Governor's Council on Biofuels

April 6, 2020 Meeting Agenda

10 am to Noon
Webex Video Conference

Agenda

10:00 a.m.

Welcome and introductions
Commissioner Thom Petersen, Minnesota Department of Agriculture (MDA)

10:05 a.m.

Overview of agenda and introduction of presenters
Bob Patton, Energy and Environment Supervisor, MDA

10:10 a.m.

Relative environmental effects of ethanol, gasoline, and electricity
Jeremy Martin, Clean Transportation Program, Union of Concerned Scientists

10:50 a.m.

Carbon intensity of feedstock
Ron Alverson, Board Member, American Coalition for Ethanol and Dakota Ethanol

11:30 a.m.

Overview of Executive Committee discussion and plans for upcoming meetings
Bob Patton

11:45 a.m.

Public comment and questions

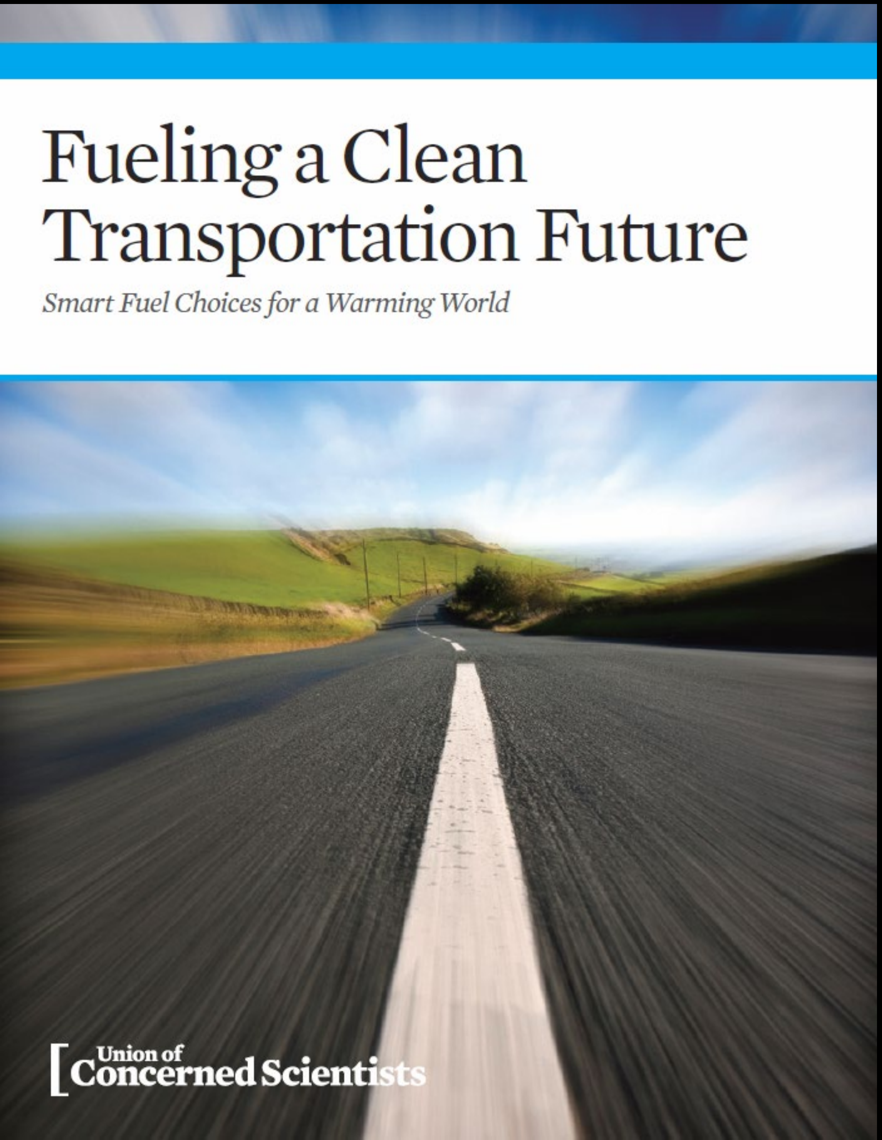
12:00 p.m.

Adjourn

Relative environmental effects of ethanol, gasoline and electricity

Jeremy Martin, Ph.D.
Director of Fuels Policy, Sr. Scientist
Clean Transportation Program
Union of Concerned Scientists

Source and outline of my talk



Union of Concerned Scientists

FACT SHEET

Clean Fuels for the Midwest

Expanding the Use of Clean Fuels Will Deliver Economic and Climate Benefits

HIGHLIGHTS

Increasing the use of cleaner transportation fuels, including low-carbon biofuels and electricity, is a smart way to help address climate change and reduce air pollution while also spending less on oil and providing more support to local economies. Midwestern states produce most of the country's ethanol and biodiesel, both of which can get cleaner through improved processes at production facilities and more sustainable practices on farms producing biofuel crops. At the same time, the Midwest leads the country in wind power generation, and electricity will play an important role in the future of clean transportation, and electric vehicles are getting cleaner as more renewable power replaces coal on the grid. Clean fuels standards would promote the increasing use of biofuels and electric vehicles and encourage all fuel producers to reduce the global warming pollution that comes from making transportation fuels.

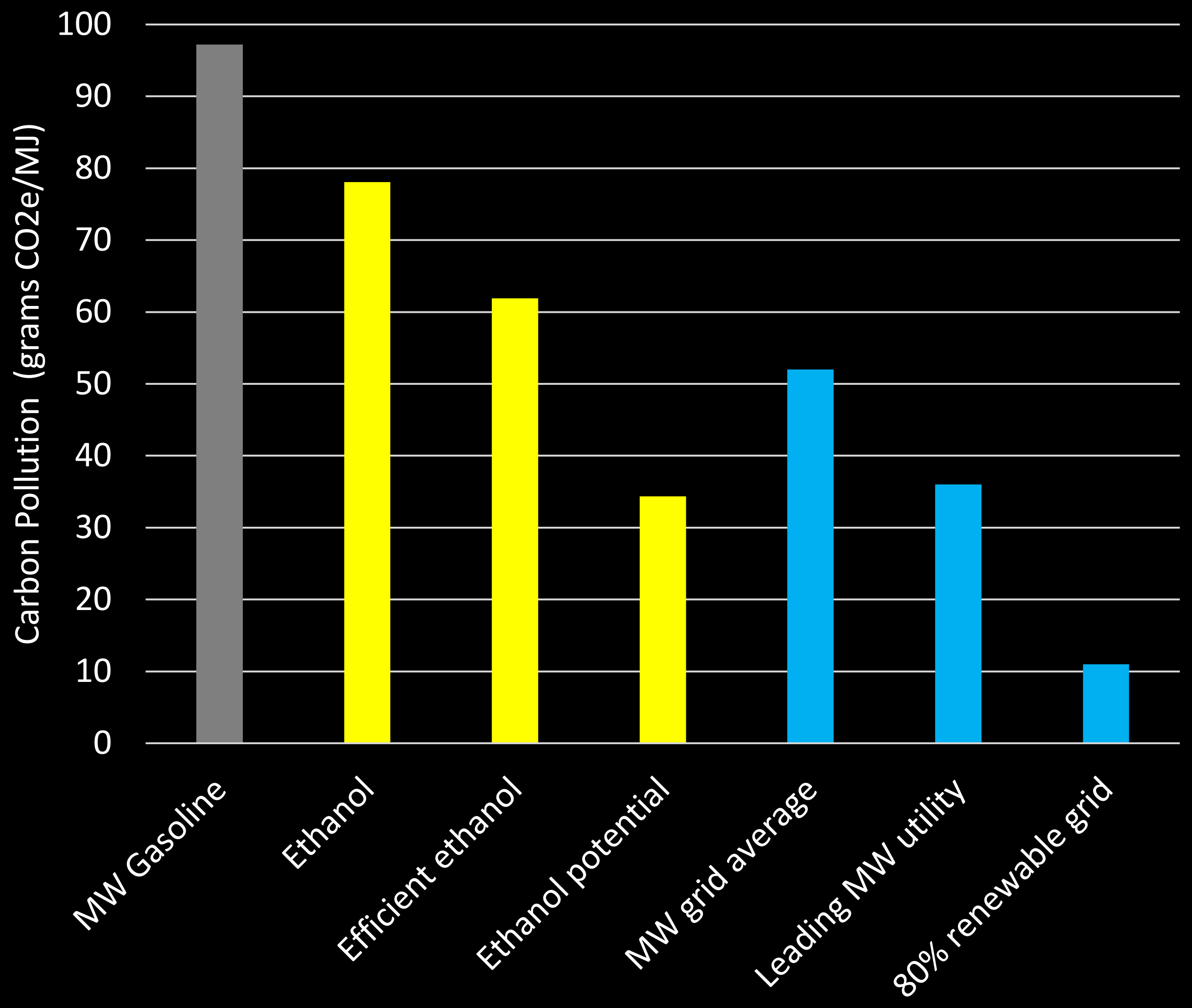
The Midwest leads the United States in producing biofuels and wind energy, yet petroleum-based fuels brought in from other states and countries meet more than 90 percent of the region's transportation energy needs. Gasoline and diesel are also the region's largest sources of global warming pollution, threatening its economic well-being and quality of life, now and in the future. Repowering the transportation sector with electricity and cleaner biofuels is a smart way to help address climate change and reduce air pollution while spending less money on oil and supporting local economies.

Transportation powered with biofuels and electricity is cleaner than gasoline and diesel, and both have the potential to be much cleaner than they are today (see the figure, p. 2). For example, Midwestern ethanol producers have made important progress in reducing global warming pollution from their operations. The region's electric grid has also been getting cleaner, as coal-fired power plants shut down and wind power expands. Farmers who produce crops for food, feed, and fuel can reduce emissions and build the healthier soils that are critical for improving yields, producing cleaner fuels, and promoting resilience in the face of a changing climate.

The Midwest is a leader in biofuels production and wind energy. Using renewable fuels and power to cut oil use and emissions in the transportation sector can help address global warming and air pollution and save consumers money.

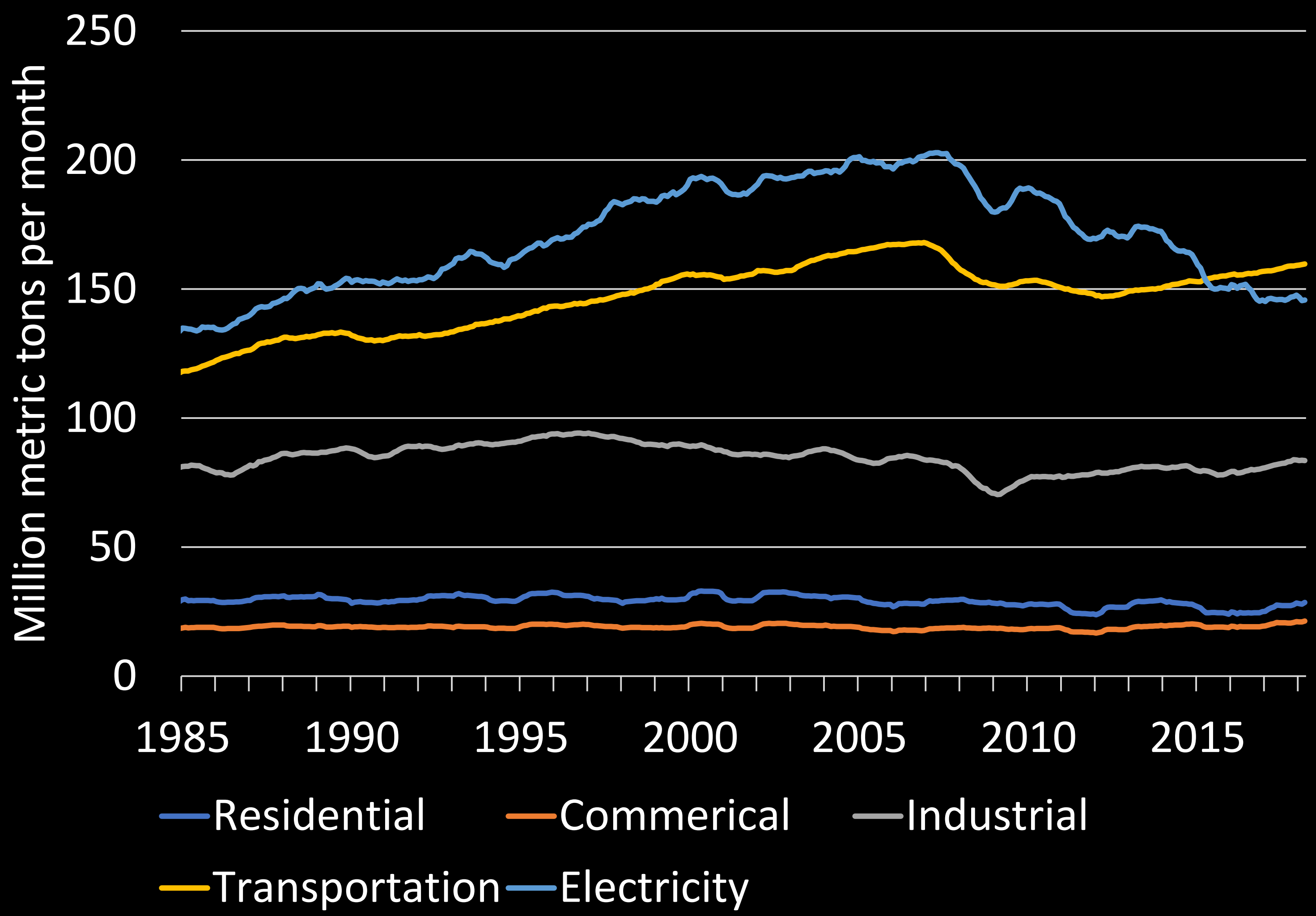
- Gasoline
- Electricity
- Ethanol

Summary Results



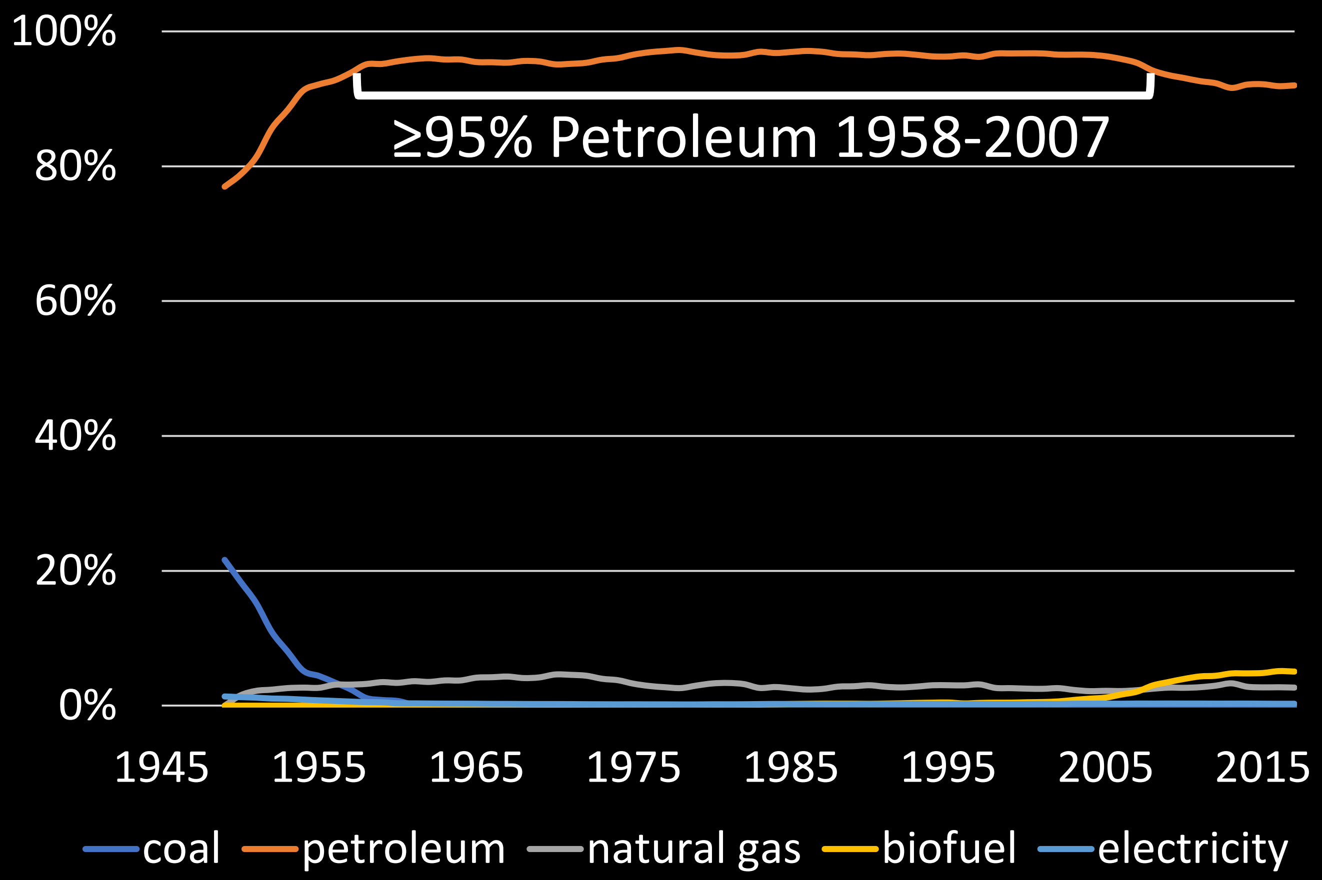
- Powering transportation with biofuels and electricity is less polluting than gasoline today
- The most efficient biofuel producers and cleanest sources of electricity are cleaner still
- With smart policy, both biofuels and electricity can get much cleaner over time.

