS, Coal
Brazilian Sugar Cane Avg. Process
Brazilian Sugar Cane Avg. Process Elec. Credit
Brazilian Sugar Cane Mech. Harvest Elec. Credit
Compressed Nat Gas
Compressed Landfill Gas
Compressed Dairy Digester Biogas
Liquefied Natural Gas
California Average Electricity Mix
Compressed Hydrogen from Natural Gas
Ultra Low Sulfur Diesel from Average Crude
Biodiesel from Midwest Soybeans
Midwest Dry Mill Corn Oil from DGS

Low Carbon Fuels Used in California for LCFS Compliance

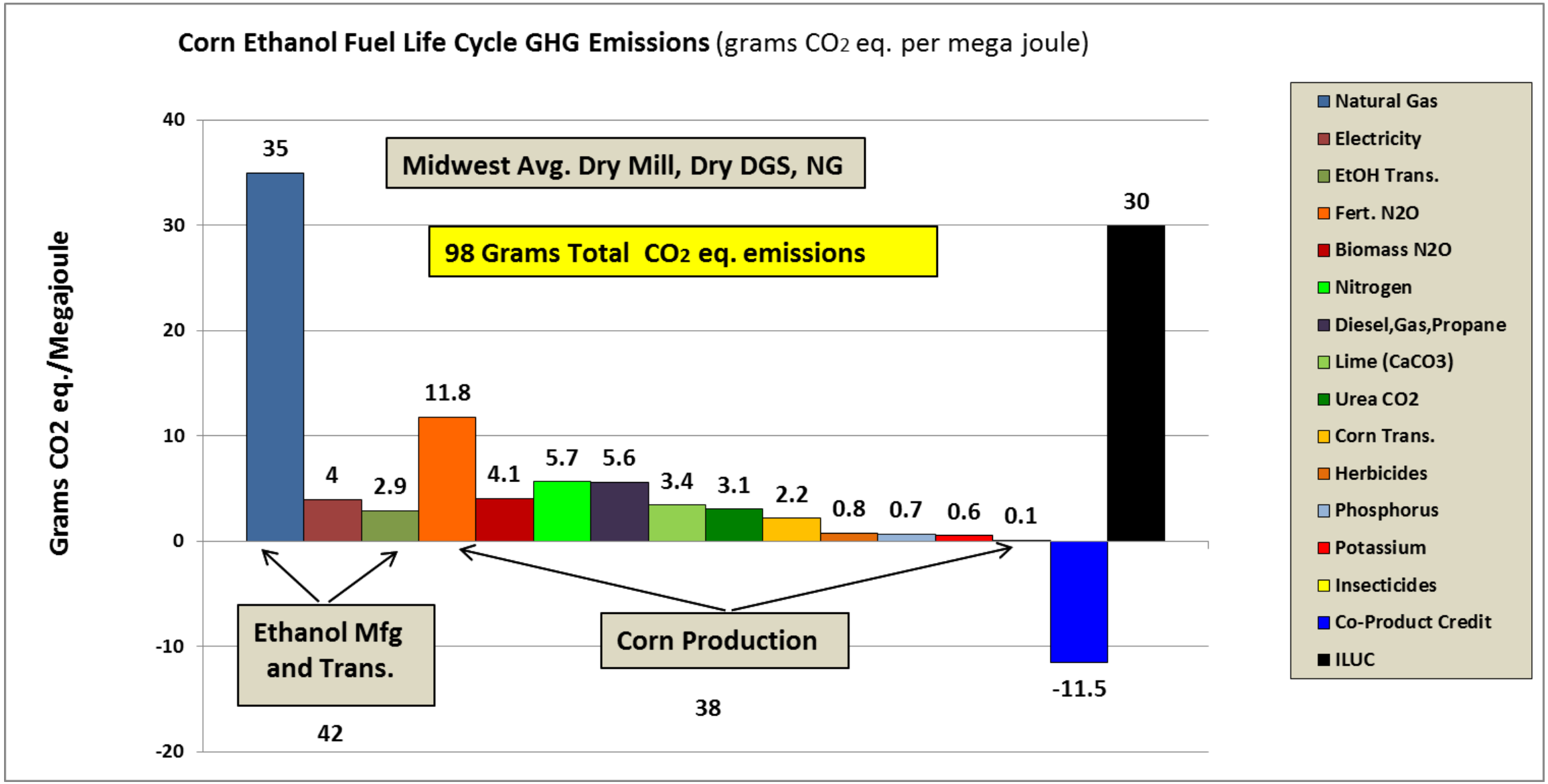
- 2013 Statistics

- Ethanol (Corn and Sugar Cane) - 62%
- Biodiesel - 27%
- Natural Gas - 9%


Twelve Month LCFS Carbon Credit Prices (per metric ton CO2)
$ CO2 per metric ton
$100
$90
$80
$70
$60
$50
$40
$30
$20
$10
$0
3/18
3/28
4/12
4/26
5/9
5/20
6/4
6/17
7/1
7/12
7/19
8/6
8/23
9/6
9/19
10/4
10/15
10/29
11/22
12/4
12/13
12/27
1/10
1/24
2/7
2/21
3/7
3/21
4/4
Uncertainty?
District Judge rules CA must re-adopt LCFS (Poet Lawsuit) CI reduction schedule frozen
CARB says re-adoption may take more than a year?
CARB says re-adoption will take 2 years. CI reductions frozen thru 2015

Economic Incentives for CI Reductions

- LCFS credits averaged about $50 per metric ton carbon dioxide in 2013.
- @ $50 per tonne, each gram CI reduction below 90 means approximately .4 cent per gallon premium in California
- Each 1,000 Btu reduction in NG energy use during ethanol manufacturing results in a 1 gram CI reduction
- Ethanol with an 80 CI that can be shipped to California could get a 4 cpg premium


Corn Ethanol Fuel Life Cycle GHG Emissions (grams CO2 eq. per mega joule)
Grams CO2 eq./Megajoule
40
30
20
10
0
-10
-20
Midwest Avg. Dry Mill, Dry DGS, NG
98 Grams Total CO2 eq. emissions
35
4
2.9
11.8
4.1
5.7
5.6
3.4
3.1
2.2
0.8
0.7
0.6
0.1
-11.5
30
Ethanol Mfg and Trans.
42
Corn Production
38
Natural Gas
Electricity
EtOH Trans.
Fert. N2O
Biomass N2O
Nitrogen
Diesel,Gas,Propane
Lime (CaCO3)
Urea CO2
Corn Trans.
Herbicides
Phosphorus
Potassium
Insecticides
Co-Product Credit
ILUC

CA-GREET 1.8b Assumptions (Midwest avg. Dry Mill, Dry DGS, NG)

- Ethanol Manufacturing Energy
  - Thermal Energy 32,300 Btu per gallon
  - Electrical Energy 1.08 kWh per gallon
  - EtOH Conversion 2.72 gallons per bushel

CA-GREET Assumptions Continued…

- **Corn Production Energy**

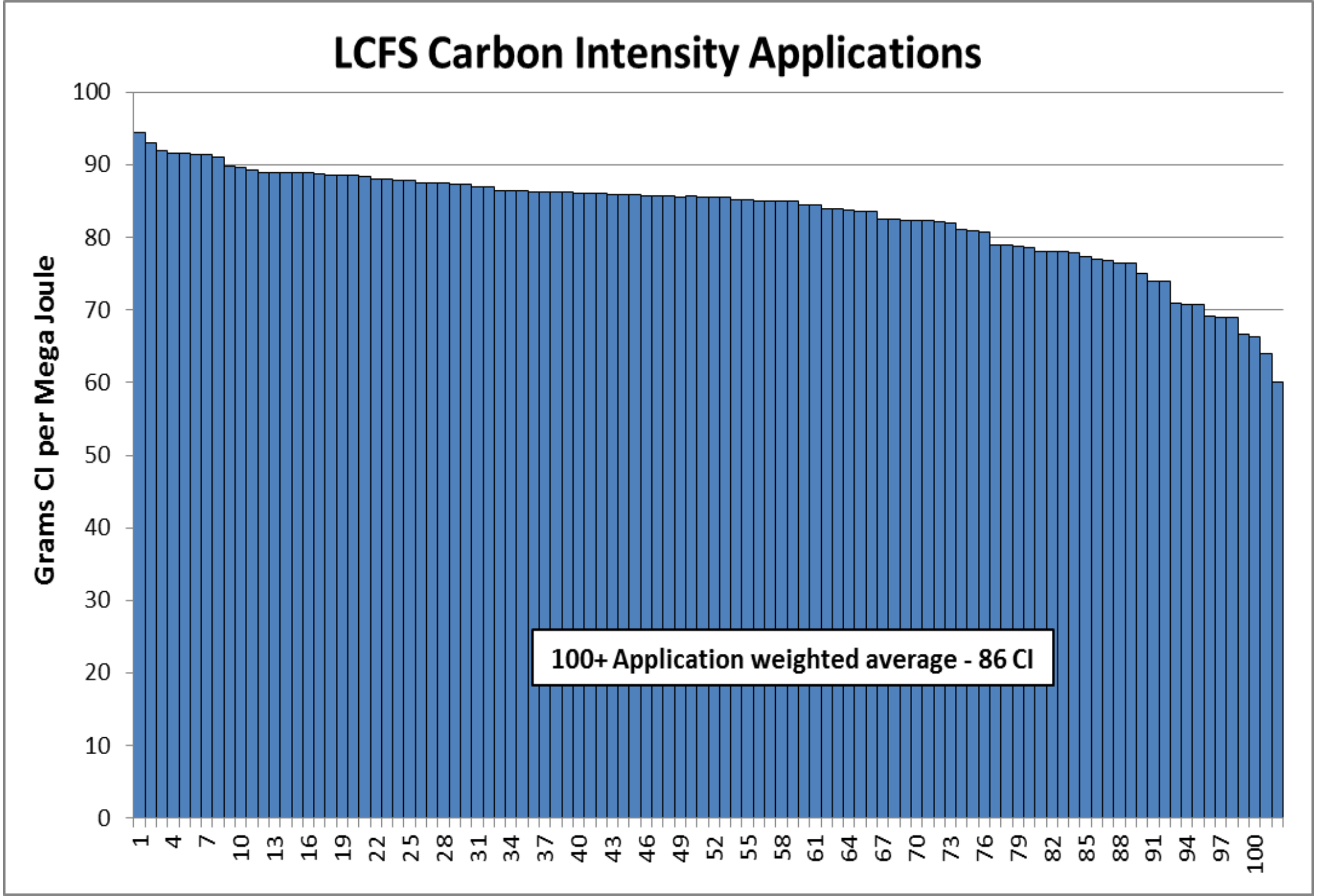
Nitrogen	420 Grams/Bu (146 lbs/acre) @ 158 bu
P_2O_5	149 Grams/Bu (52 lbs/acre)
K_2O	174 Grams/Bu (61 lbs/acre)
Lime ($CaCO_3$)	1202 Grams/Bu (418 lbs/acre)
Diesel/Gas/Propane/Nat Gas	12,635 Btus/Bu
Herbicides	8.1 Grams/Bu (2.82 lbs a.i./acre)
Insecticides	.68 Grams/Bu (.23 lbs a.i./acre)

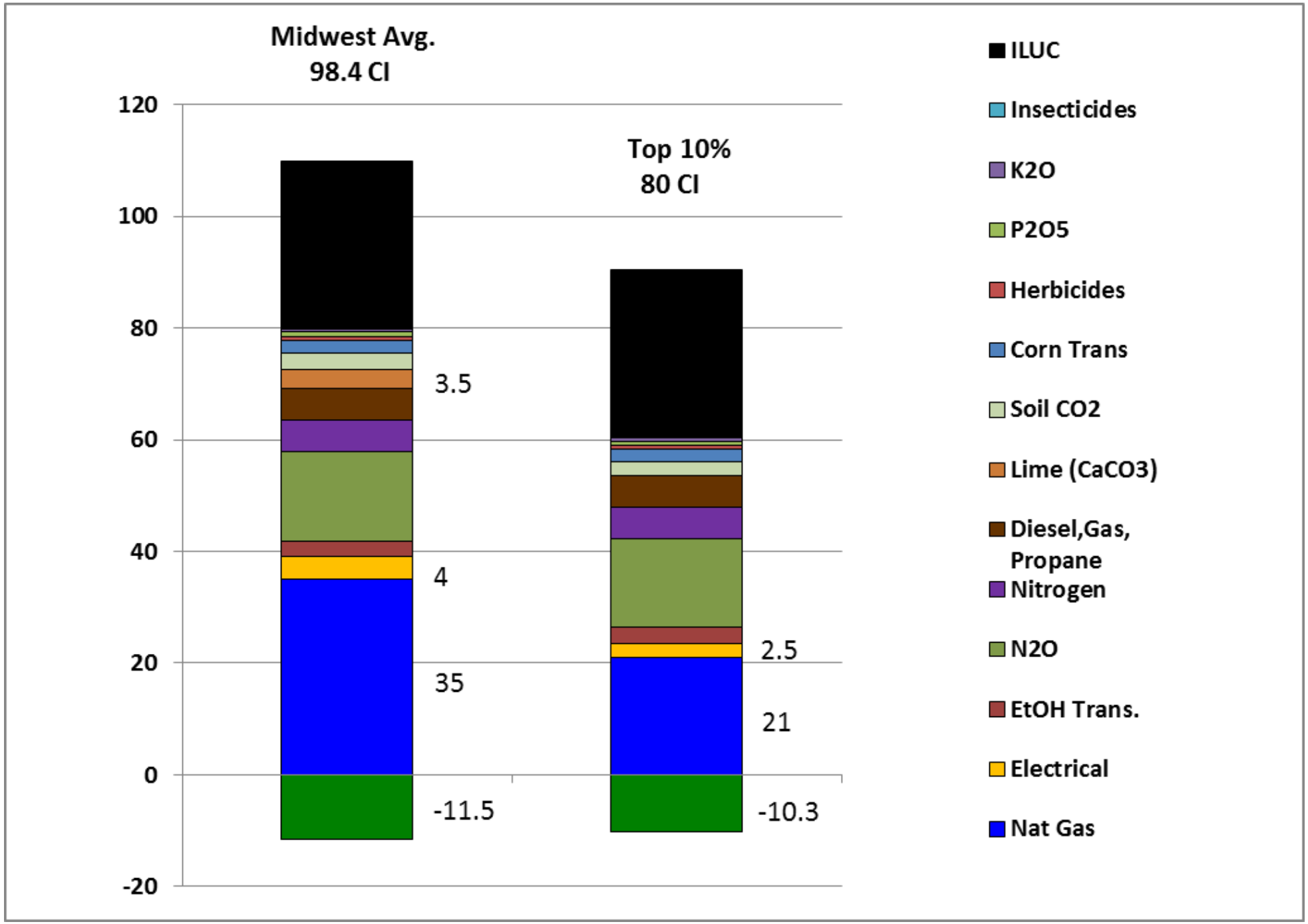
CA-GREET Assumptions Continued…

- **Soil Emissions from Fertilizer and Lime**
  - N_2O: 1.325% of applied Nitrogen is converted to N_2O
  - CO_2 emissions from $CaCO_3$ and Urea fertilizer decay
- **Co-Product Credit (CARB uses "Displacement" Method)**
  - Assumes 1 lb. DGS displaces 1 lb. corn
    - So, the emissions generated from the production of 1 lb. corn is credited back to lifecycle