U.S. CO2 emissions by sector (EIA data)



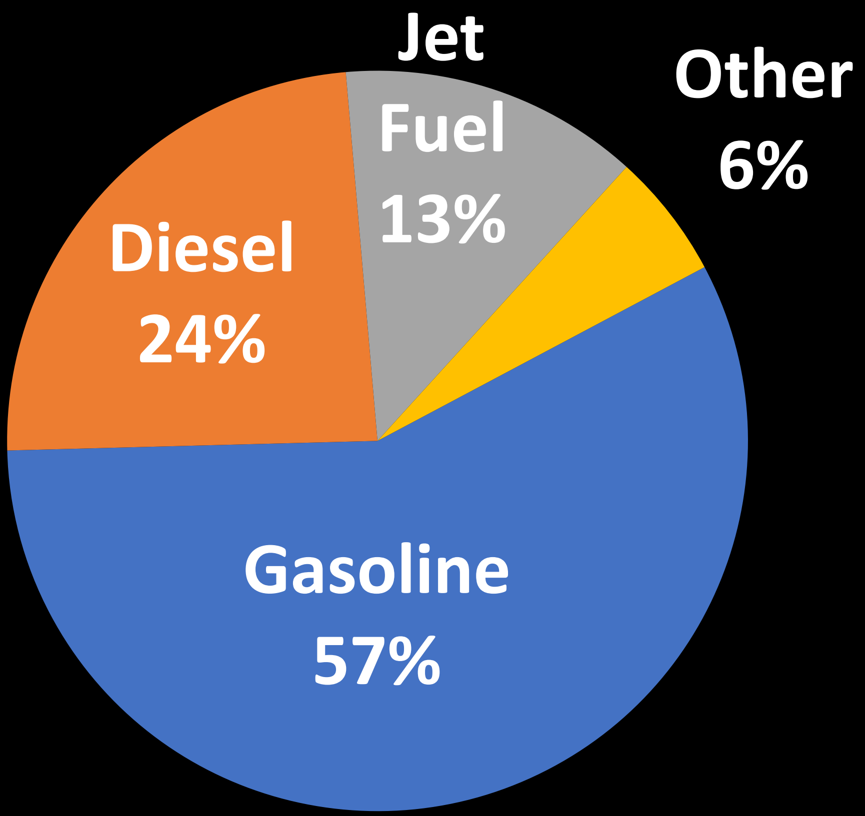
- Transportation is now the largest source of U.S. CO2 emissions.
- Emissions from electricity generation are falling
- Emissions from transportation have continued to rise

U.S. transportation energy consumption
EIA Data



- For exactly 50 years, from 1958 to 2007 more than 95% of US transportation energy comes from petroleum
- In 2008 the share of transportation energy from petroleum fell below 95% for the first time in 50 years

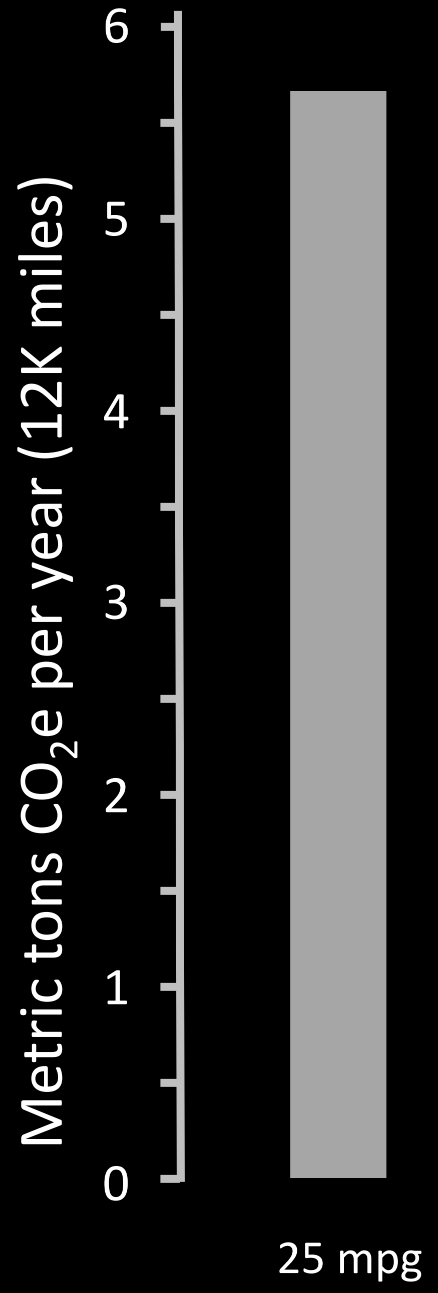
US 2018 Transportation Emissions (EIA Data)



- Gasoline accounts for more than half of transportation fuel emissions
- Diesel account for a quarter

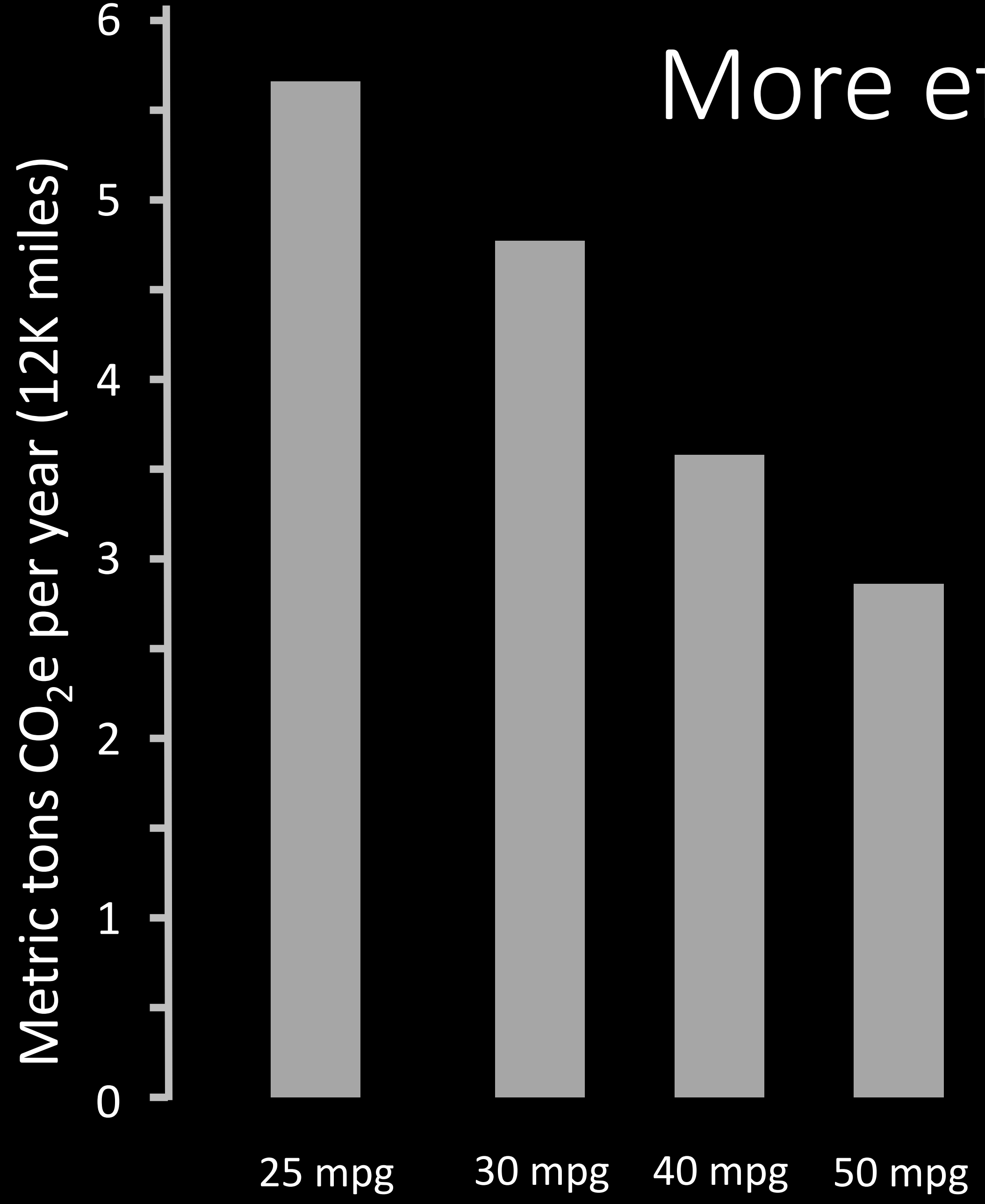
Gasoline

Emissions from driving



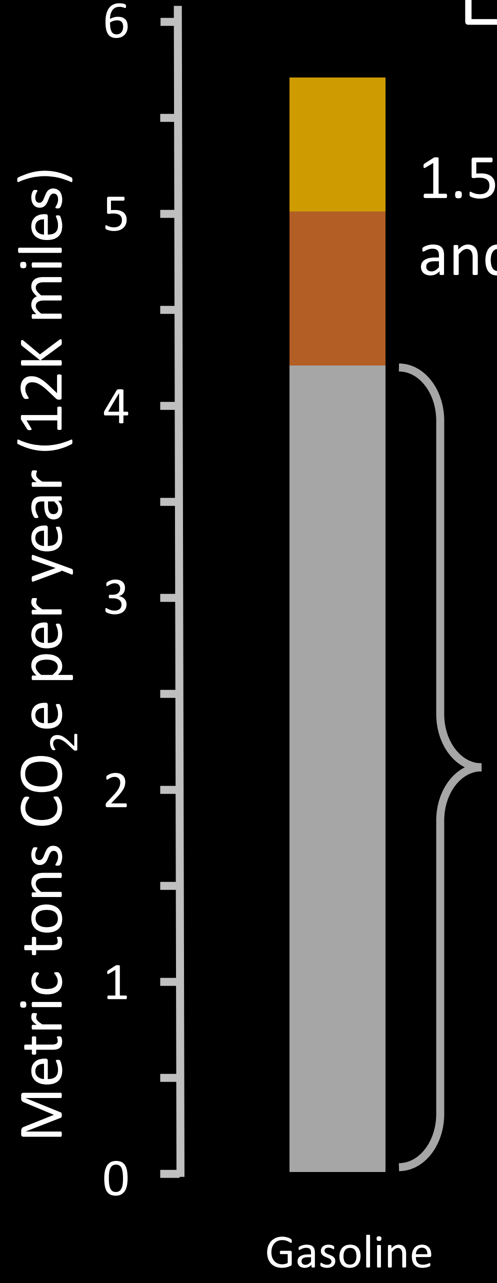
- A typical (25 mpg) car driven 12,000 miles is responsible for 5.7 tons of global warming pollution per year

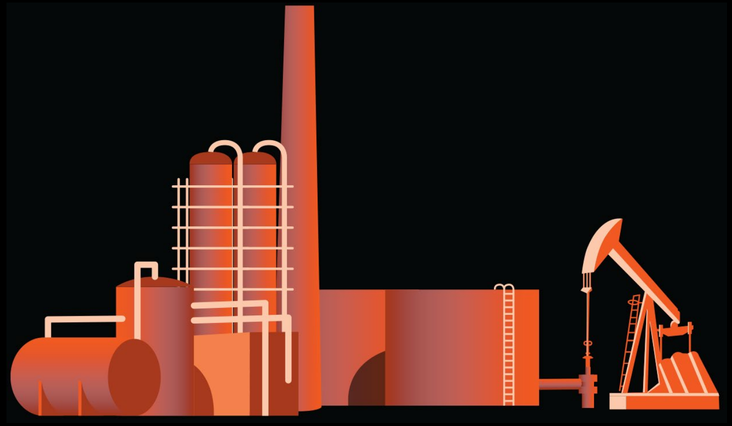
More efficient cars reduce emissions



- The most efficient cars can cut average emissions in half, to under 3 tons per year

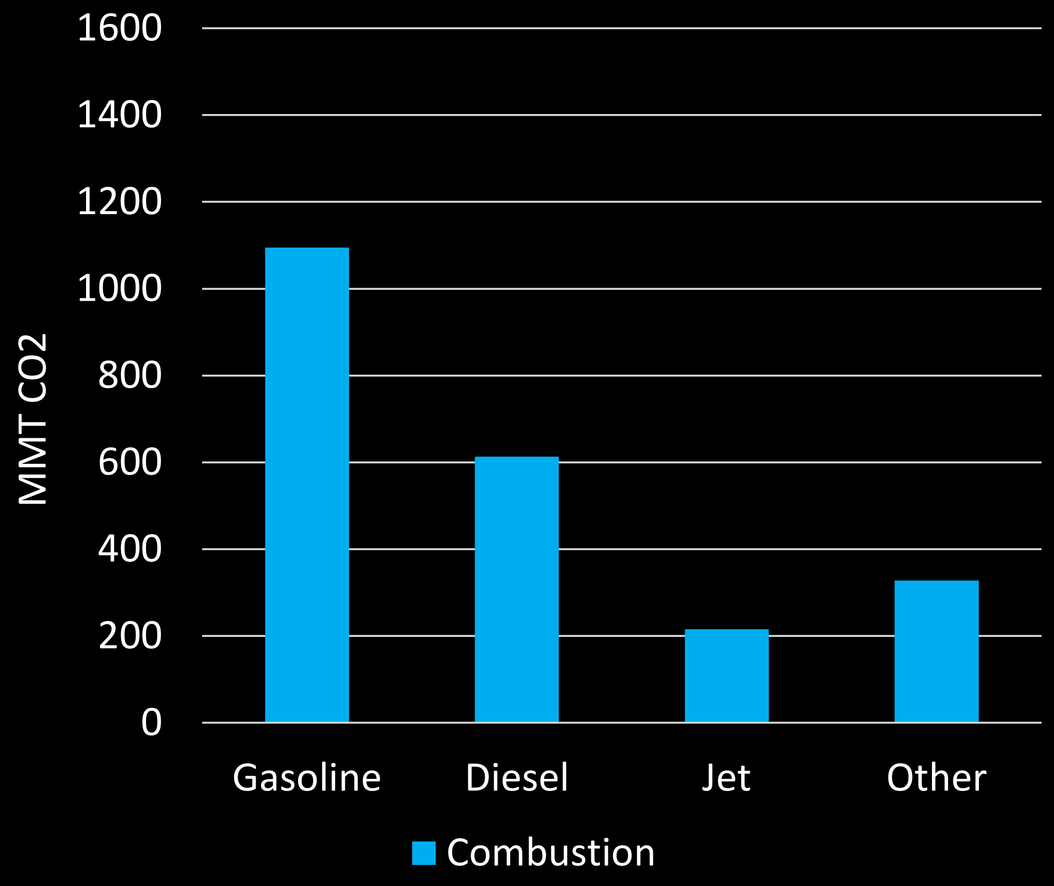
Emissions from oil production and refining





- 4.2 tons come from the tailpipe of the car, while an additional 1.5 tons are emitted in the process of extracting and refining oil into gasoline

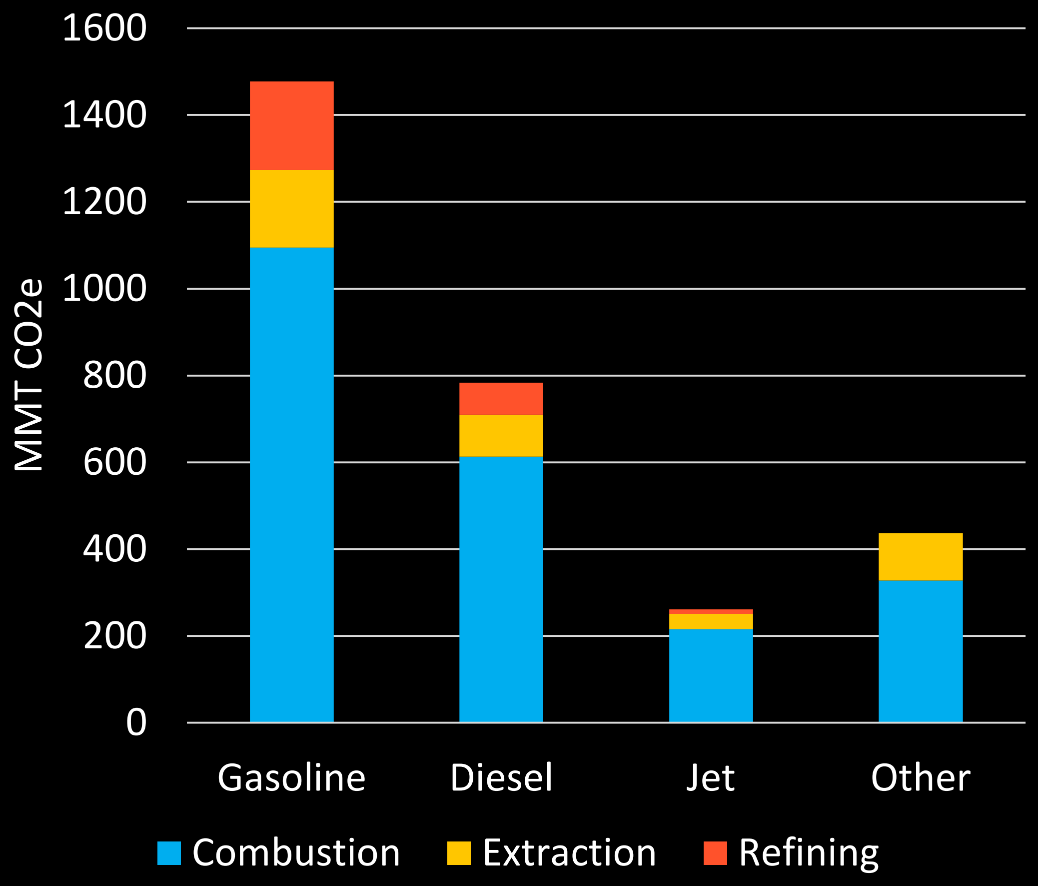
Emissions of transportation fuel usage



CO_2 from combustion of US petroleum products (EIA)

- Burning petroleum-based transportation fuels is the single largest part of the U.S. CO2 emission inventory

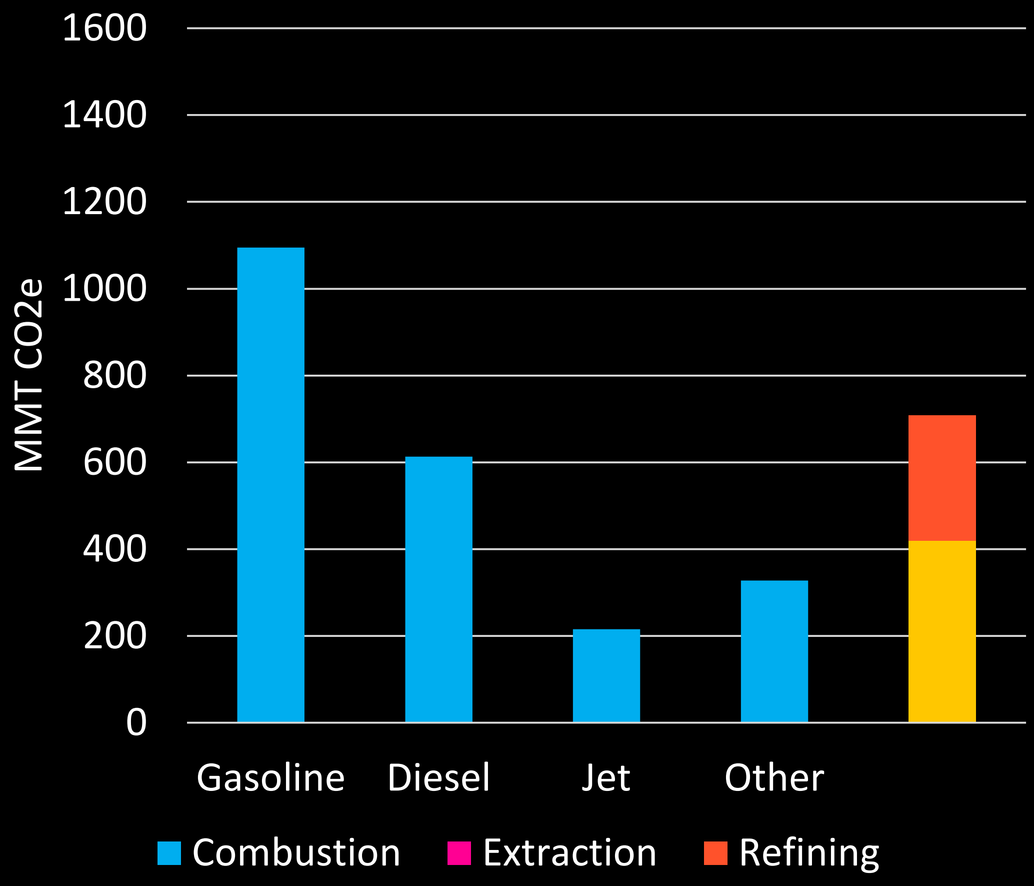
Emissions of transportation fuel production



- Emissions from oil extraction and refining are not classified as transportation emissions
- But emissions from extraction and refining are a big part of the transportation fuel life cycle

CO_2 from combustion of US petroleum products (EIA)
CO_2 & methane from **extraction** and **refining** of oil for US petroleum products (Cooney et al.)