LCFS Low Carbon Pathway Applications

- About 60 corn/sorghum ethanol plants have made applications for over 100 new low CI pathways
  - Average CI: 86
  - Low CI: 60
  - 25 plants below 80
  - To date, almost all applications are for reductions in thermal and electrical energy use for ethanol manufacturing
  - Three EtOH companies have received reductions in CI for no lime, herbicides, and natural gas use to produce grain sorghum


LCFS Carbon Intensity Applications
Grams CI per Mega Joule
100
90
80
70
60
50
40
30
20
10
0
1
4
7
10
13
16
19
22
25
28
31
34
37
40
43
46
49
52
55
58
61
64
67
70
73
76
79
82
85
88
91
94
97
100
100+ Application weighted average - 86 CI

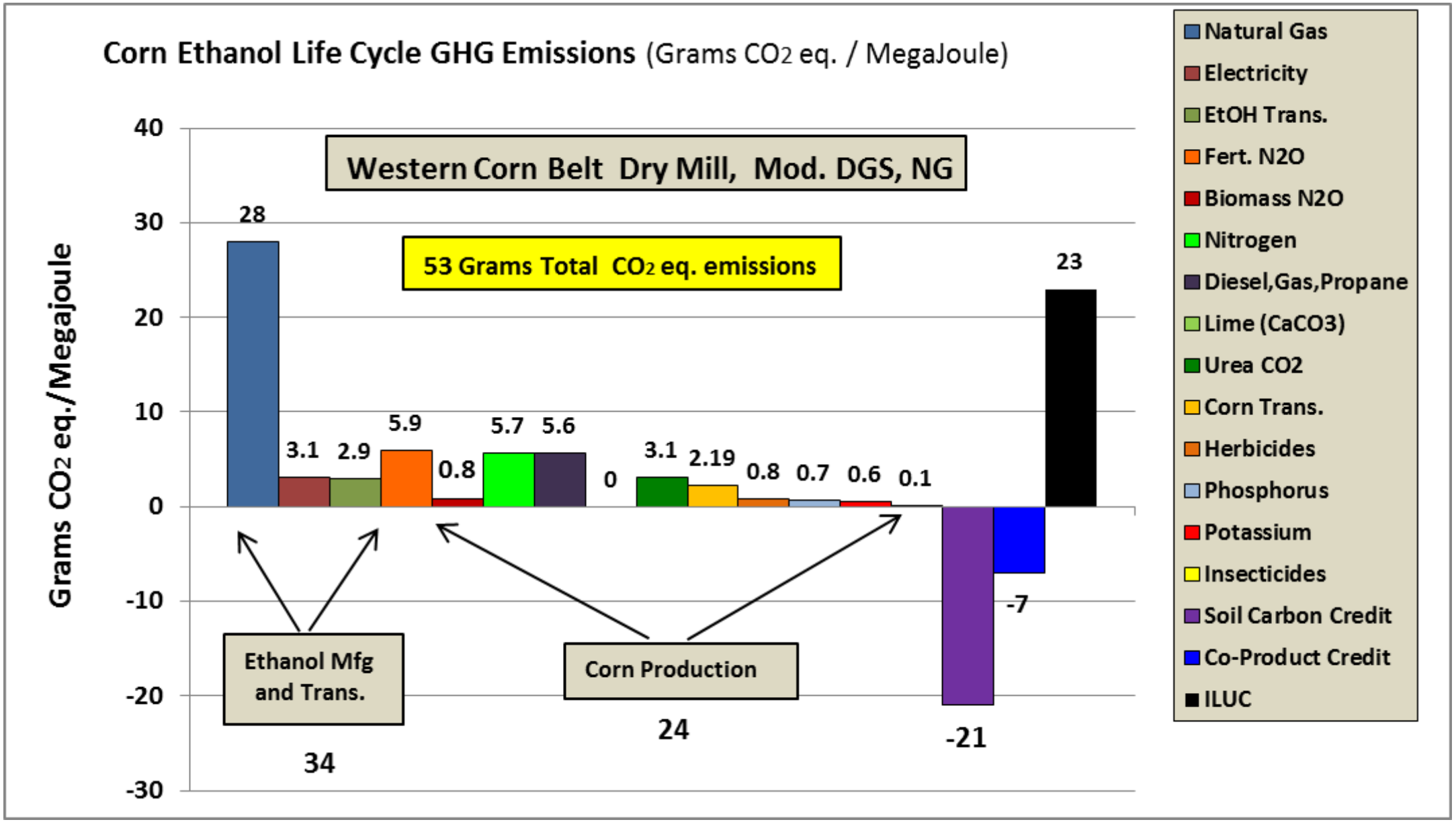

Midwest Avg.
98.4 CI
Top 10%
80 CI
120
100
80
60
40
20
0
-20
3.5
4
35
-11.5
2.5
21
-10.3
ILUC
Insecticides
K2O
P2O5
Herbicides
Corn Trans
Soil CO2
Lime (CaCO3)
Diesel,Gas, Propane
Nitrogen
N2O
EtOH Trans.
Electrical
Nat Gas

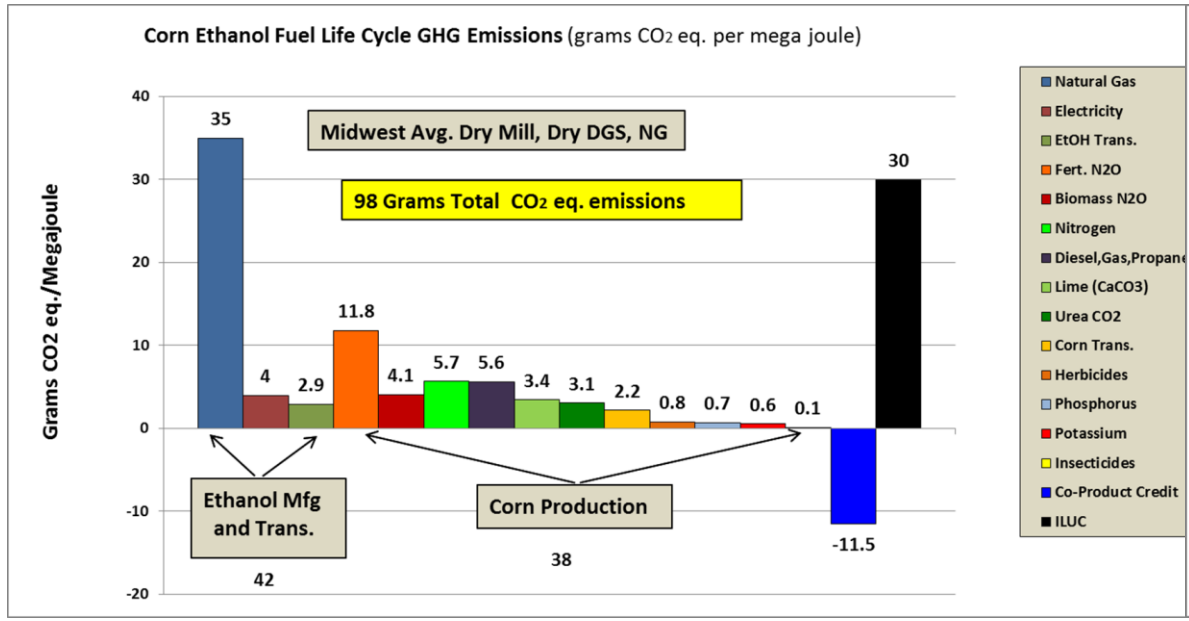
CARB LCFS Sustainability Workgroup

- Goal – Incentivize ethanol feedstock producers to reduce energy use/green house gas emissions through the LCFS pathway application process
- CARB is currently developing verification protocols

Western Corn Belt Dry Mill potential for CI reductions

- Less Nat Gas & Elec. Consumption – Energy Efficiency & Less DGS Drying.
- Reduce N2O Emissions from N in Fertilizer & Biomass with best management practices
- Little or no Lime applications for Corn Production
- Soil Carbon Sequestration Credit for Conservation Tillage Corn Production
- ILUC is reduced (March 11 CARB Proposal)


Corn Ethanol Life Cycle GHG Emissions (Grams CO2 eq. / MegaJoule)
Western Corn Belt Dry Mill, Mod. DGS, NG
53 Grams Total CO2 eq. emissions
Grams CO2 eq./Megajoule
40
30
20
10
0
-10
-20
-30
28
3.1
2.9
5.9
0.8
5.7
5.6
0
3.1
2.19
0.8
0.7
0.6
0.1
-7
23
Ethanol Mfg and Trans.
34
Corn Production
24
-21
Natural Gas
Electricity
EtOH Trans.
Fert. N2O
Biomass N2O
Nitrogen
Diesel,Gas,Propane
Lime (CaCO3)
Urea CO2
Corn Trans.
Herbicides
Phosphorus
Potassium
Insecticides
Soil Carbon Credit
Co-Product Credit
ILUC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Grams CO2 eq./Megajoule
Midwest Avg. Dry Mill, Dry DGS, NG
98 Grams Total CO2 eq. emissions
35
4
2.9
11.8
4.1
5.7
5.6
3.4
3.1
2.2
0.8
0.7
0.6
0.1
-11.5
30
Ethanol Mfg and Trans.
42
Corn Production
38
Natural Gas
Electricity
EtOH Trans.
Fert. N2O
Biomass N2O
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Urea CO2
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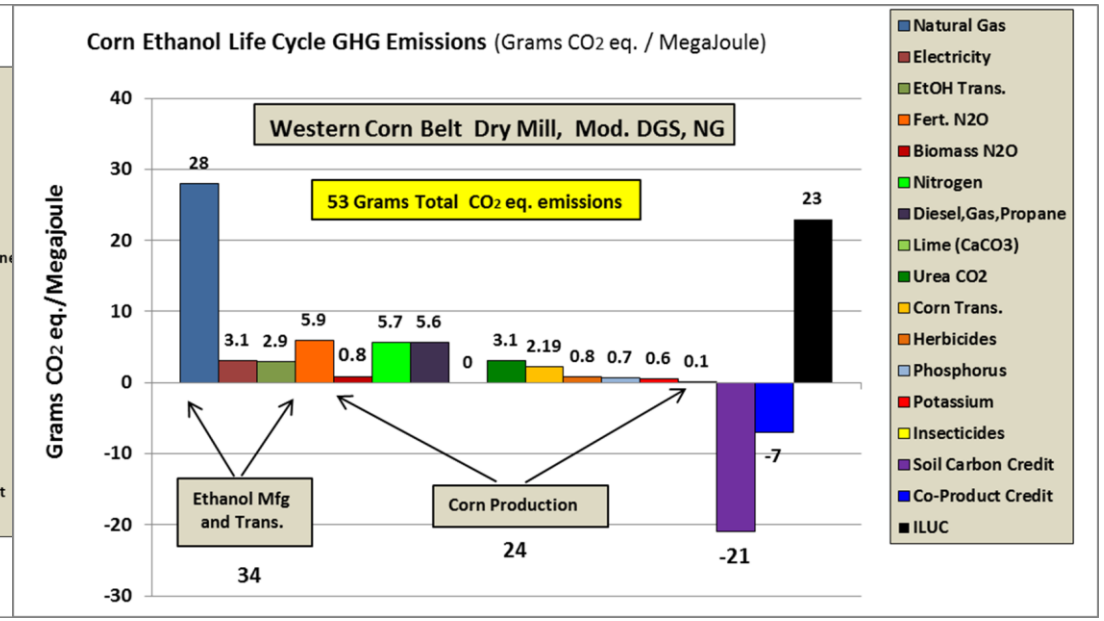
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2.19
0.8
0.7
0.6
0.1
-21
-7
23
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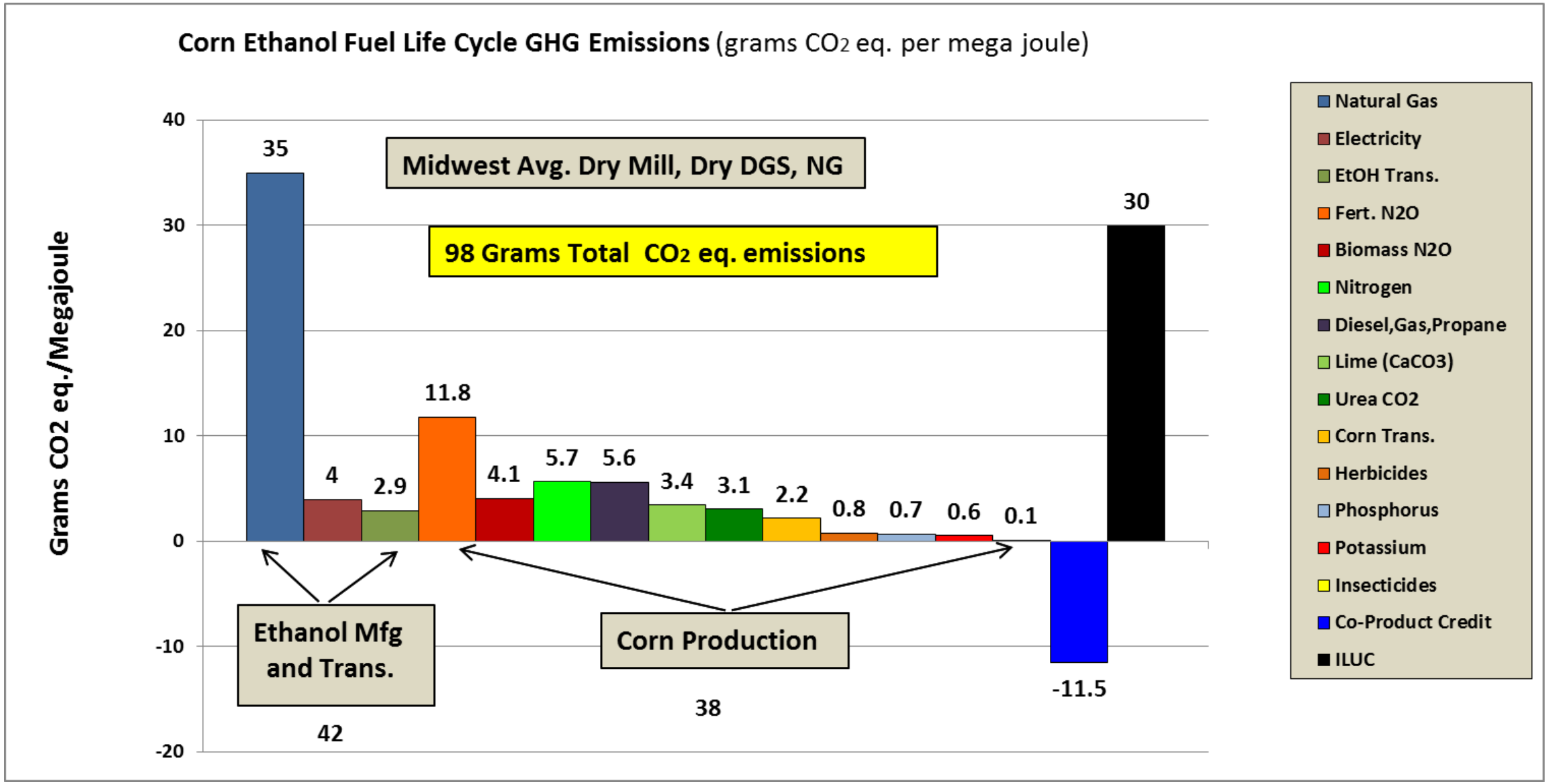