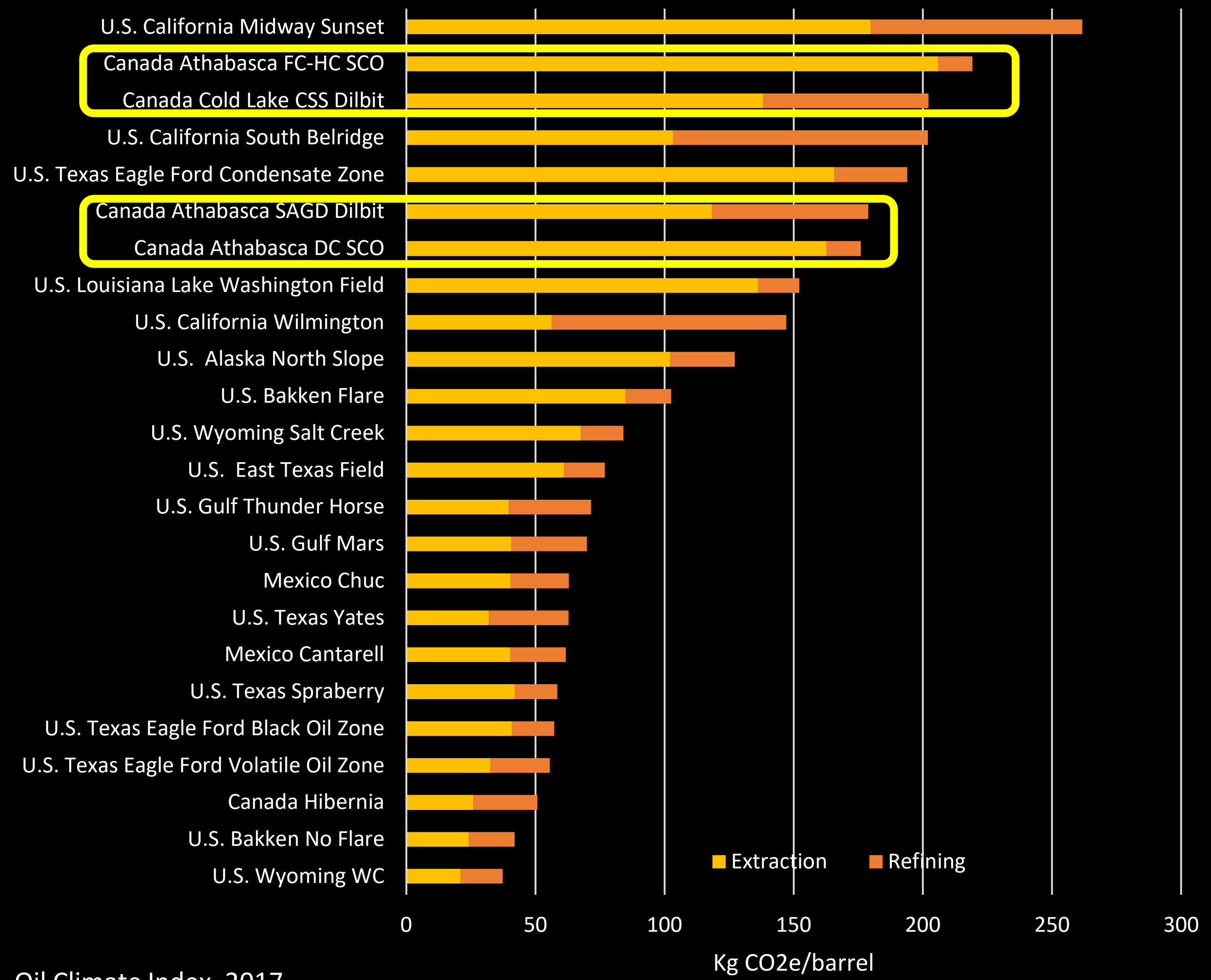
Emissions of fuel production versus usage



- Emissions from oil extraction and refining of the petroleum-based transportation fuels used in the US exceed the emissions from combustion of all the diesel fuel used in the U.S.
- Car and truck manufacturers must meet standards to reduce emissions from driving
- Oil companies should also reduce emissions from fuel production

CO_2 from combustion of US petroleum products (EIA)
CO_2 & methane from **extraction** and **refining** of oil for US petroleum products (Cooney et al.)

Oil Climate Index North American extraction and refining emissions



Oil Climate Index, 2017

- Emissions from oil extraction and refining vary widely
- The most polluting crudes in North America exceed 200 kg per barrel
- The least polluting crudes are less than 50 kg per barrel
- Crudes from the Canadian tar sands are among the most polluting

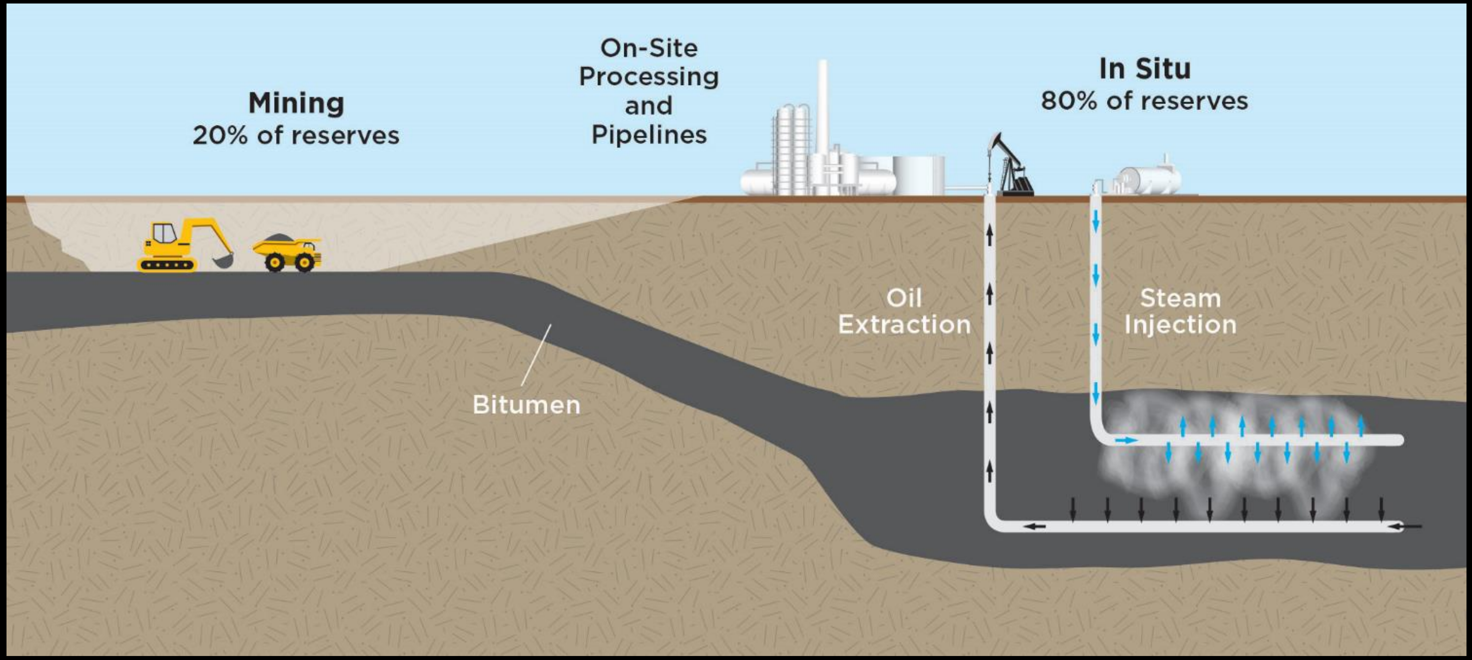
Tar sands surface mining

- Tar sands oil is mixed with sand and clay
- For deposits close to the surface, the tar sands are mined from huge open mines and trucked to separation and upgrading facilities

Tar sands separation, upgrading and refining

- The tar sands oil must be separated from sand and clay in an energy and water intensive process
- It is mixed with lighter crude or upgraded before transportation by pipeline to oil refineries

In situ tar sands

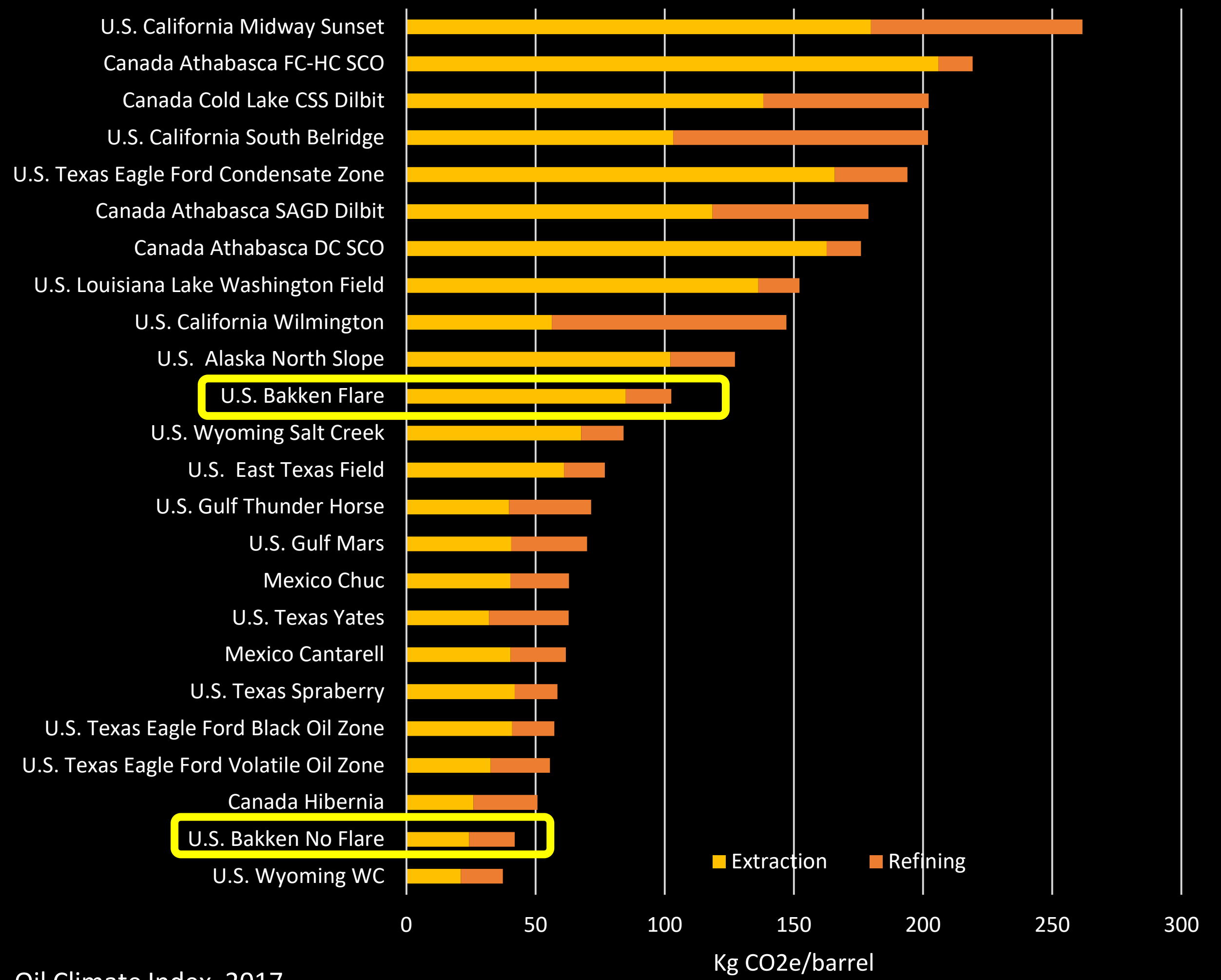


- Deeper deposits of tar sands are extracted by injected steam into the reservoir to allow the oil to flow
- This is an energy intensive process that produces a lot of extra pollution

Venting and flaring

- Rather than collecting natural gas for sale or use, or reinjecting it into the ground, a great deal of gas is vented and flared
- Venting and flaring increases emissions from oil production
- Reducing venting and flaring is a low-cost means of reducing pollution from oil production

Flaring has a big impact on emissions



Oil Climate Index, 2017

- The same source of oil can have much higher emission because of venting and flaring of natural gas associated with oil production
- Oil from the U.S. Bakken with flaring have emissions more than twice as high as the same source without flaring

CO_2 Enhanced Oil Recovery

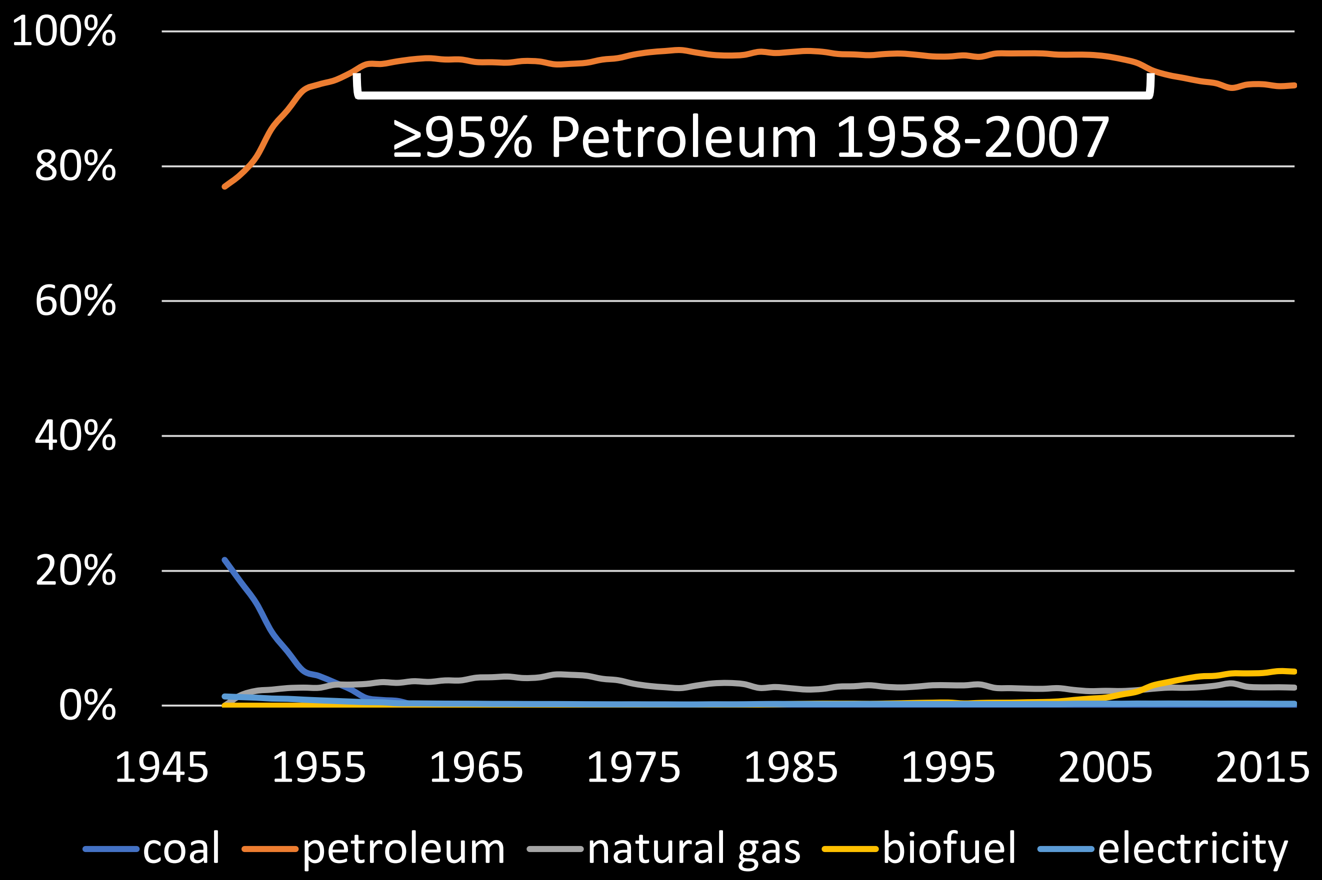
- Enhanced oil recovery involves injecting steam or chemicals into oil fields to increase the flow of oil.
- Replacing steam with CO_2 can reduce emissions from steam generation and leave CO2 sequestered in the oil well.
- Using captured CO_2 from power plants or ethanol facilities can reduce oil lifecycle emissions

Solar steam for enhanced oil recovery

- Using solar energy to generate steam for enhanced oil recovery can reduce emissions from steam generation.