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30
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10
0
-10
-20
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98 Grams Total CO2 eq. emissions
35
4
2.9
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Potassium
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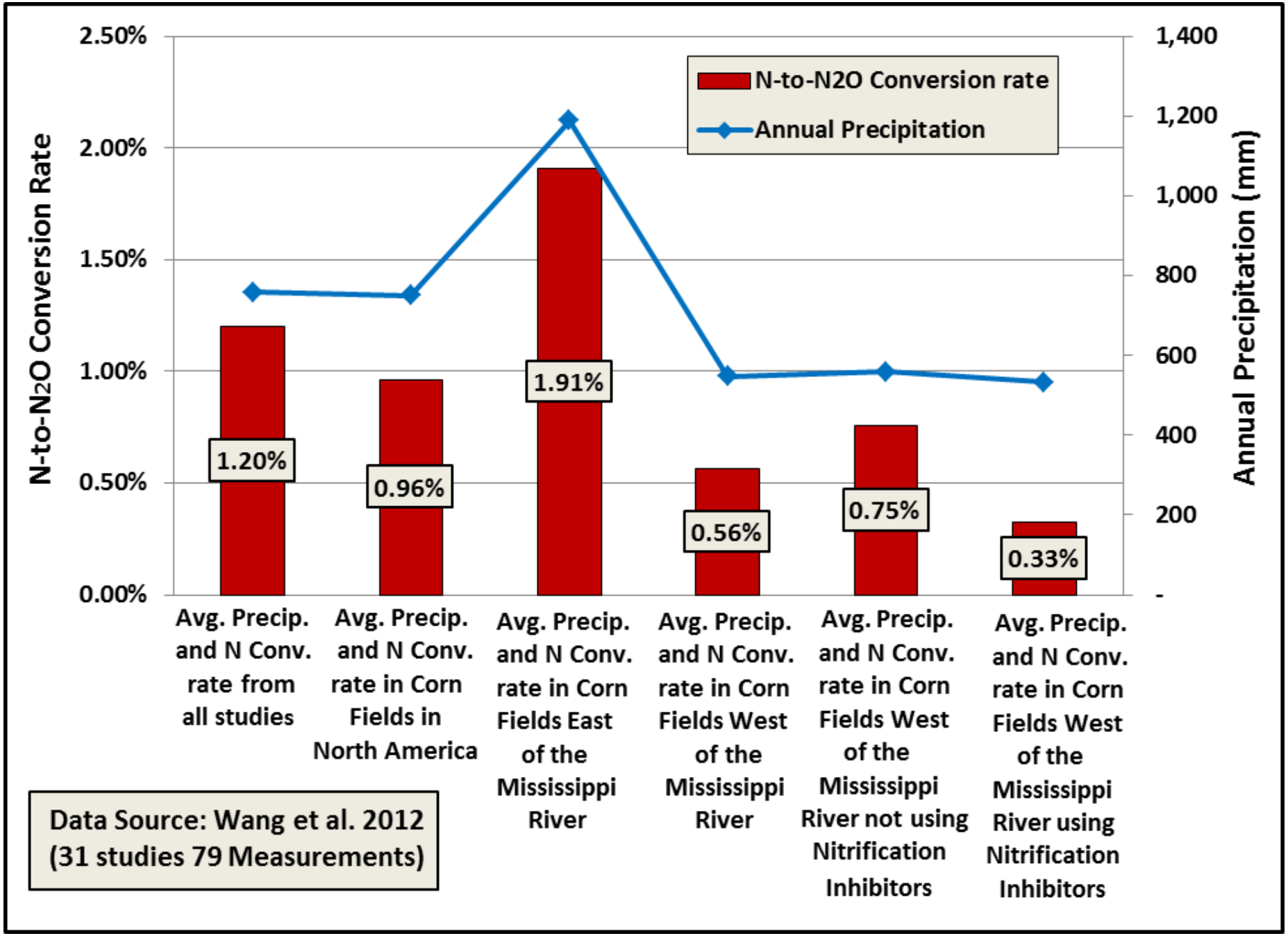
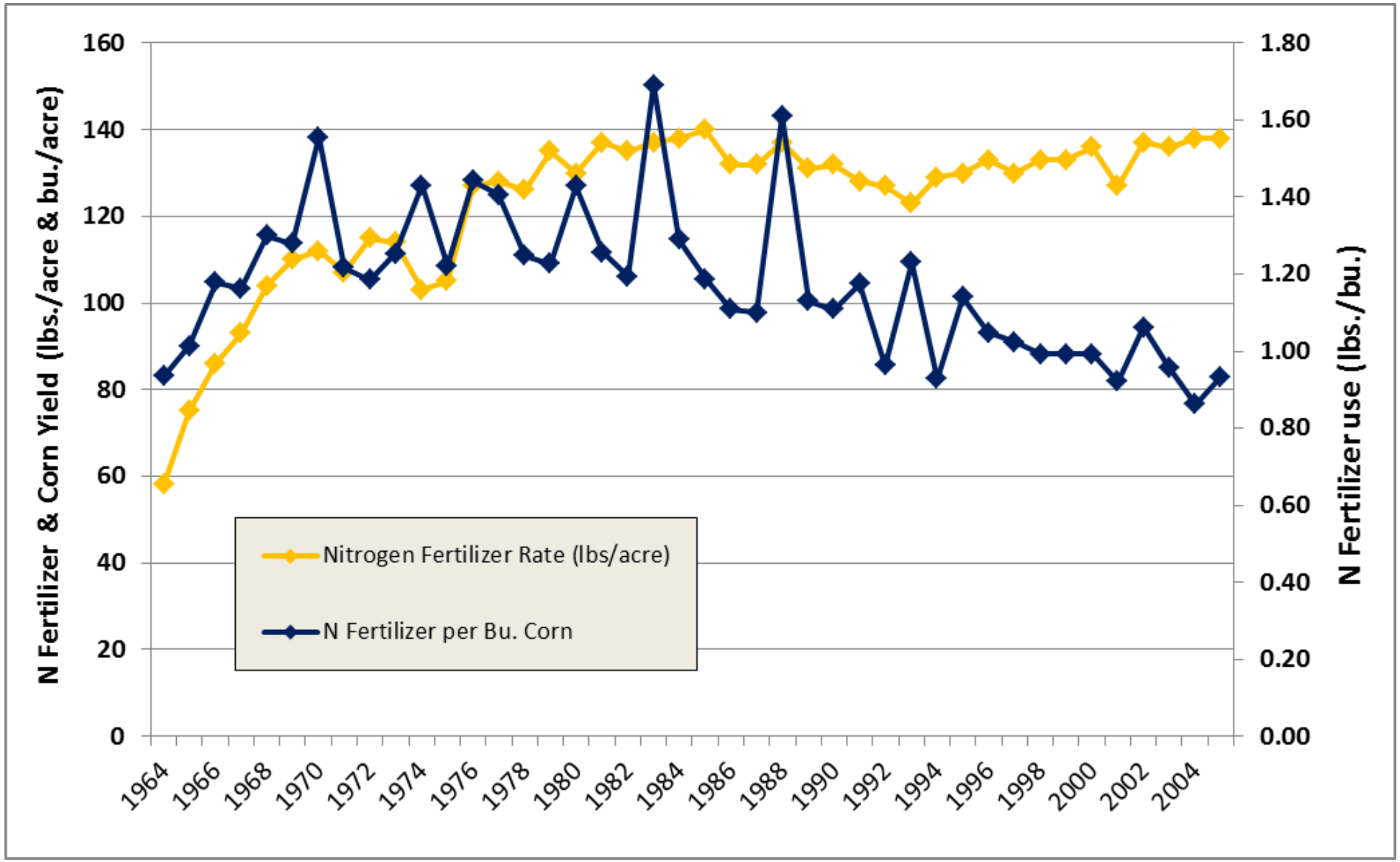
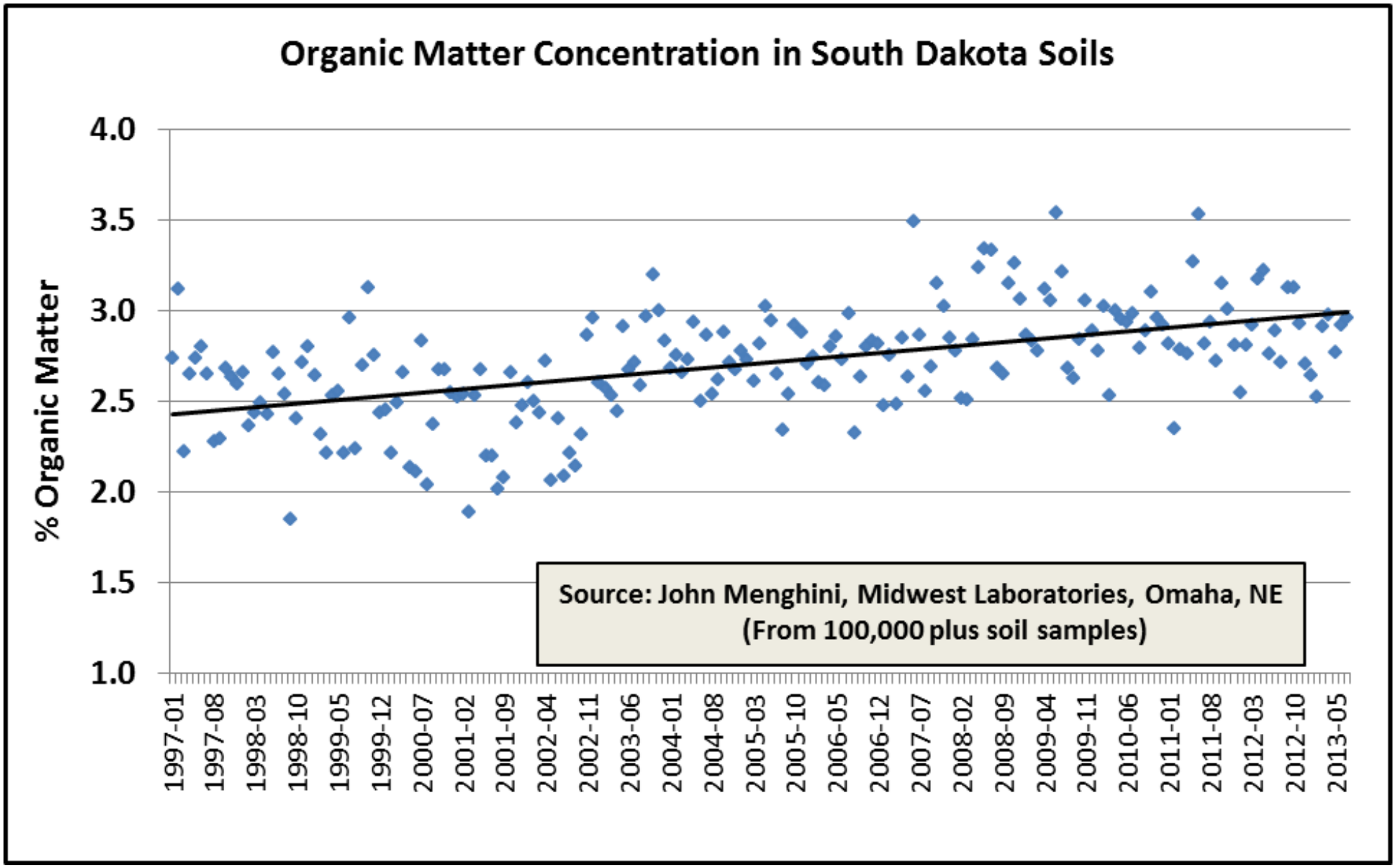
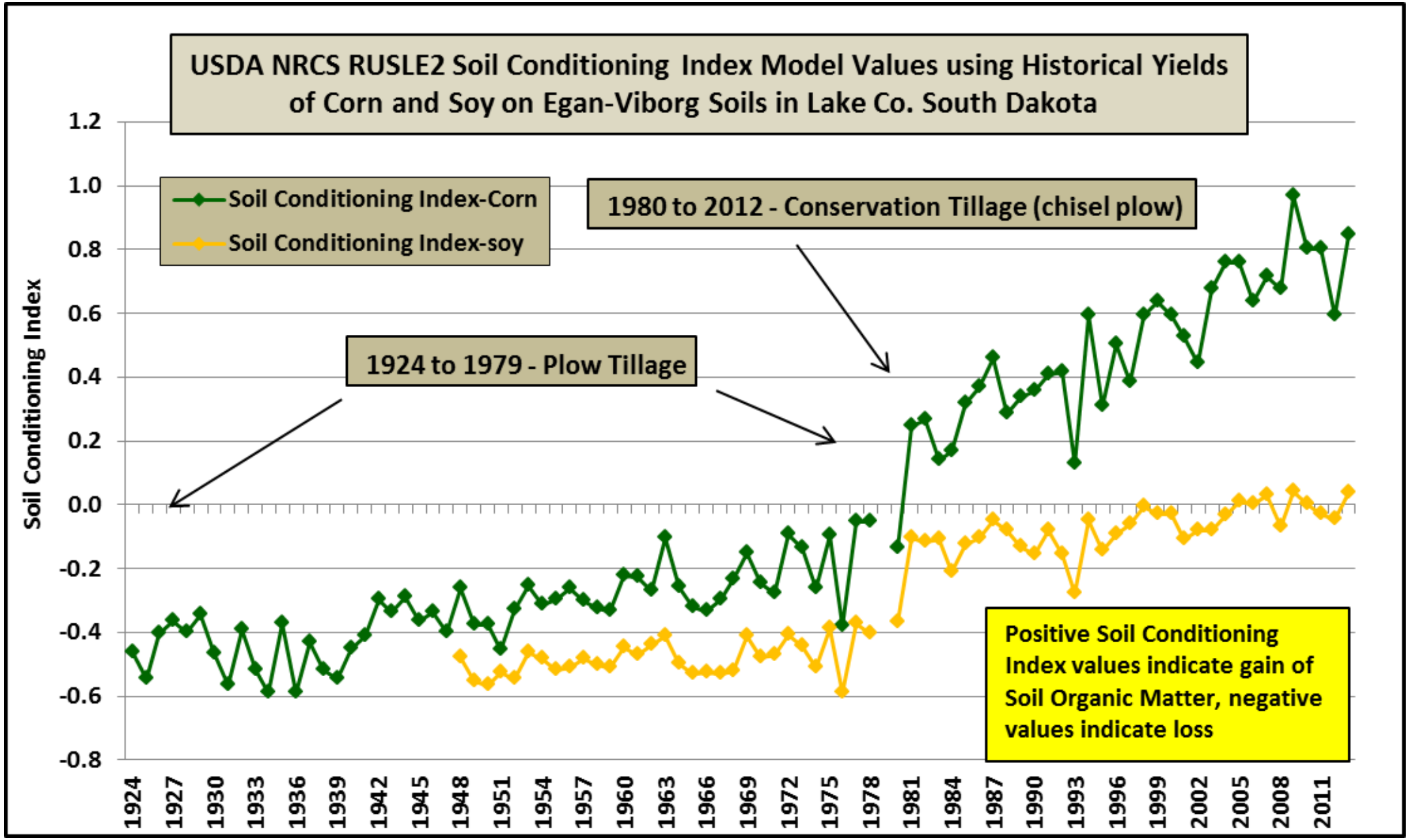
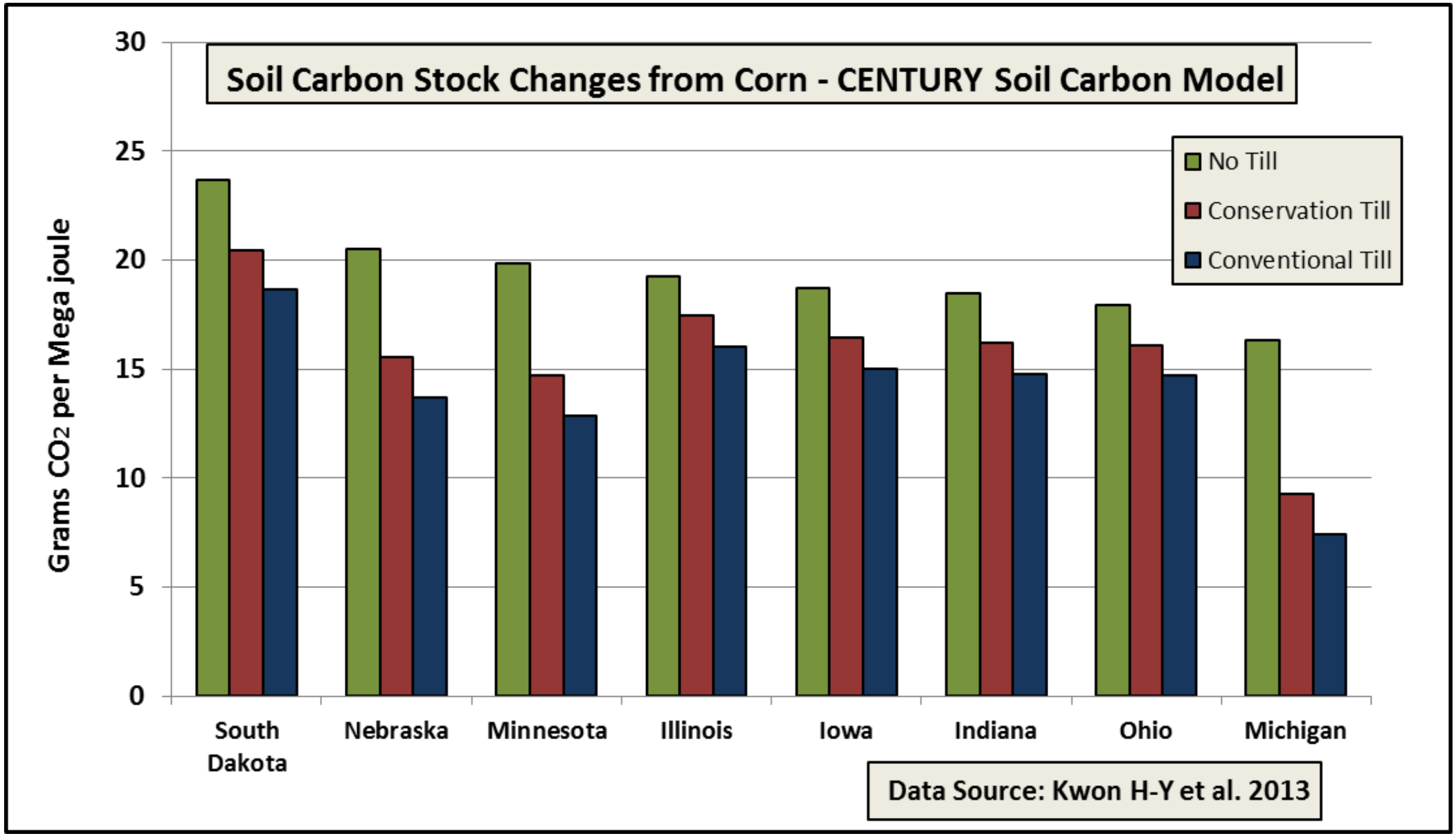

N-to-N2O Conversion rate
Annual Precipitation
N-to-N2O Conversion Rate
Annual Precipitation (mm)
2.50%
2.00%
1.50%
1.00%
0.50%
0.00%
1,400
1,200
1,000
800
600
400
200
-
1.20%
0.96%
1.91%
0.56%
0.75%
0.33%
Avg. Precip. and N Conv. rate from all studies
Avg. Precip. and N Conv. rate in Corn Fields in North America
Avg. Precip. and N Conv. rate in Corn Fields East of the Mississippi River
Avg. Precip. and N Conv. rate in Corn Fields West of the Mississippi River
Avg. Precip. and N Conv. rate in Corn Fields West of the Mississippi River not using Nitrification Inhibitors
Avg. Precip. and N Conv. rate in Corn Fields West of the Mississippi River using Nitrification Inhibitors
Data Source: Wang et al. 2012
(31 studies 79 Measurements)


N Fertilizer & Corn Yield (lbs./acre & bu./acre)
N Fertilizer use (lbs./bu.)
160
140
120
100
80
60
40
20
0
1.80
1.60
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
1964
1966
1968
1970
1972
1974
1976
1978
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004
Nitrogen Fertilizer Rate (lbs/acre)
N Fertilizer per Bu. Corn


Organic Matter Concentration in South Dakota Soils
% Organic Matter
4.0
3.5
3.0
2.5
2.0
1.5
1.0
1997-01
1997-08
1998-03
1998-10
1999-05
1999-12
2000-07
2001-02
2001-09
2002-04
2002-11
2003-06
2004-01
2004-08
2005-03
2005-10
2006-05
2006-12
2007-07
2008-02
2008-09
2009-04
2009-11
2010-06
2011-01
2011-08
2012-03
2012-10
2013-05
Source: John Menghini, Midwest Laboratories, Omaha, NE
(From 100,000 plus soil samples)


USDA NRCS RUSLE2 Soil Conditioning Index Model Values using Historical Yields of Corn and Soy on Egan-Viborg Soils in Lake Co. South Dakota
Soil Conditioning Index-Corn
Soil Conditioning Index-soy
1980 to 2012 - Conservation Tillage (chisel plow)
1924 to 1979 - Plow Tillage
Positive Soil Conditioning Index values indicate gain of Soil Organic Matter, negative values indicate loss
Soil Conditioning Index
1.2
1.0
0.8
0.6
0.4
0.2
0.0
-0.2
-0.4
-0.6
-0.8
1924
1927
1930
1933
1936
1939
1942
1945
1948
1951
1954
1957
1960
1963
1966
1969
1972
1975
1978
1981
1984
1987
1990
1993
1996
1999
2002
2005
2008
2011


Soil Carbon Stock Changes from Corn - CENTURY Soil Carbon Model
Grams CO2 per Mega joule
30
25
20
15
10
5
0
No Till
Conservation Till
Conventional Till
South Dakota
Nebraska
Minnesota
Illinois
Iowa
Indiana
Ohio
Michigan
Data Source: Kwon H-Y et al. 2013

A Surprising Supply of Deep Soil Carbon – USDA ARS, Lincoln, NE

http://www.ars.usda.gov/is/AR/archive/feb14/soil0214.htm

For years, many agronomists believed that significant levels of soil carbon only accumulated near the soil surface. **So when four Agricultural Research Service scientists submitted a research paper claiming that large amounts of soil carbon were sequestered as deeply as 5 feet in the soil profile—and by annual as well as perennial crops—they had some trouble getting their paper through the review process.**

The study was a 9-year project that evaluated the effects of nitrogen fertilizer and harvest treatments on soil organic carbon sequestration in switchgrass and no-till maize crops managed for bio feedstock production.

"Soil organic carbon sequestration has a major impact on the long-term sustainability of bioenergy crop production because it can significantly affect soil fertility and greenhouse gas emissions," says ARS geneticist Ken Vogel (retired). "So using accurate sequestration rates is essential in developing life-cycle analyses that assess the long-term environmental costs and benefits of biofuel crop production."

Vogel, soil scientists Ron Follett (retired) and Gary Varvel, and agronomist Rob Mitchell conducted their study on marginally productive fields similar to the croplands that would be suitable for commercial switchgrass production. Mitchell and Varvel are with ARS research units in Lincoln, Nebraska. Follett was with ARS in Fort Collins, Colorado.