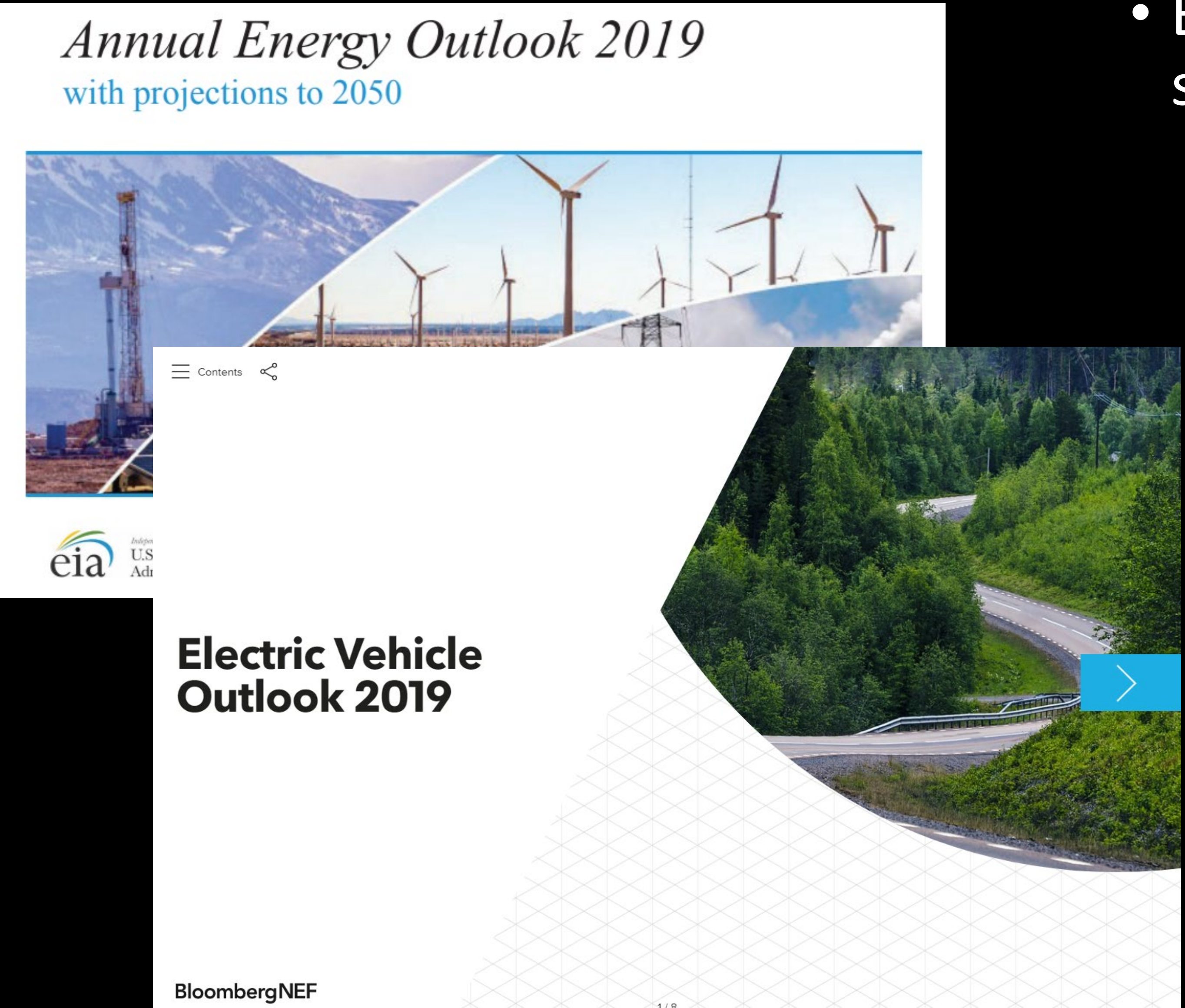
Electricity

U.S. transportation energy consumption
EIA Data



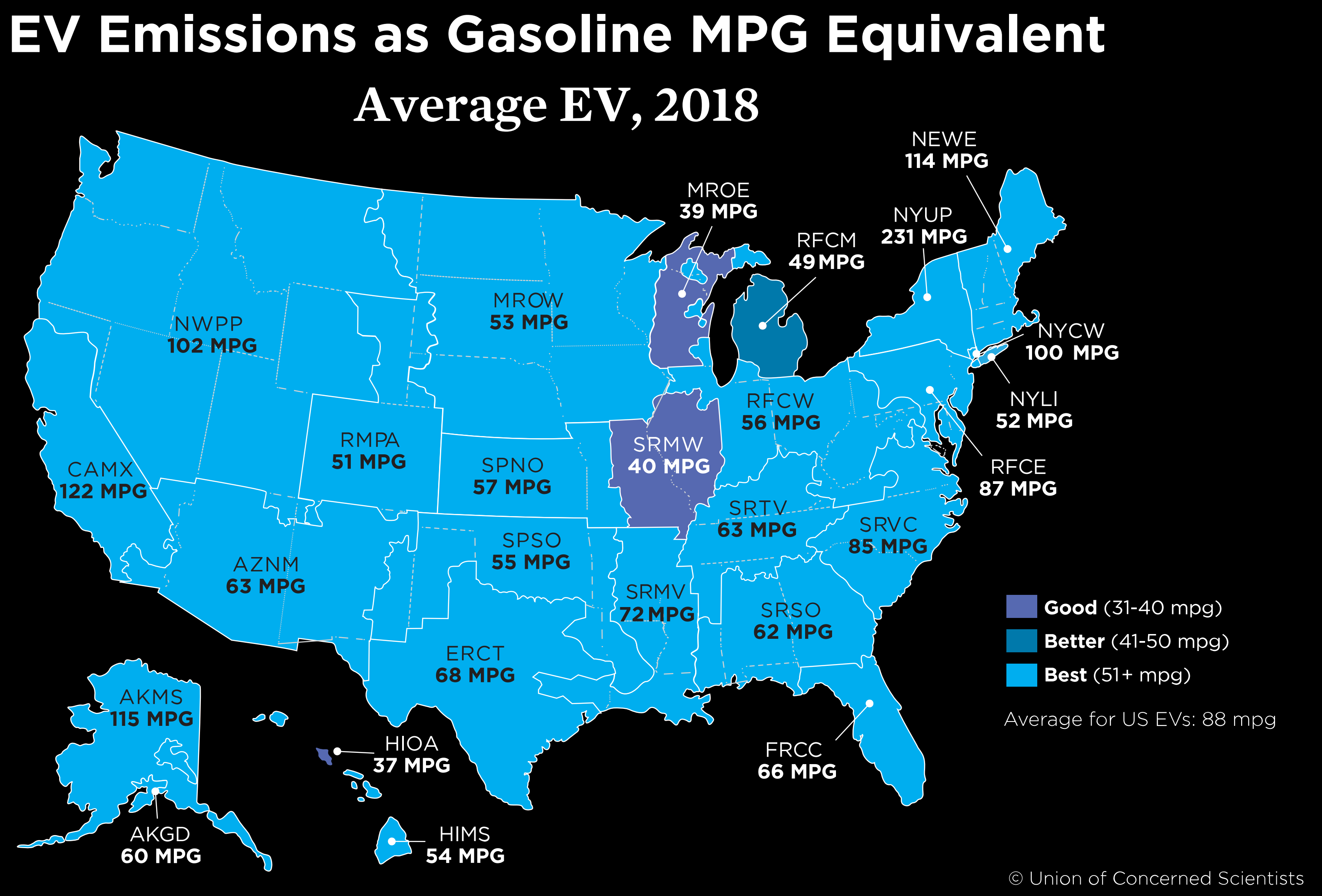
- Electricity does not play a significant role as a source of transportation energy today

Timeline for transportation electrification



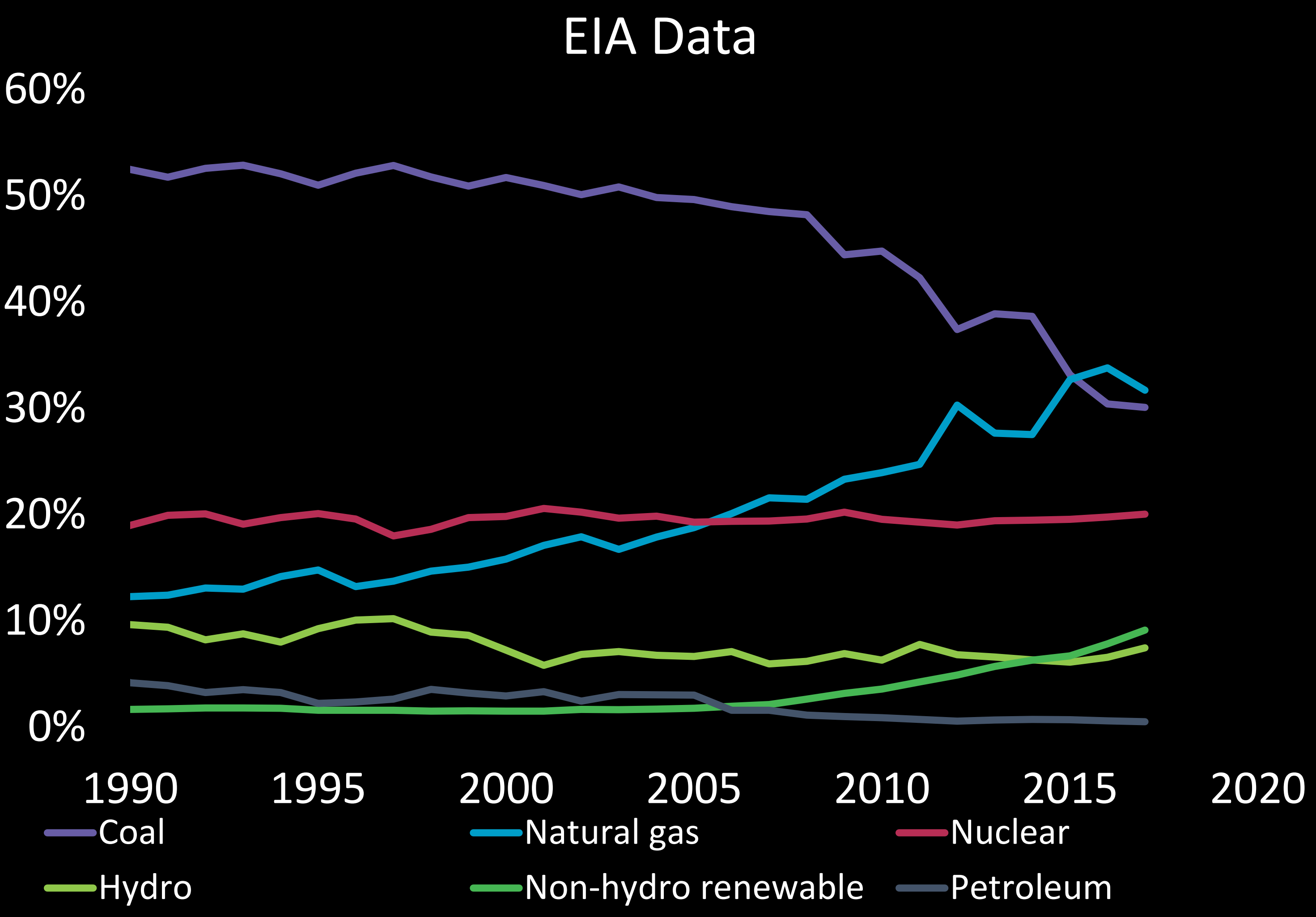
- Estimates of how quickly EV market share will grow vary widely.
  - EIA projects 11% new car sales in 2030, 19% in 2050
  - Bloomberg New Energy Finance projects 50% new car sales by 2035

EV Emissions as Gasoline MPG Equivalent



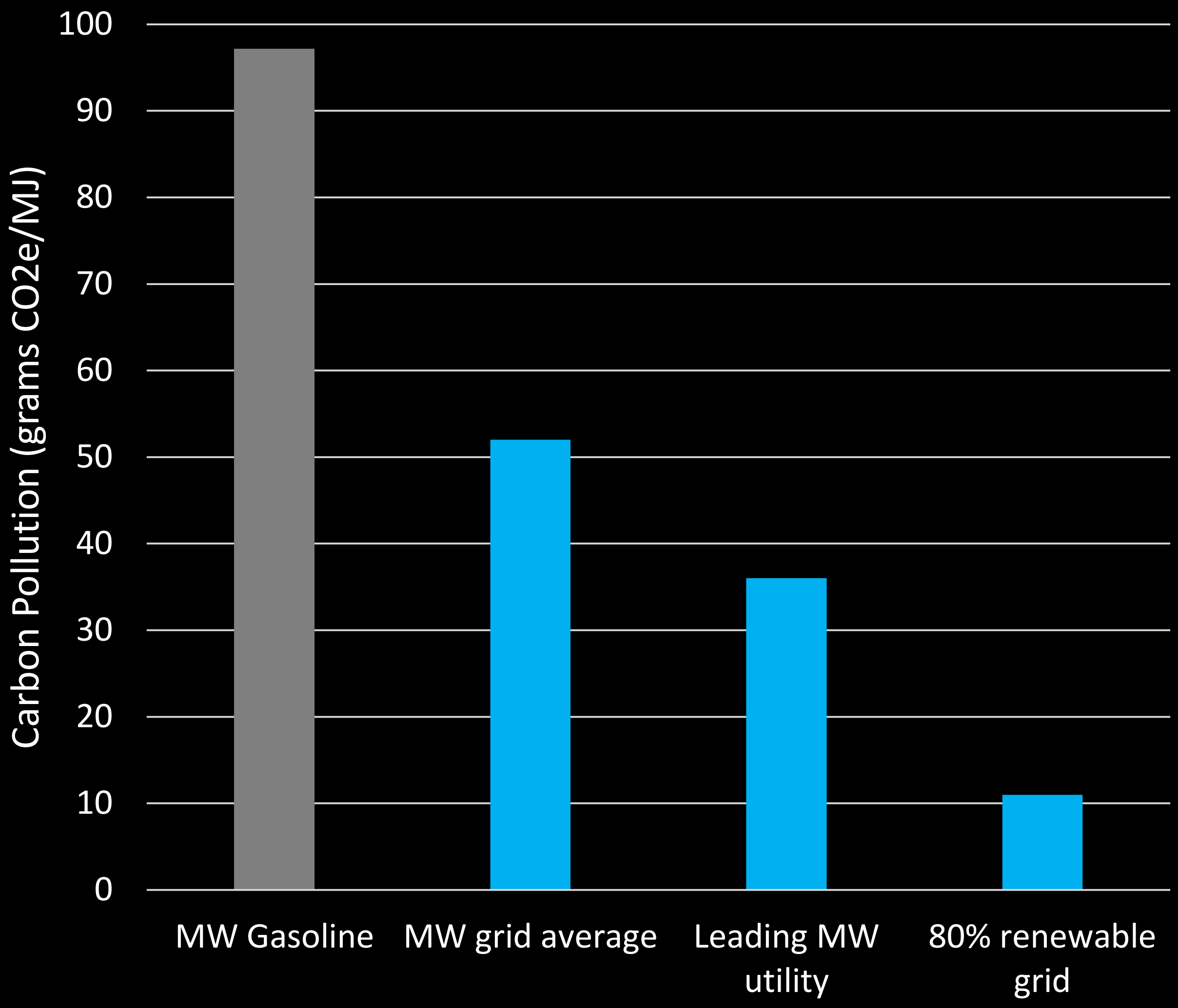
- EVs are cleaner than an average gasoline car in every grid region
- EVs and less polluting than the best hybrids over much of the country
- The weighted average for US EVs is 88 MPG
- The MROW value covering Minnesota is 53 MPG

U.S. Share of Electricity Generation



- EVs get cleaner every year together with the electric grid
- The share of coal fired generation continues to fall
- Renewable energy and natural gas are growing quickly

Electric vehicles powered by renewable energy are key to our clean transportation future



- An EV charged on the average MW grid is 40% cleaner than gasoline
- An EV charged on the Xcel grid is 60% cleaner than gasoline
- EVs continue to get cleaner every year as more renewable come on-line.

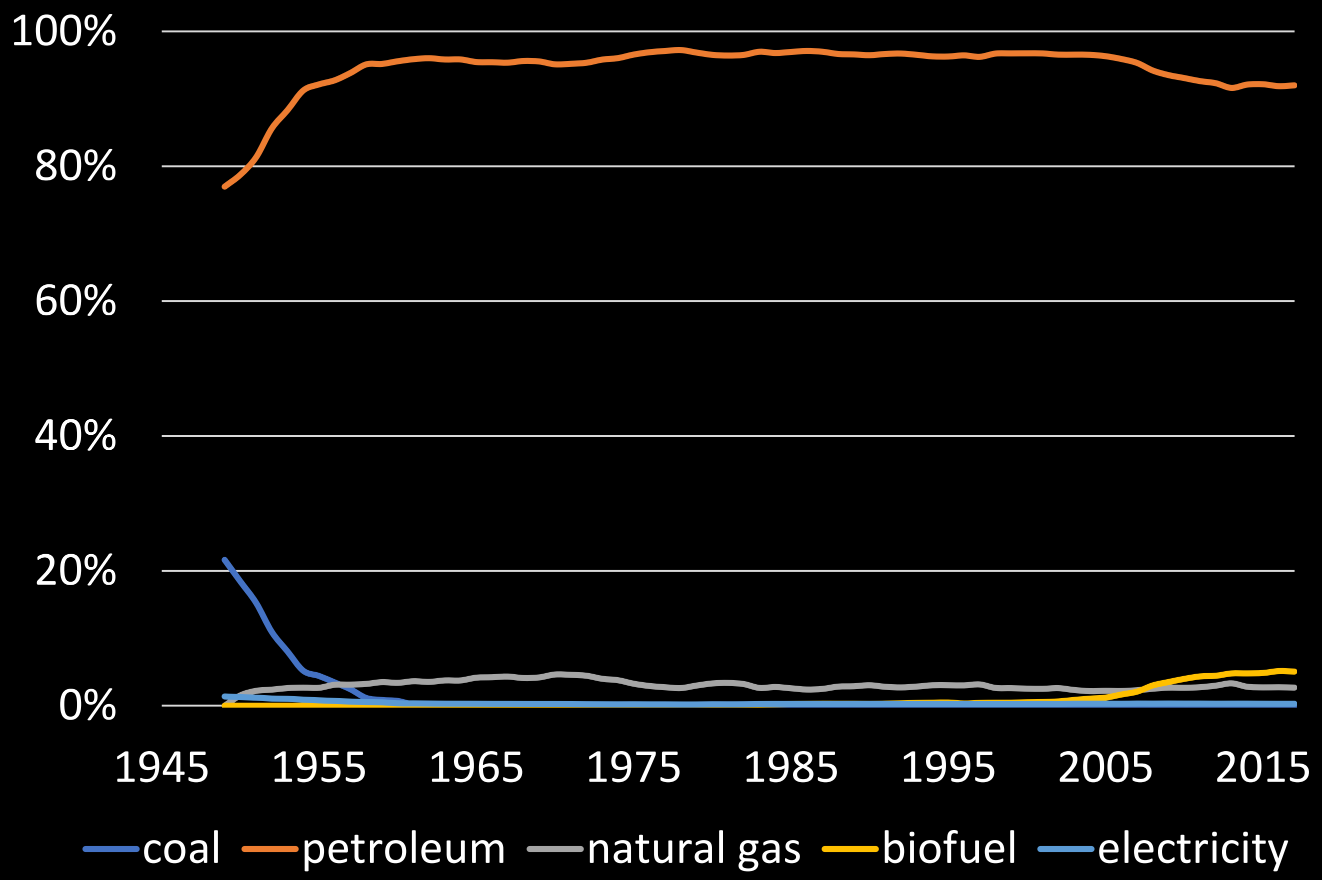
Electric vehicles complement renewable power

- Smart charging of EVs can improve utilization of intermittent renewable power reducing costs for all electricity users