The team established large plots that could accommodate field-scale equipment and took baseline soil samples to a depth of 5 feet before the first crops were cultivated. These baseline samples showed that soil organic carbon levels varied within the first foot of the subsoil by as much as around 18 tons per acre, while soil carbon levels 5 feet below the soil surface varied by as much as almost 90 tons per acre.

Soil Carbon Stores: Annual vs. Perennial

To explore this phenomenon, the scientists then planted two switchgrass cultivars and no-till maize and applied nitrogen fertilizers at three different rates ranging from 54 pounds per acre to around 160 pounds per acre. Nitrogen fertilizers support biomass production, and the scientists wanted to see if the production of more plant biomass resulted in sequestration of more carbon in the soil. Some switchgrass plots were also maintained without any nitrogen amendments.

Postharvest crop residue, or "stover"—which also contributes to soil carbon—was not removed on half of the no-till maize fields; on other fields, half of the stover was removed. After the crops were established, the researchers resampled soils in the production fields at 3-year intervals.

What was their biggest surprise? In the no-till maize field, soil organic carbon levels increased over time at all depths, with all nitrogen treatments, and with either type of postharvest stover management. Maize grain yields were greatest from fields that had been amended with 107 pounds of nitrogen per acre and where no stover had been removed, a management strategy that resulted in an average annual increase in soil carbon that exceeded 0.9 tons per acre.

The researchers were equally surprised that more than 50 percent of the soil organic carbon was found at depths between 1 foot and 5 feet below the soil surface. This region of the soil profile, which typically has not been sampled by other researchers investigating carbon sequestration levels, is below the tillage zone and is therefore more stable over time.

In the switchgrass plots, the researchers also observed impressive increases of soil carbon sequestration throughout the soil profile. Sequestration rates increased as nitrogen fertilization rates increased, and almost all increases of soil carbon were statistically significant.

As they observed with the no-till maize plots, more than 50 percent of the soil carbon was found between 1 and 5 feet below the soil surface. The average annual increase of soil organic carbon throughout the first 5 feet of subsoil also exceeded 0.9 tons per acre per year, which was equivalent to 3.25 tons of carbon dioxide per acre per year.

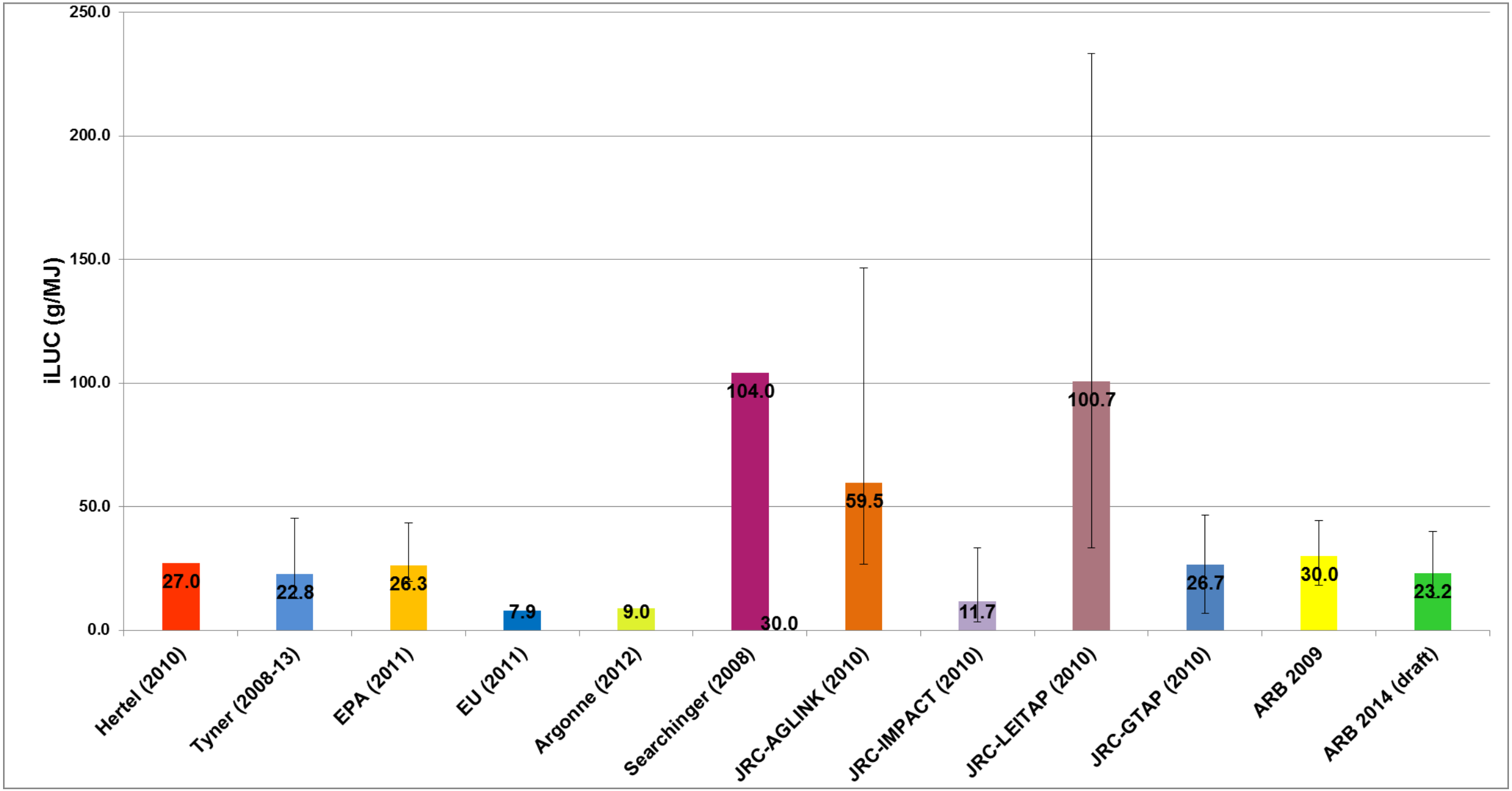
"We had not expected to find these stores of deep soil carbon, even though we always knew plant roots reached this deep, because we didn't realize how much the activity around roots can affect soil carbon budgets," Follett says. "Most studies only sample soils for carbon to a depth of 18 inches."

Because of their findings, the team concluded that calculating soil carbon sequestration rates for bioenergy crops is not a one-size-fits-all proposition. Crop selection, soil differences, environmental conditions, and management practices affect sequestration rates differently from one region to another. As a result, bioenergy crop production models will probably need some major adjustments.

"Our work suggests that carbon sequestration rates used in current life-cycle analysis models for bioenergy crops are probably resulting in underestimates of how much carbon is being sequestered in the soil," says Vogel. "It also highlights how nitrogen amendments and other management decisions do matter when it comes to corn and carbon sequestration — **and that annual crops can make important contributions to soil carbon."**

The paper was accepted by Bioenergy Research and published in 2012. **But even though its results were so surprising, two other ARS studies had highlighted similar dynamics.**

http://www.ars.usda.gov/is/AR/archive/feb14/soil0214.htm


iLUC (g/MJ)
250.0
200.0
150.0
100.0
50.0
0.0
27.0
22.8
26.3
7.9
9.0
104.0
30.0
59.5
11.7
100.7
26.7
30.0
23.2
Hertel (2010)
Tyner (2008-13)
EPA (2011)
EU (2011)
Argonne (2012)
Searchinger (2008)
JRC-AGLINK (2010)
JRC-IMPACT (2010)
JRC-LEITAP (2010)
JRC-GTAP (2010)
ARB 2009
ARB 2014 (draft)

SUMMARY

- Expanding Low Carbon Fuel Markets offer Opportunities for Ethanol Producers and Corn Producers
- Incentives can be Large – $.05 - $.15 per gallon
- Corn Ethanol may regain status as a Low Carbon Fuel