Ethanol

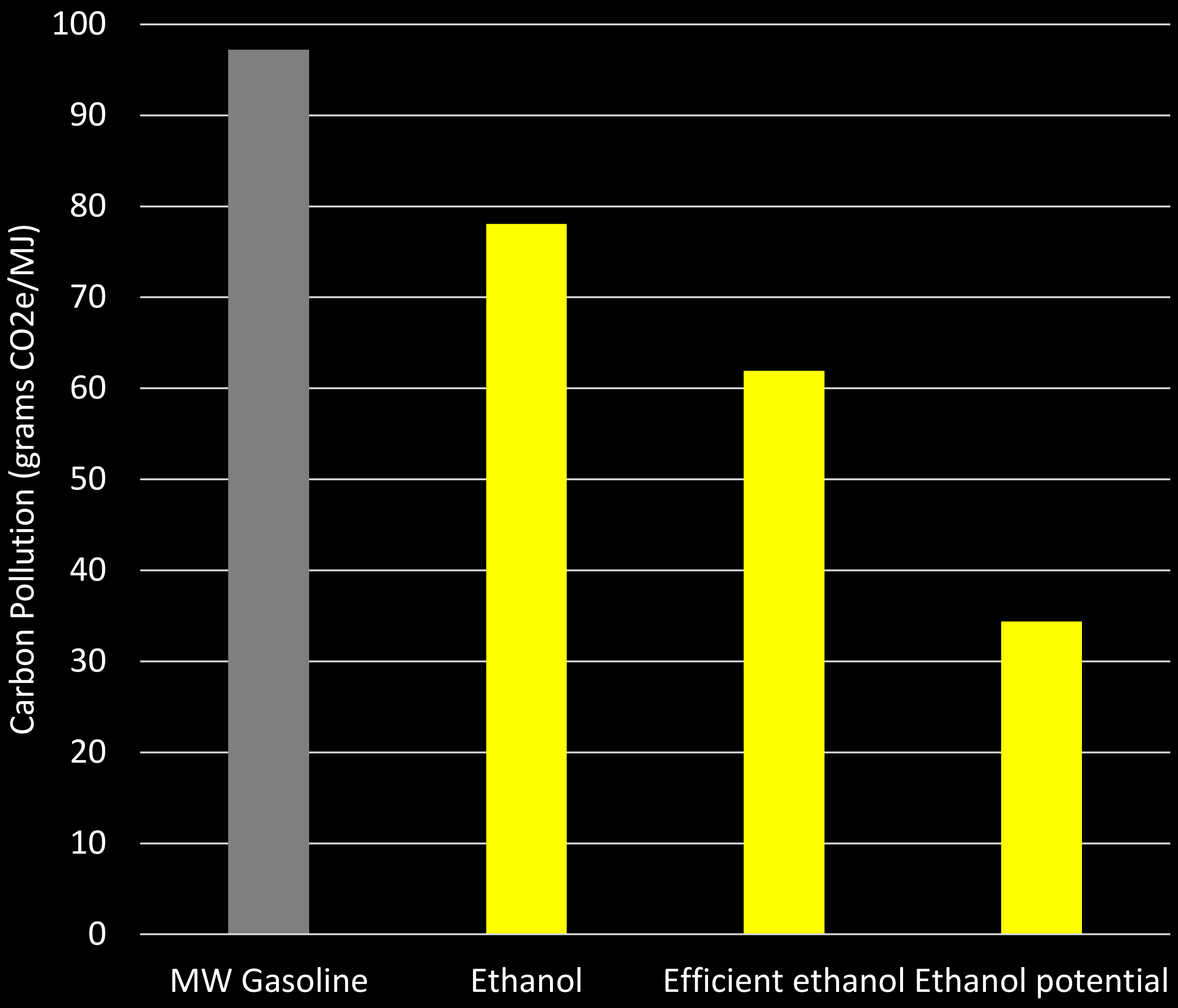
U.S. transportation energy consumption

EIA Data

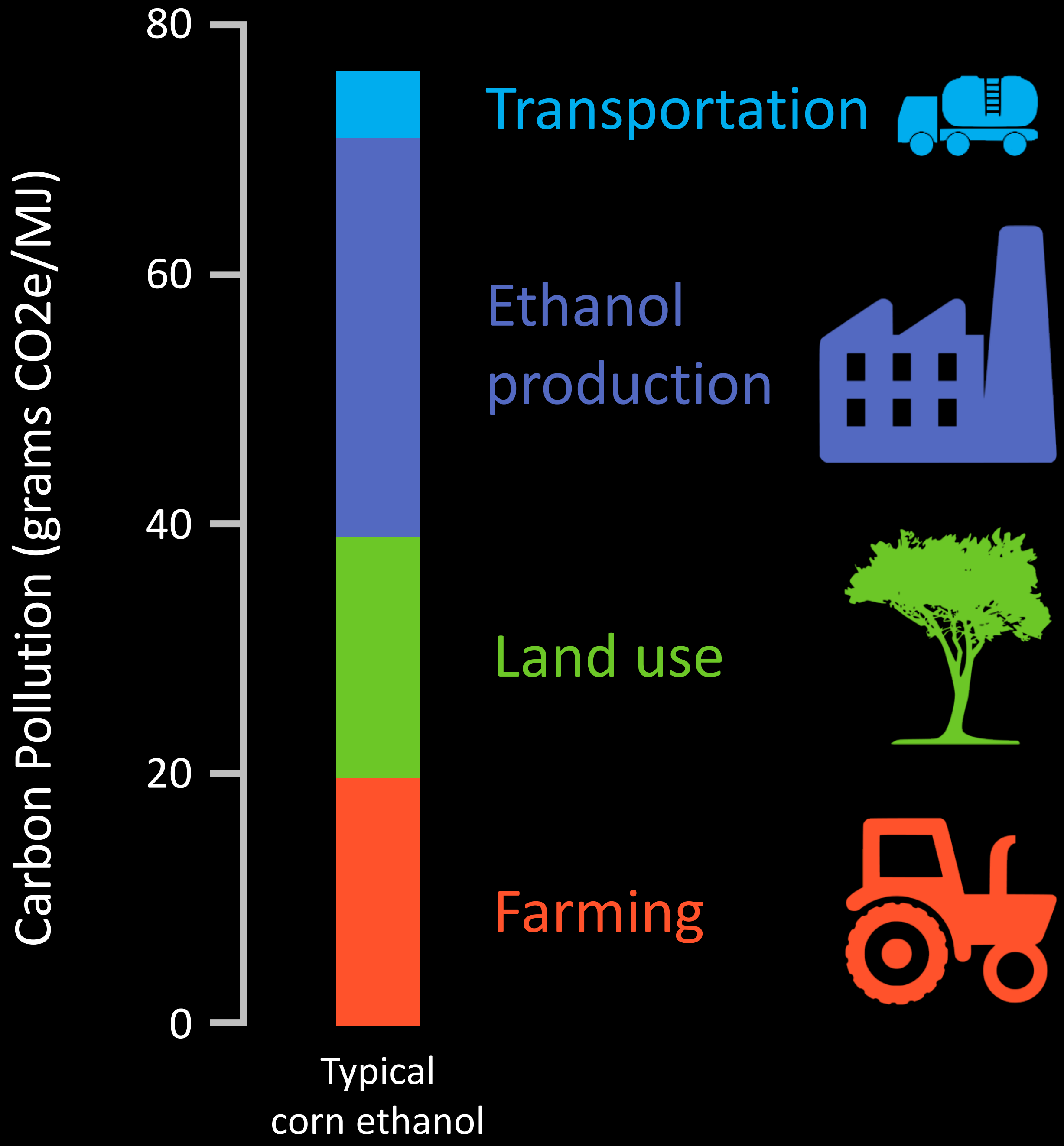


- Biofuels grew from 1% of transportation energy in 2004 to 5% in 2017
- Ethanol accounts for most current biofuels production, although biodiesel, renewable diesel and renewable natural gas have also grown recently

Carbon pollution from ethanol compared

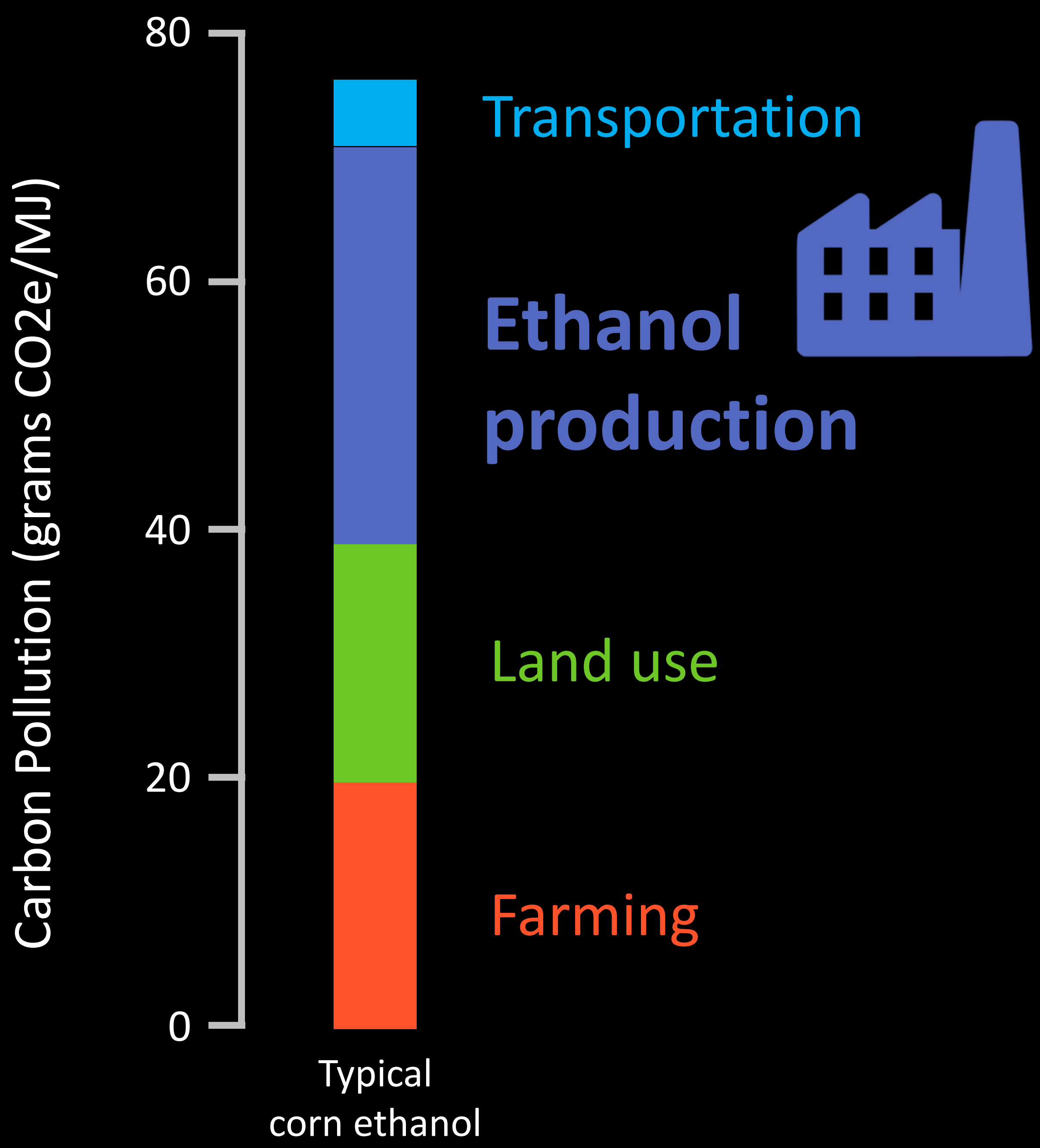


- Lifecycle carbon pollution from ethanol produced at a typical facility are 20% lower than gasoline
- The most efficient producers are 20% less polluting that typical
- Ethanol has the potential to cut emissions by more than half from what they are today



Corn ethanol lifecycle

- The major elements of the corn ethanol lifecycle are
  - Transportation
  - Ethanol production
  - Land use
  - Farming



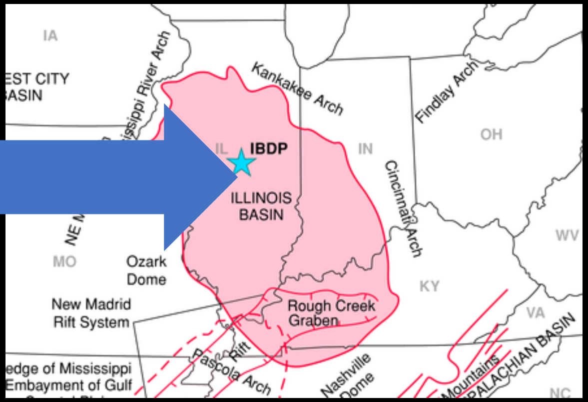
Ethanol production

- The largest part of lifecycle emissions takes place at the ethanol production facility
- Natural gas used for heat to run the distillation and dry DDGS
- Heat recovery, switching to biomethane and renewable power, reducing DDGS drying and other efficiency improvements reduce production emissions

CO_2 capture and sequestration at ethanol facilities

CO_2 released during fermentation

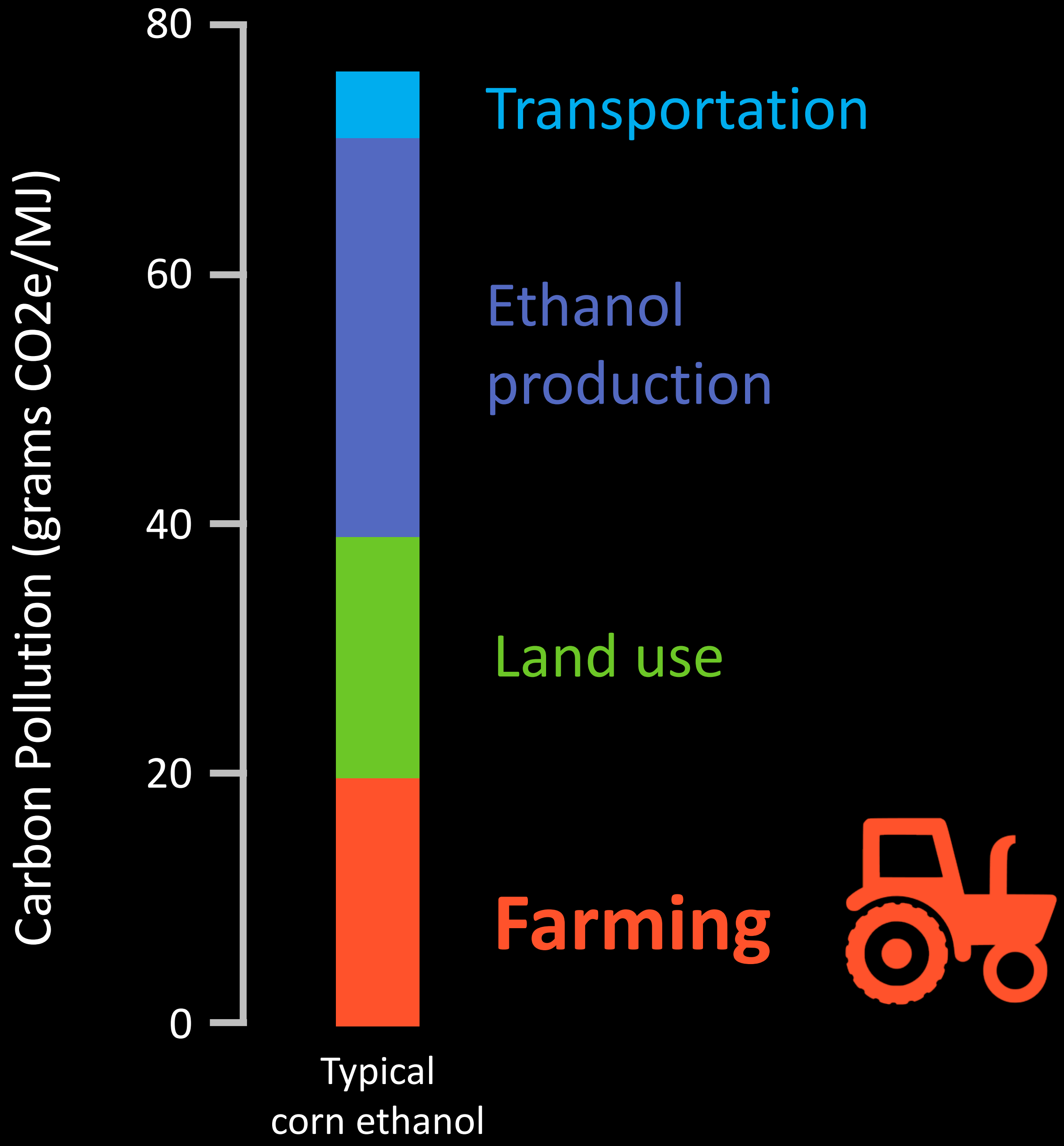
Sequestered in deep saline reservoir



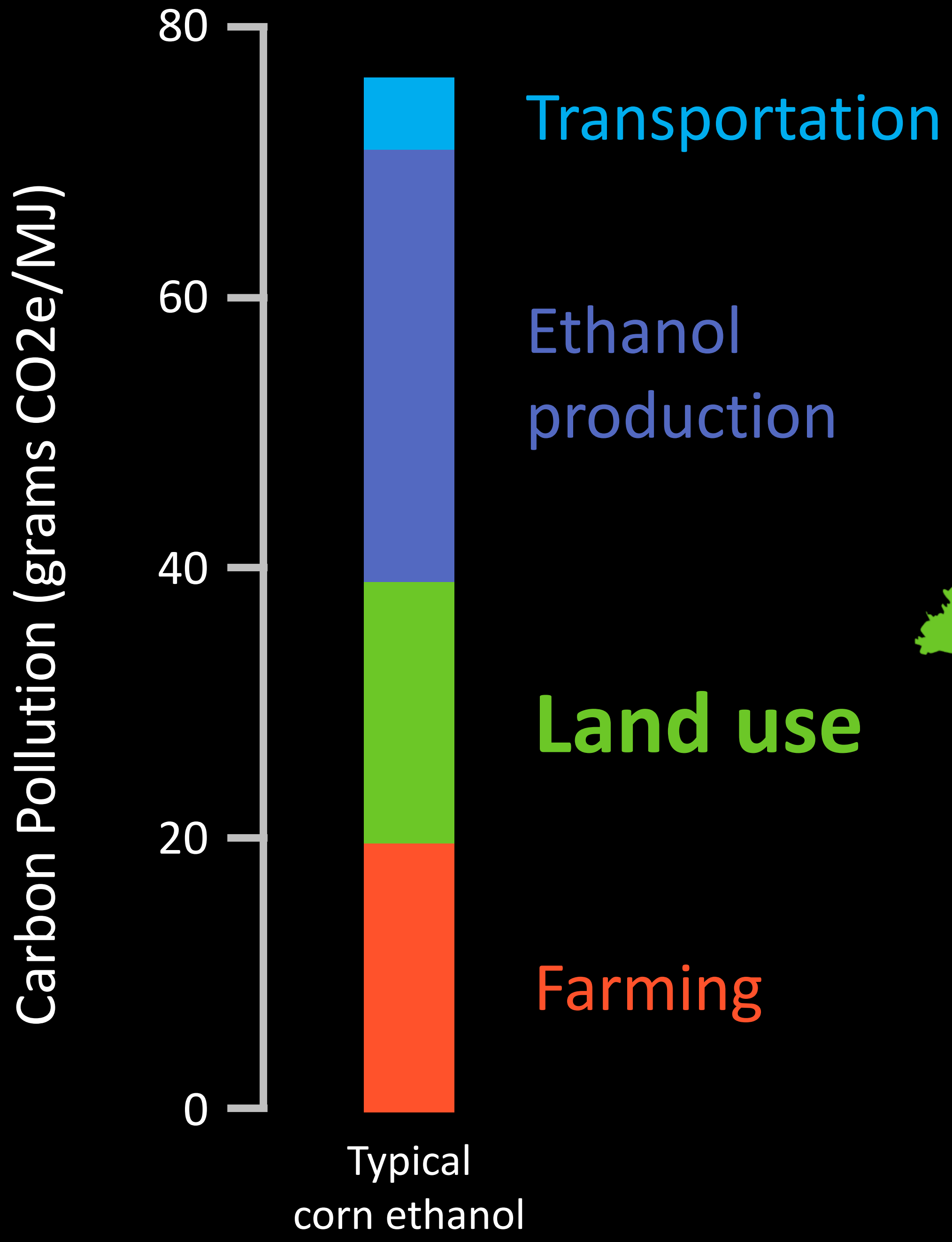
- Ethanol fermentation releases CO_2 that can be cost effectively captured for sequestration in saline aquifers of used for enhanced oil recovery
- Capturing CO_2 can reduce the ethanol lifecycle by 30 g/MJ or more

Near-term deployment of carbon capture and sequestration from biorefineries in the United States Sanchez, et al. PNAS 2018

Corn farming



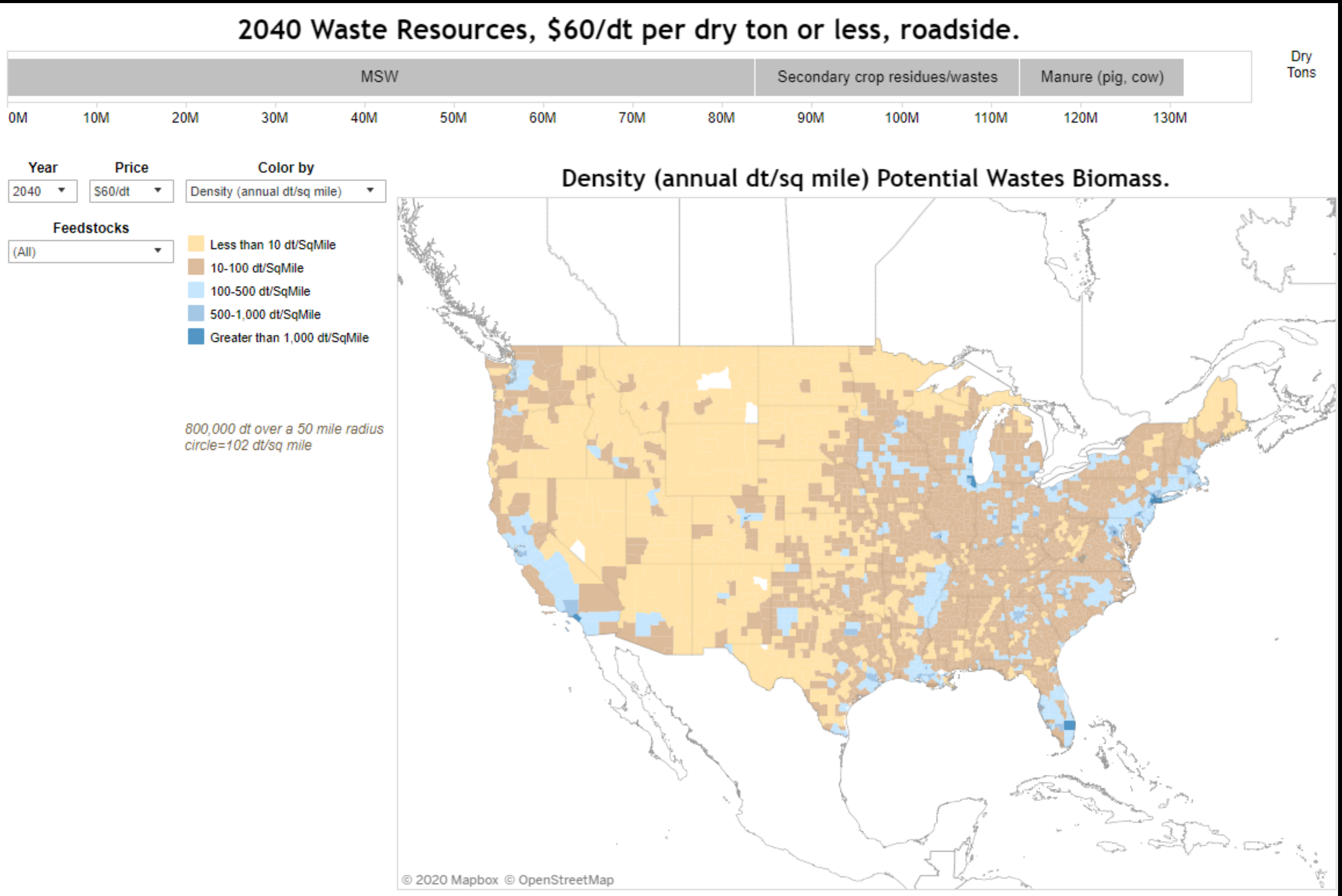
- Farm practices can reduce emissions per bushel of corn and increase soil carbon, which reduce the farm contribution to the corn ethanol lifecycle
- Documenting on farm emissions reductions and soil carbon sequestration is more complicated than energy use during ethanol production



Land use emissions

- Part of the ethanol lifecycle reflects the emissions cost of using crop land for fuel production
- Land use emissions can be reduced by improving yields, producing fuel from residues from agriculture and forestry
- Perennial crops grown on land less suitable for row crops also minimize cropland expansion

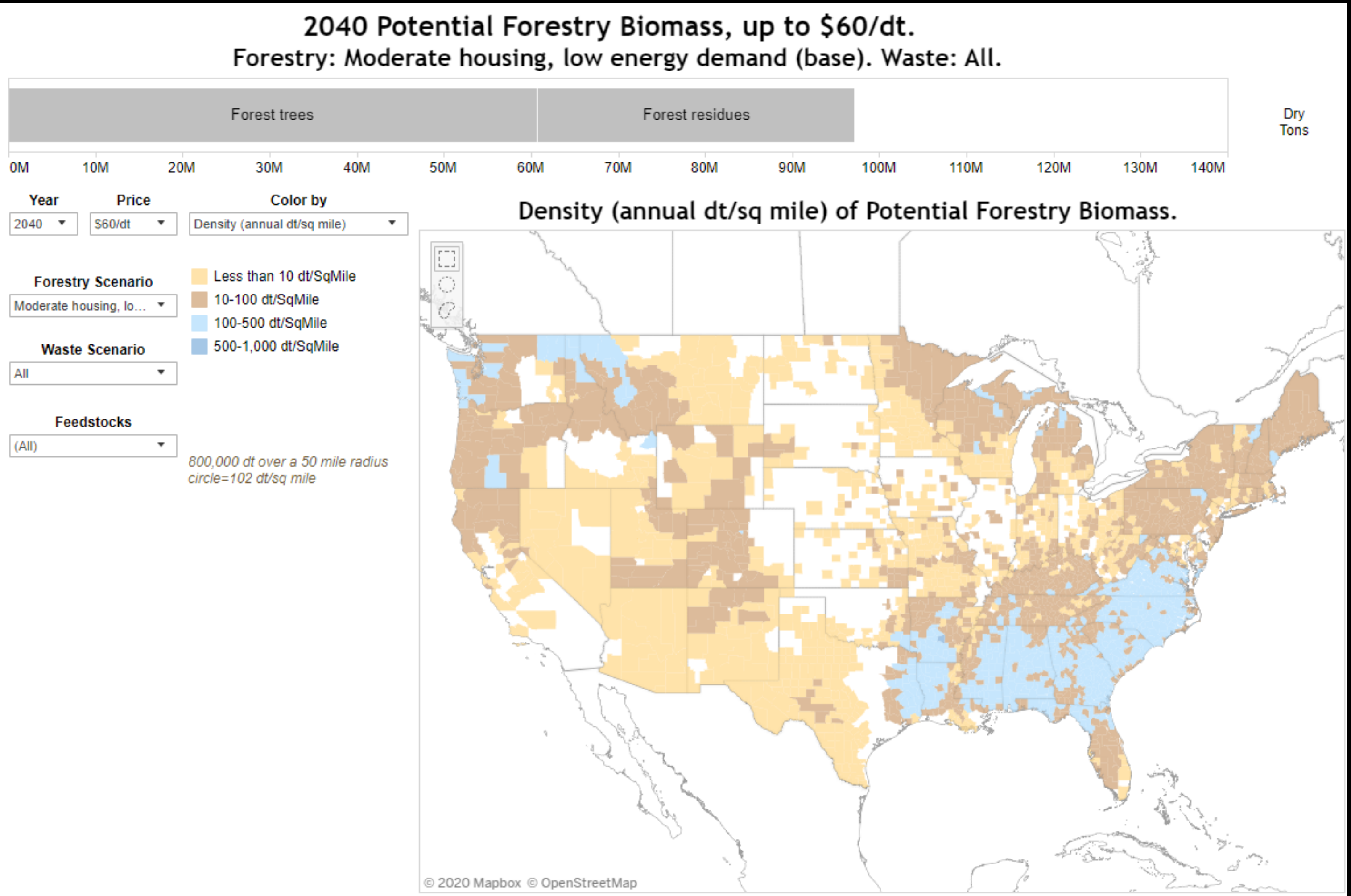
Wastes and residues



Please cite as: U.S. Department of Energy. 2016. 2016 Billion-Ton Report: Advancing Domestic Resources for a Thriving Bioeconomy, Volume 1: Economic Availability of Feedstocks. M. H. Langholtz, B. J. Stokes, and L. M. Eaton (Leads), ORNL/TM-2016/160. Oak Ridge National Laboratory, Oak Ridge, TN. 448p. doi: 10.2172/1271651.

- Biofuels made from wastes and residues do not require additional crops and land
- Sources of wastes and residues include corn stover, manure, as well as municipal solid waste

Forest biomass, including residues



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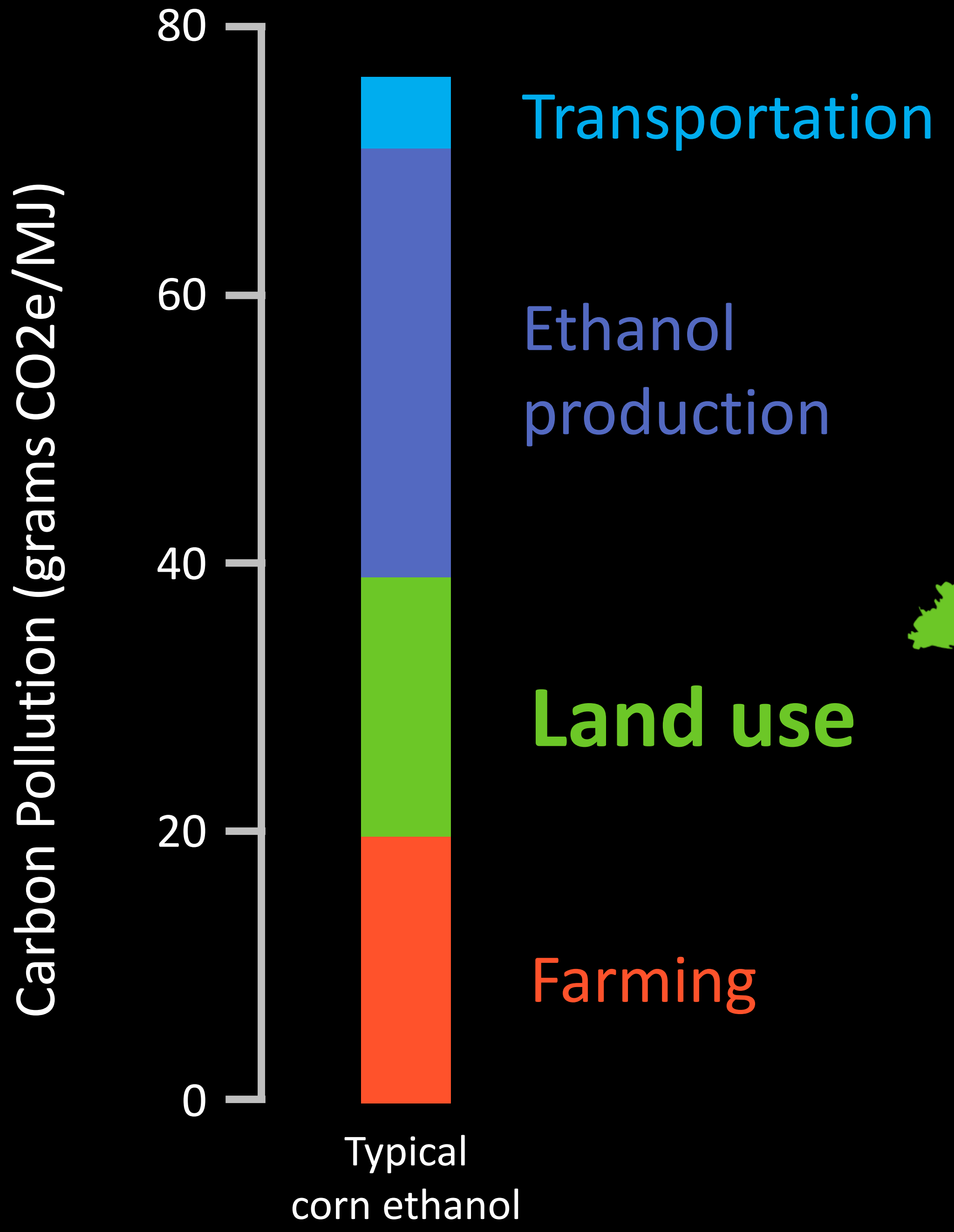
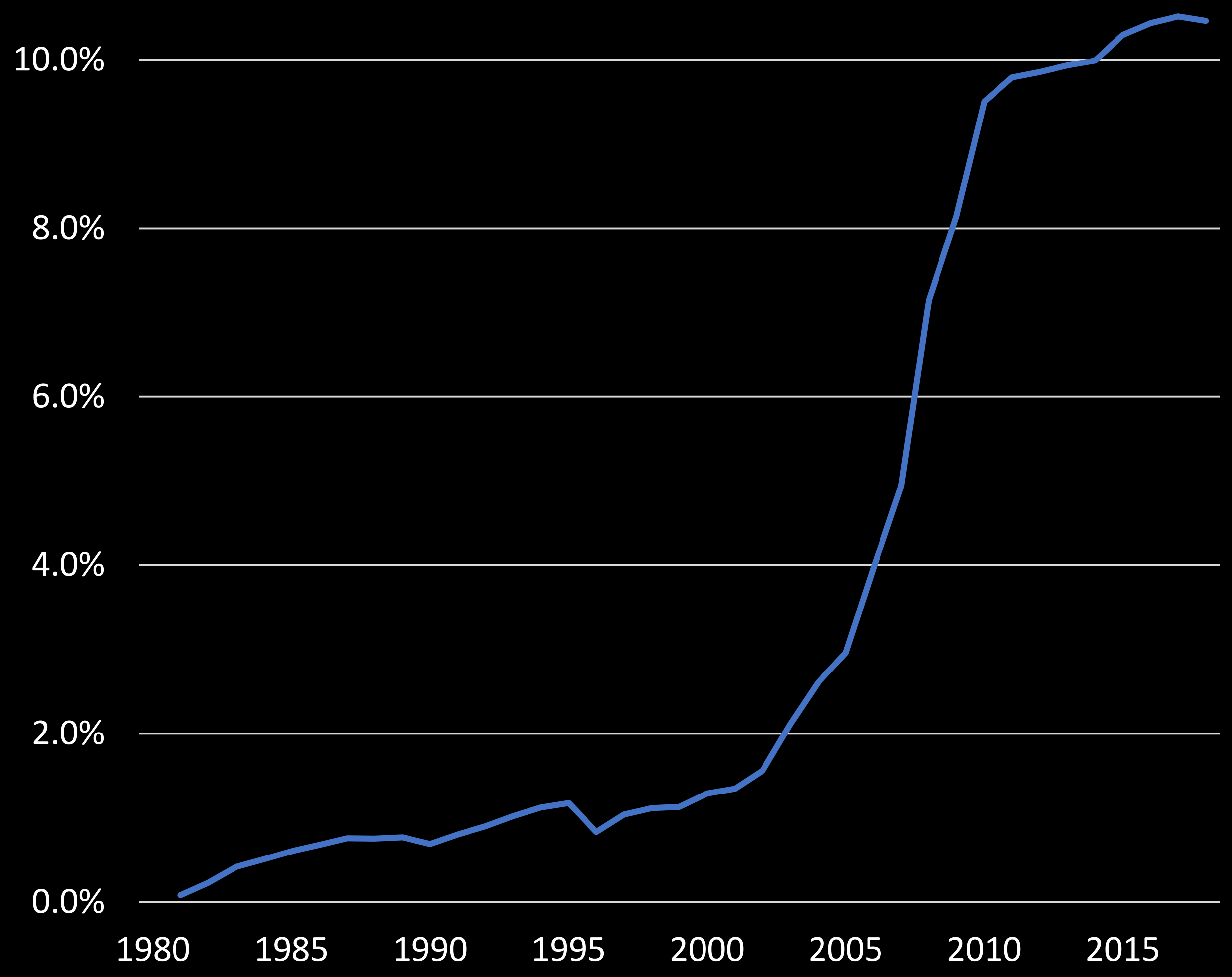
- Forest biomass is another resource for biofuel and bioenergy production
- Forest biomass includes wastes and residues from mills and forest operations without land use emissions
- Growing trees for bioenergy has climate costs and benefits that are part of the lifecycle



Land use emissions

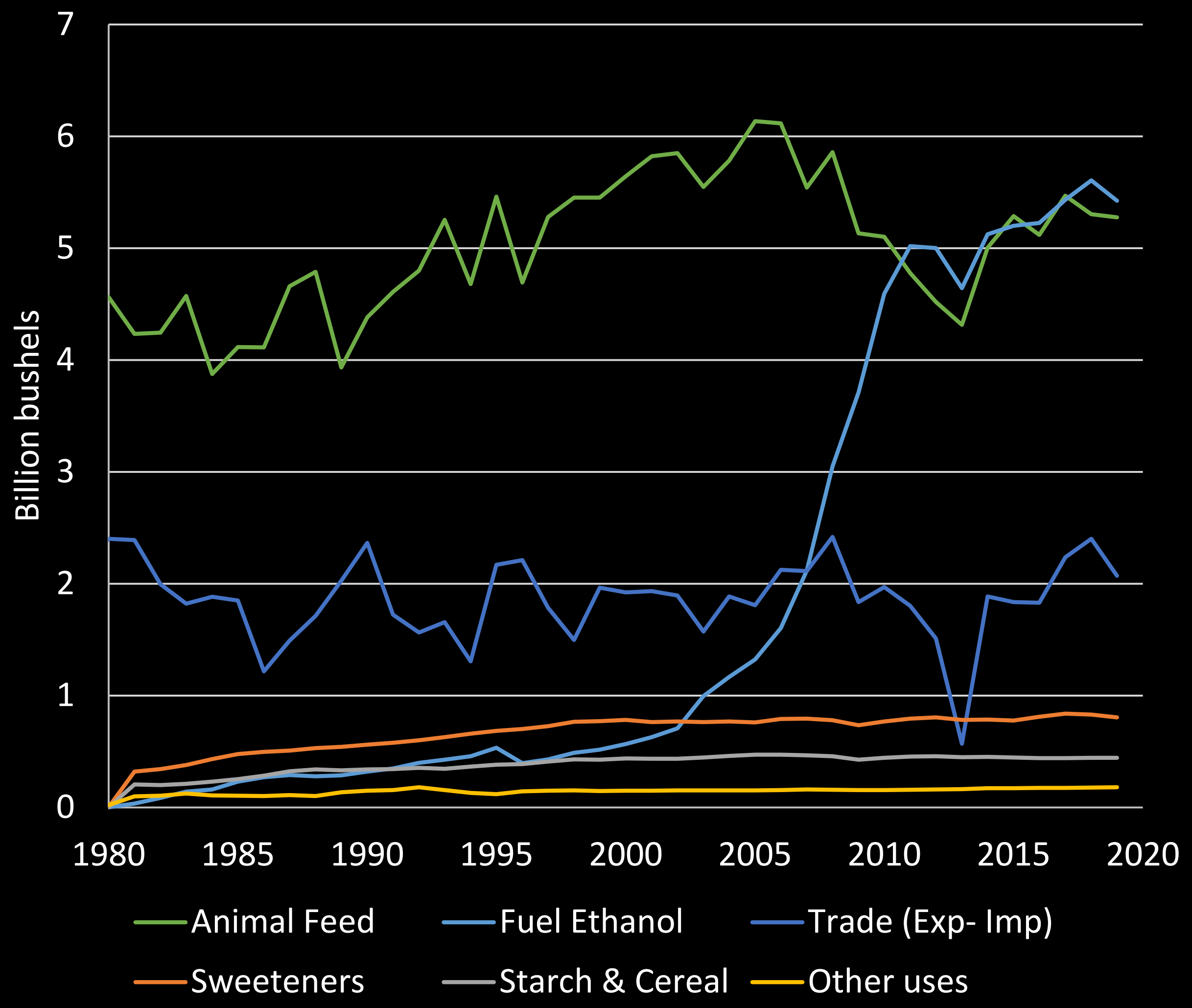
- Vigorous debates about land use modelling have led to a better understanding of complex global land use dynamics but not consensus on a precise land use emissions value
- But debates over complex models can obscure the commonsense reality that cropland is limited and serves multiple markets
- The scale of biofuel growth should be sensitive to competing demands for crops and land

Share of ethanol in gasoline



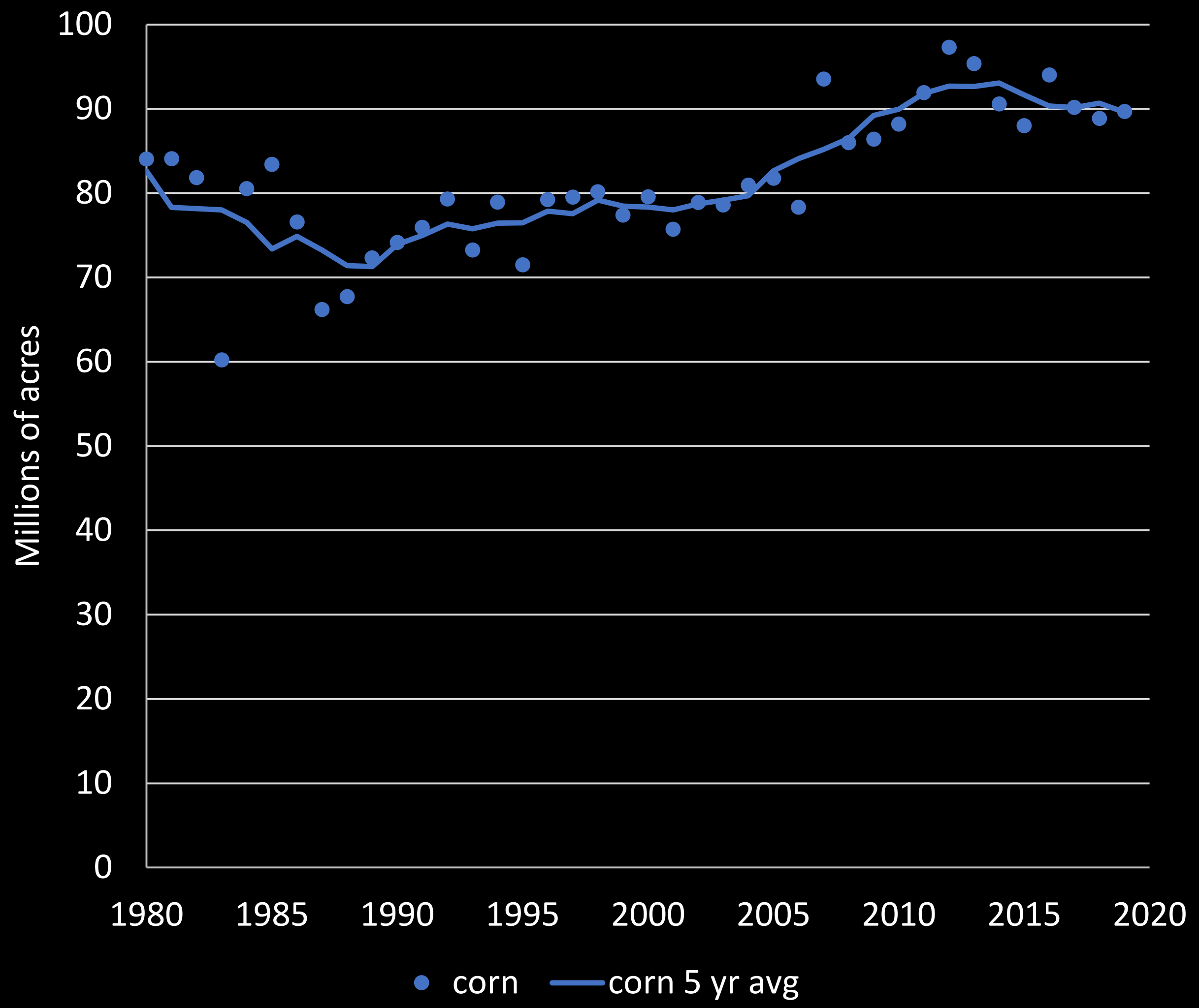
- The share of ethanol in gasoline grew rapidly between 2000 to 2010, especially after 2005
- By 2010 10% ethanol blending was the most common type of gasoline use nationwide, and have grown slowly
- Minnesota has the highest ethanol blending level, over 12%
- Only one other state, Iowa, is over 11%

Uses of U.S. corn: Source USDA-ERS



- US corn production used for ethanol grew from 600 million bushels in 2000 to 4.6 billion bushels in 2010
- In 2010, almost 40% of the corn crop was used to produce about 10 percent of the gasoline pool
- The rate of growth of total corn production vastly exceeded yield growth in this timeframe

Acres of Corn Planted USDA NASS Data

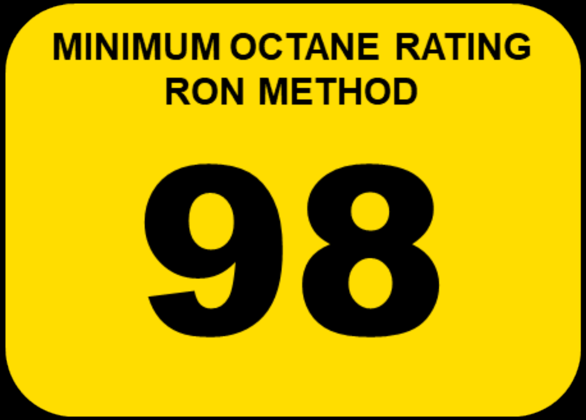


- As production grew faster than yield, total acreage of corn planted grew significantly
- Corn planting averaged less than 80 million acres in the 1980s and 1990s
- As E10 became the gasoline standard, corn planting grew to more than 90 million acres and then stabilized in recent years

Future Ethanol blends

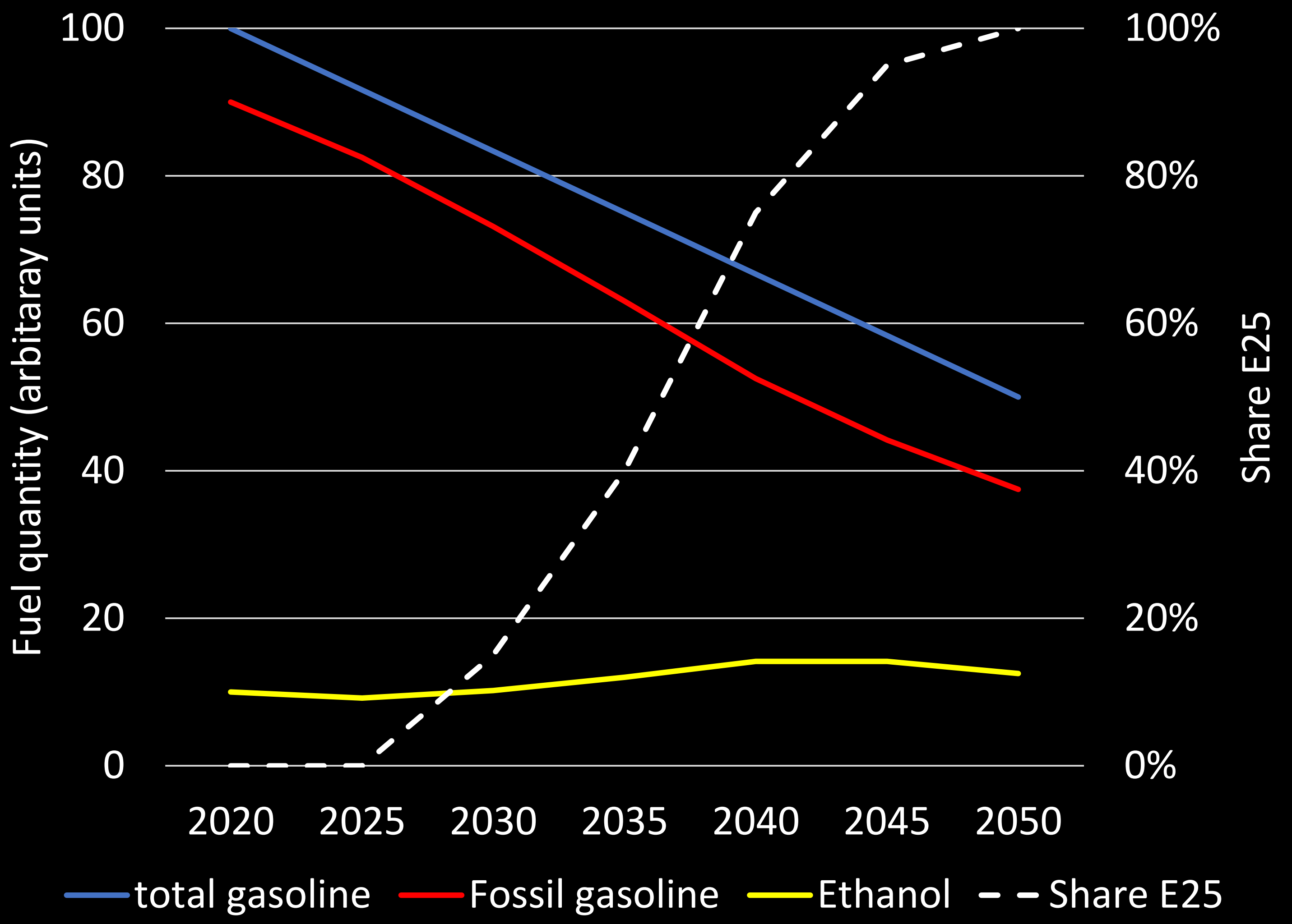
- The transition to E10 was disruptive, but happened about 10 years ago
- Several higher ethanol blends are plausible
  - E85 has been available for decades with progress limited to MN
  - E15 poised to grow, but how quickly it picks up nationwide is unclear
  - High octane gasoline could also be an opportunity longer term
- How would a transition to higher blends effect ethanol demand?

The future of octane and ethanol



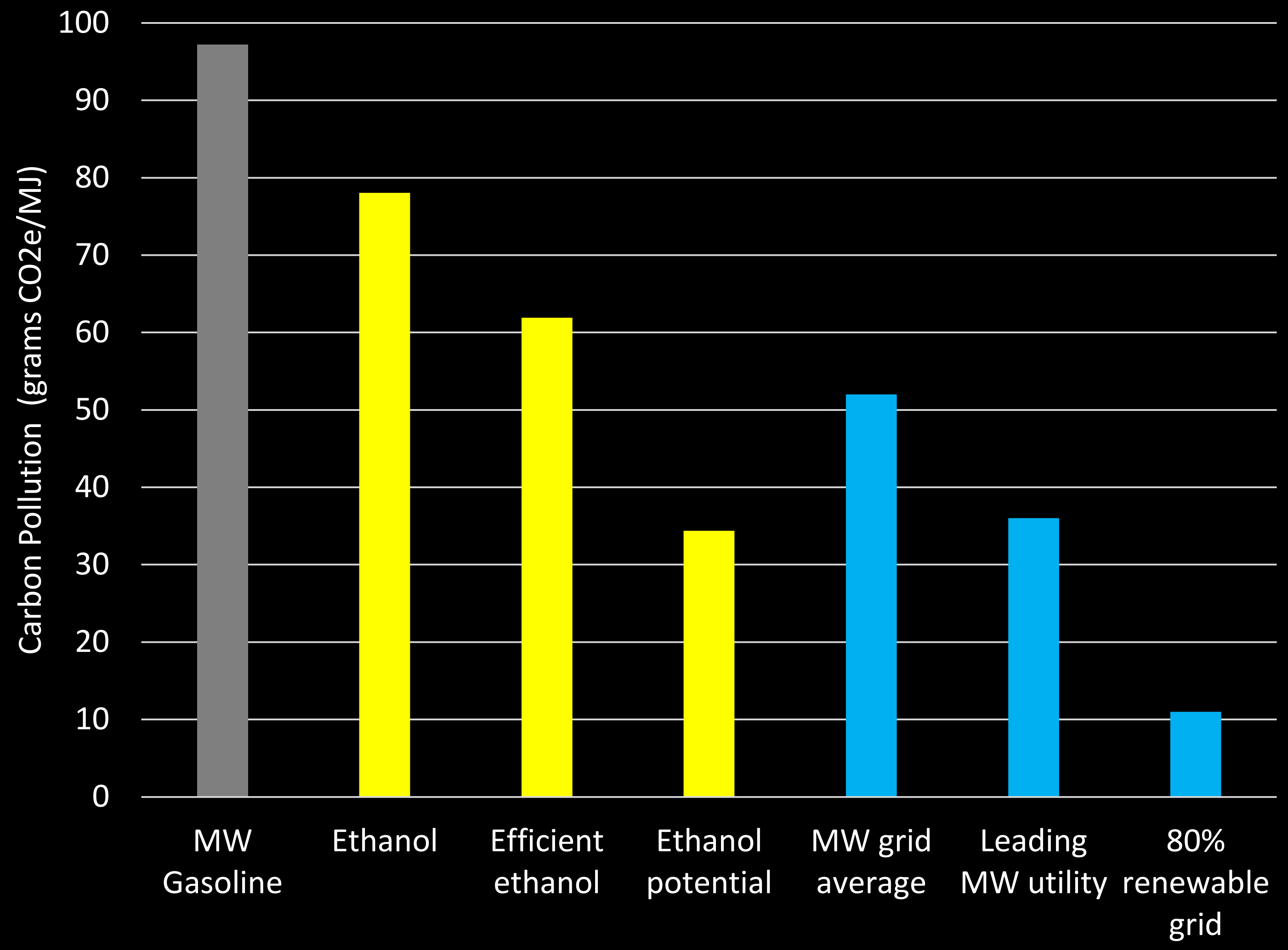
- Cars optimized for the higher octane of E25 (98 RON) can improve efficiency by about 5% versus E10
- This offsets the lower energy content, also about 5%
- Moving to a higher-octane standard (95 RON or 98 RON) could be met cost effectively with ethanol
  - 95 RON could also be met without ethanol, although with higher cost and emissions than with ethanol blending
- Would moving from E10 to E25 mean 2.5 times more ethanol and 2.5 time more corn?

Phasing in higher blends of ethanol



- Gasoline demand is poised to fall as cars get more efficient and EVs gain market share
- The COVID-19 crisis is pushing down short-term demand dramatically as well
- Balance rising ethanol blends with falling gasoline use can avoid demand shocks either up or down

Clean Fuels for the Midwest



- Biofuels and electricity are cleaner than gasoline today and can get cleaner over time.
- Fuels producers, farmers and utilities can reduce lifecycle transportation emissions
- A Clean Fuel Standard can advance emissions reductions from the fuel supply chain

Union of Concerned Scientists

FACT SHEET

Clean Fuels for the Midwest

Expanding the Use of Clean Fuels Will Deliver Economic and Climate Benefits

HIGHLIGHTS

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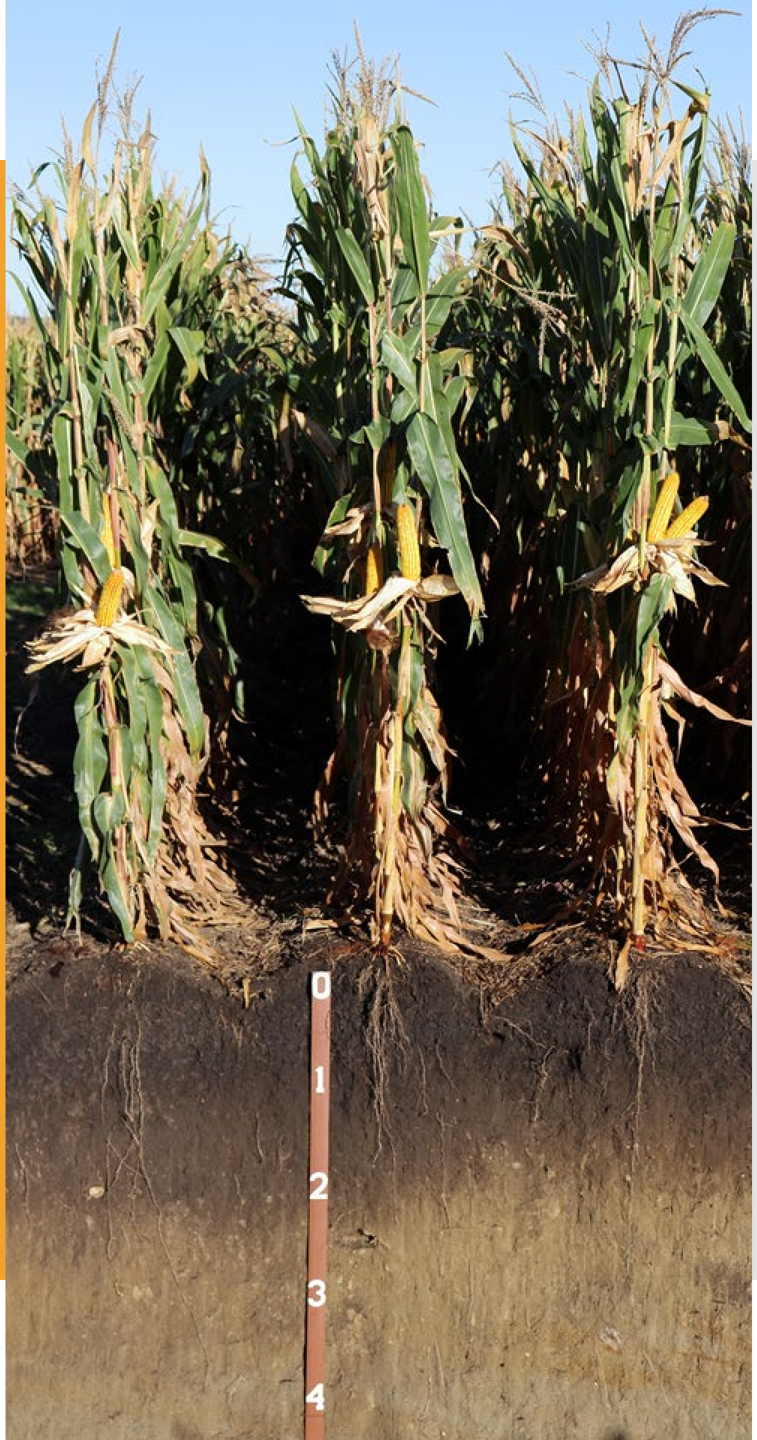
UCS Clean Fuel Resources

- Clean Fuels for the Midwest
  - ucsusa.org/resources/clean-fuels-midwest
- Fueling a Clean Transportation Future
  - ucsusa.org/FuelingaCleanFuture
- Or just reach out
  - Jeremy Martin
  - jmartin@ucsusa.org
  - 202 331 6946

Biofuel Feedstock Carbon Footprints in Low Carbon Fuel Markets

Ron Alverson
Crop Producer,
American Coalition for Ethanol BOD,
Dakota Ethanol BOD



Caiden and Connor Alverson

Potential 13th Generation "Alverson" Farmers in the United States

Massachusetts, Rhode Island, New York, Wisconsin, Minnesota, and South Dakota

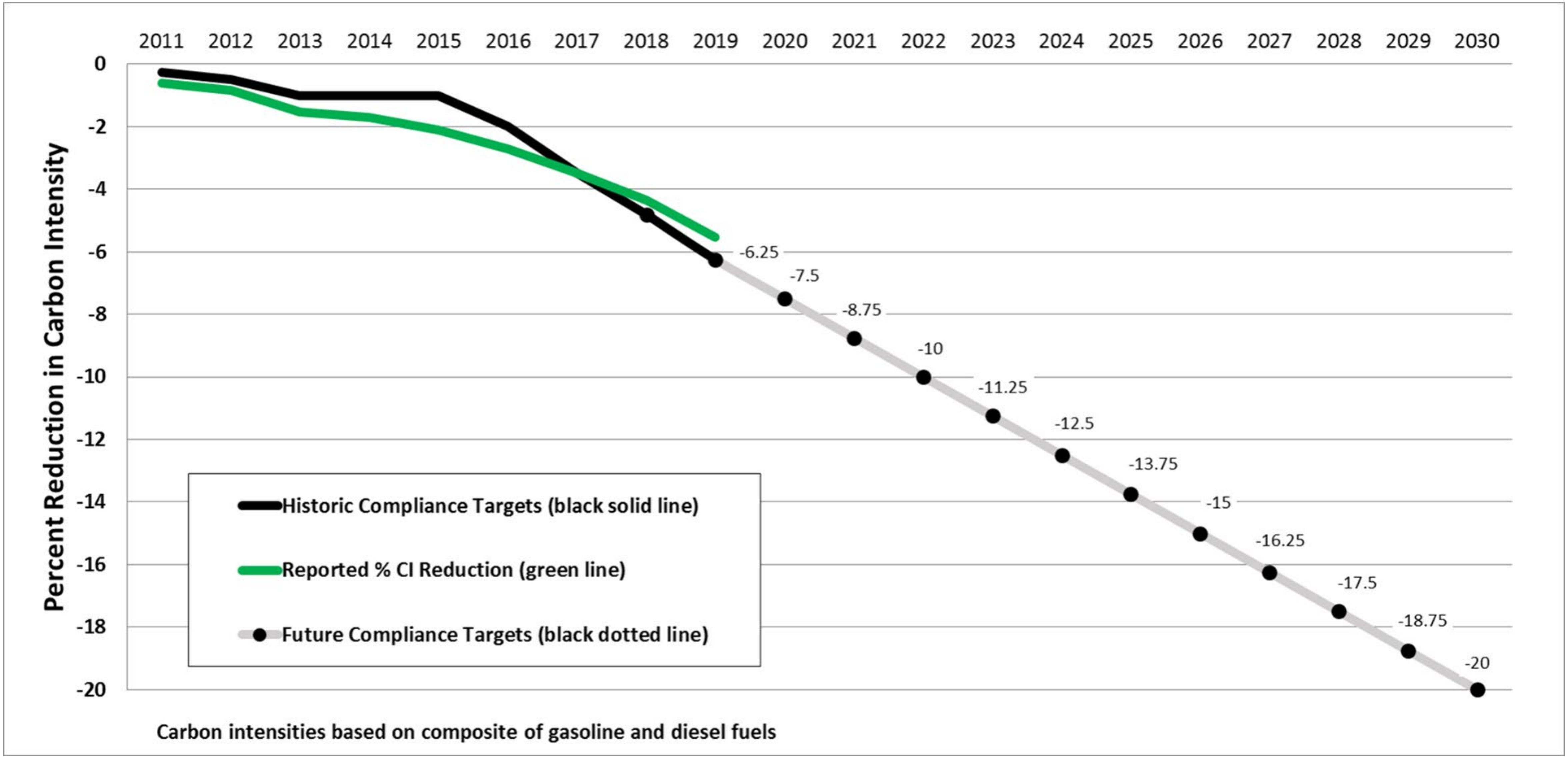
Topics

- 1. Low Carbon Fuel Standard Markets
- 2. Corn Ethanol GHG Accounting Basics
- 3. Mid-west Avg. and Minnesota Corn Ethanol GHGs
- 4. Carbon/GHG Accounting Issues and Low Carbon Corn Management
  - Soil Organic Carbon
  - Nitrous Oxide
  - Land Use Change
- 5. Future Corn Ethanol GHGs

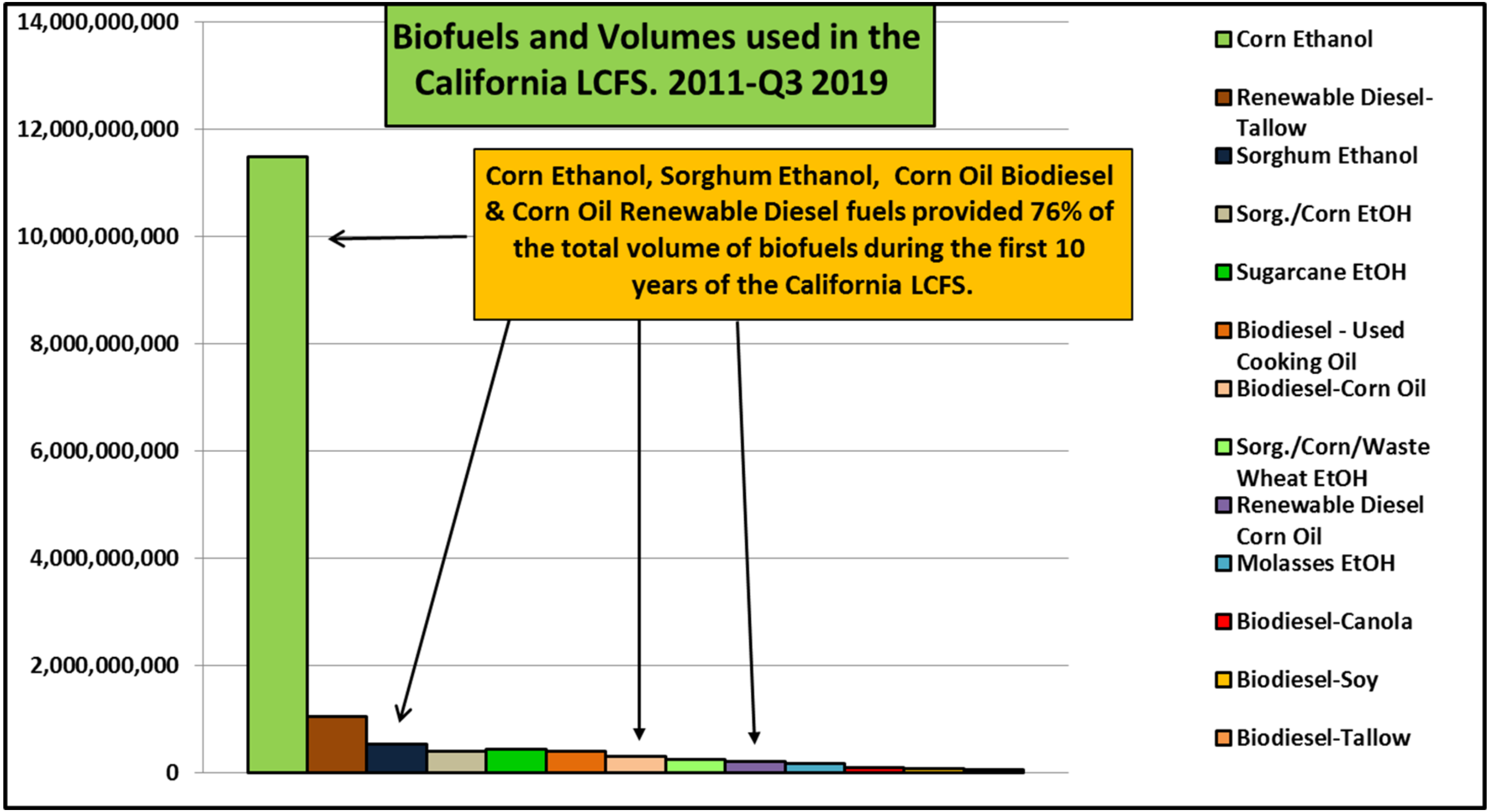
Low Carbon Fuel Markets

- California Low Carbon Fuel Standard
- Oregon Clean Fuels Program
- Clean Fuels Standard Canada
- Brazilian RENOVA-BIO
- European Union Clean Air Policy
- Potential New Programs
  - Puget Sound Clean Fuels Standard
  - New York State LCFS
  - Mid-west Clean Fuels Standard
  - Colorado LCFS

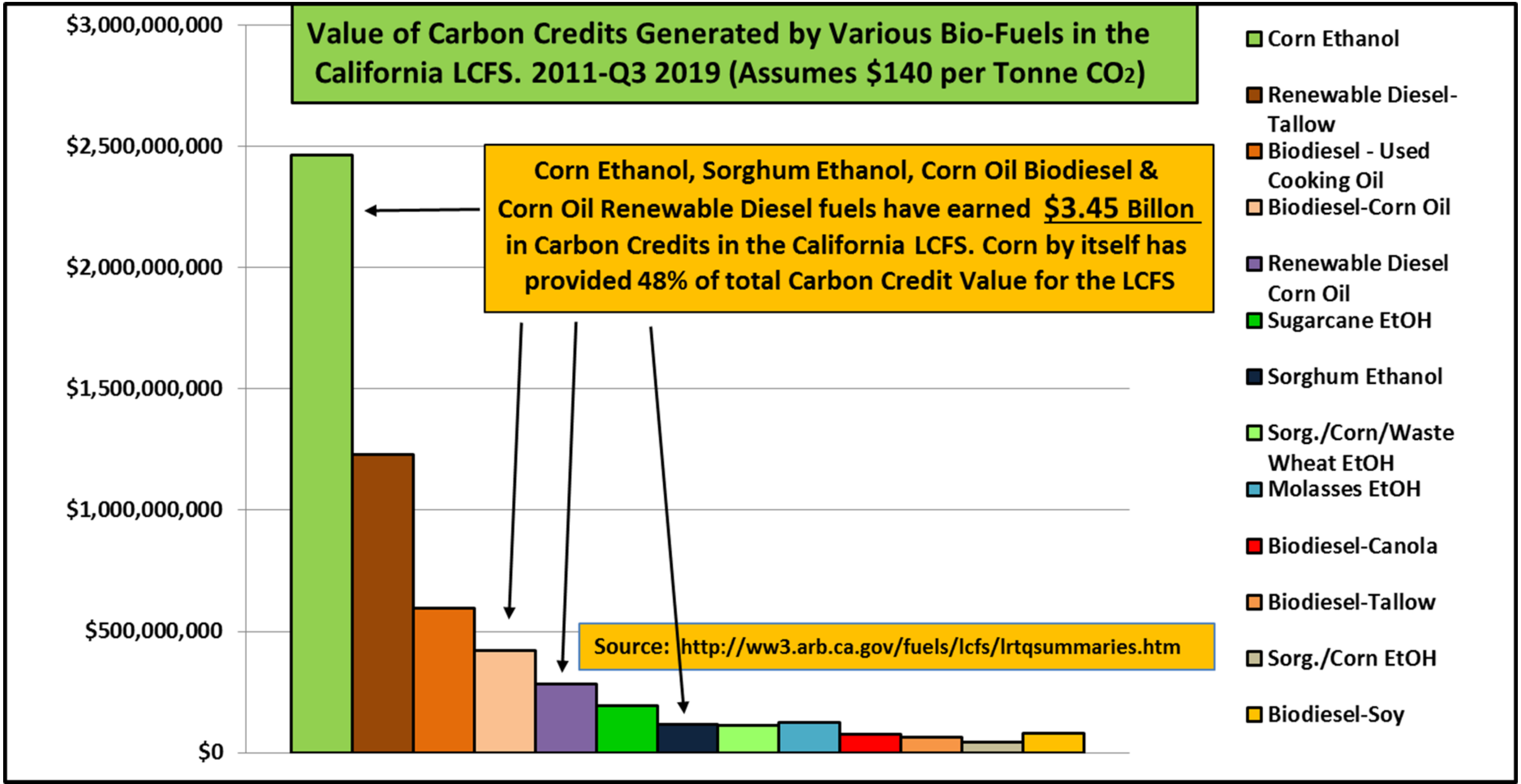
2011-2019 Performance of the California Low Carbon Fuel Standard

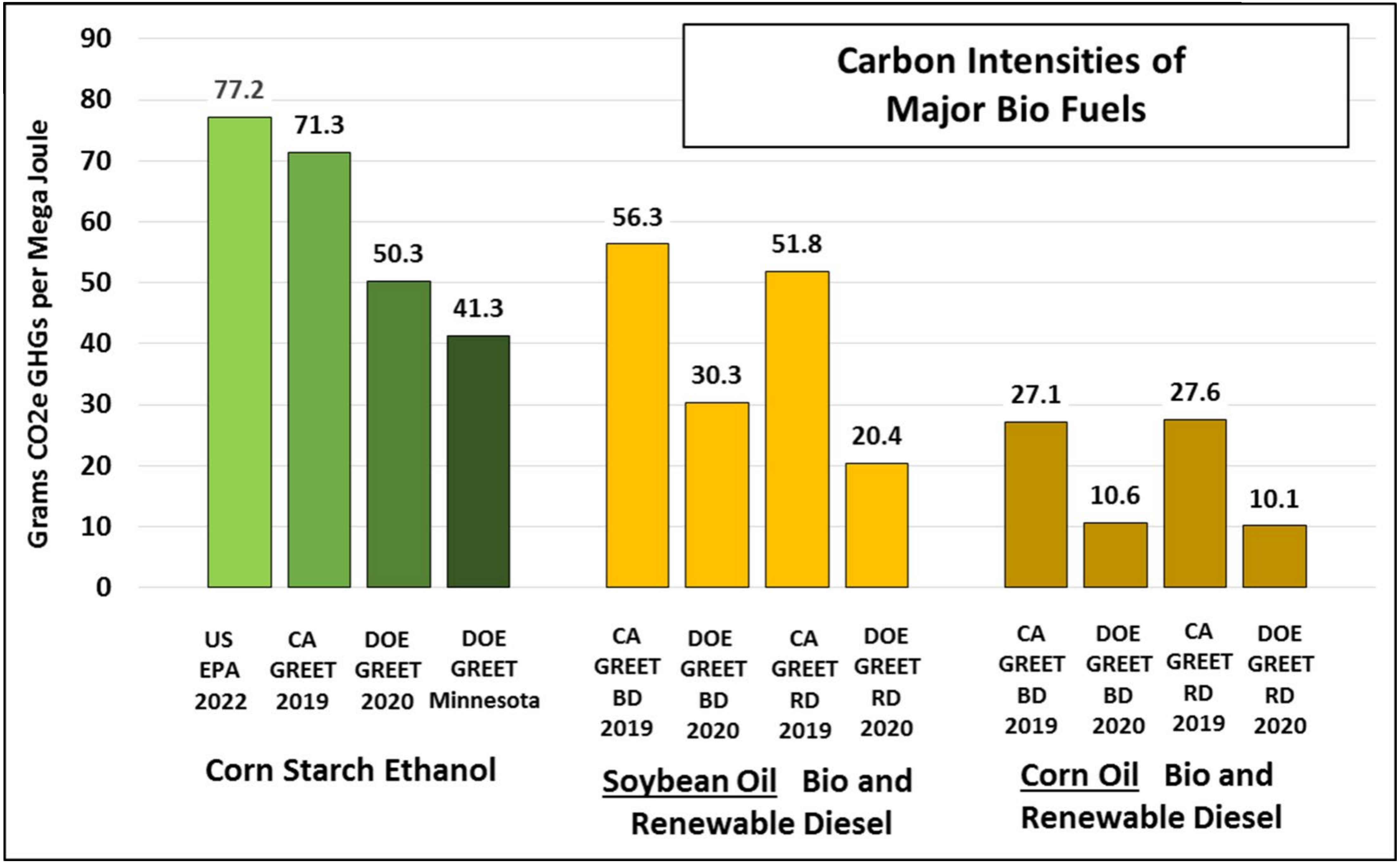


10 Years of the California Low Carbon Fuel Standard



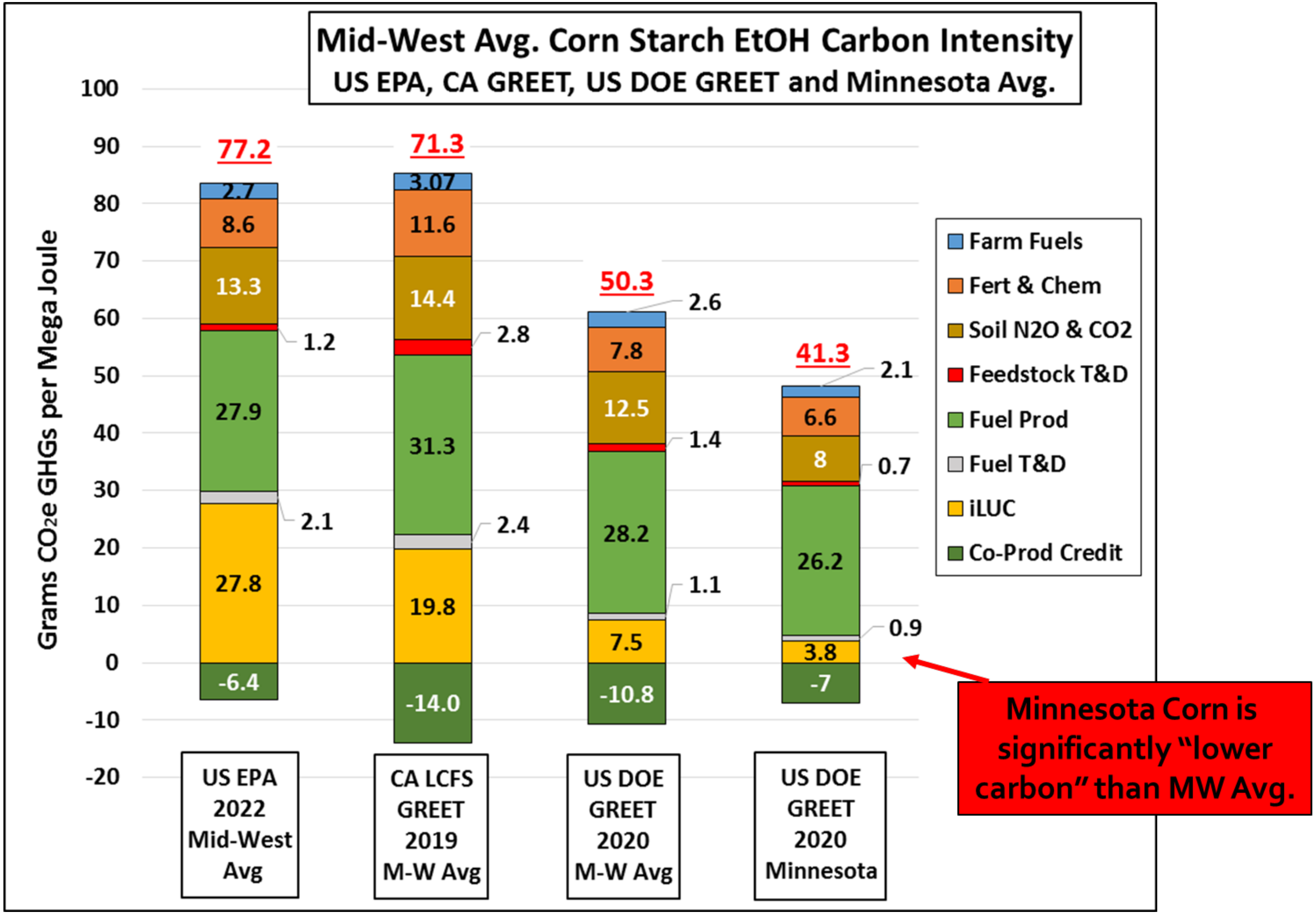
Value of Carbon Credits over 10 Years in the LCLS



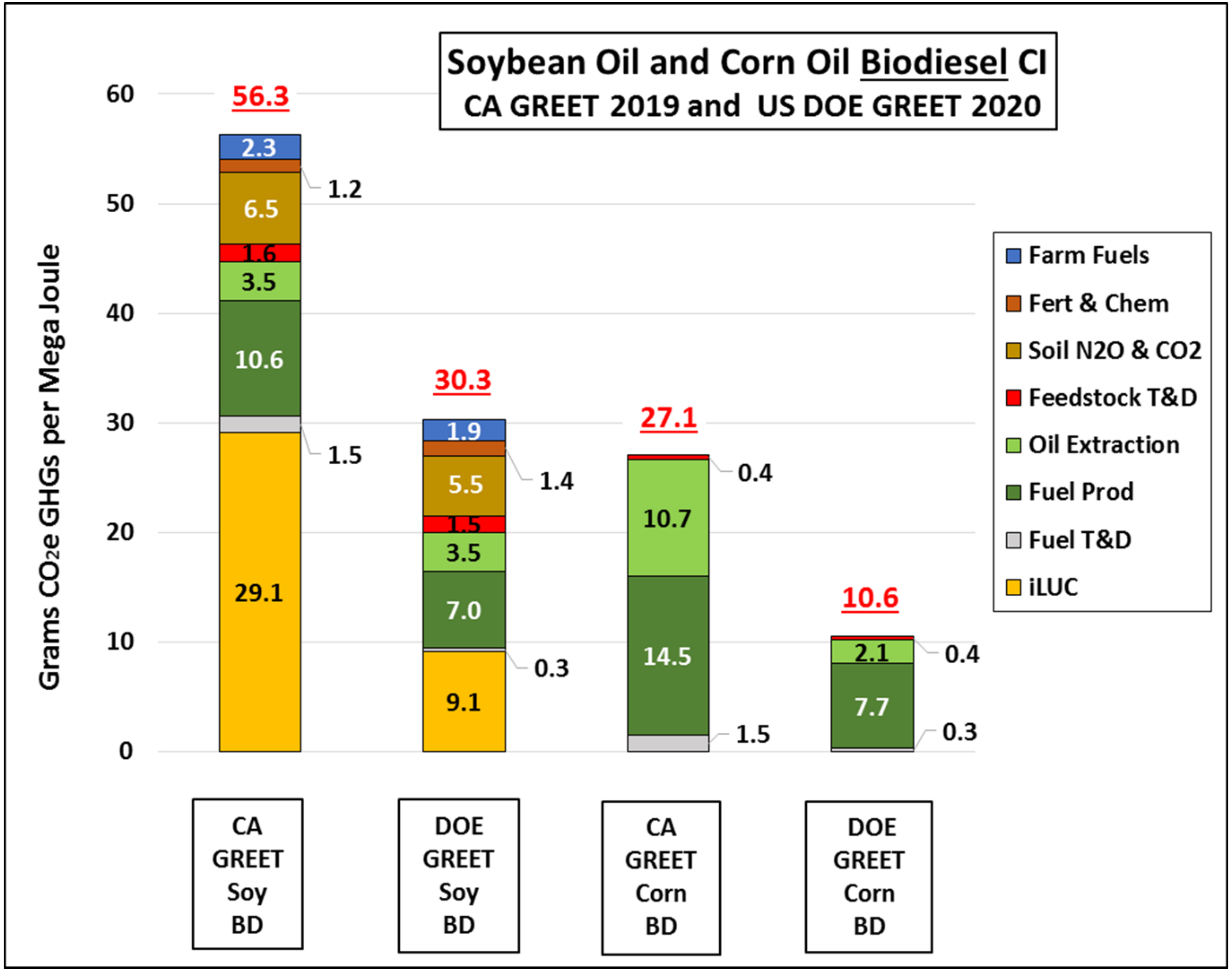

Carbon Intensities of Major Bio Fuels
Grams CO2e GHGs per Mega Joule
90
80
70
60
50
40
30
20
10
0
77.2
71.3
50.3
41.3
56.3
30.3
51.8
20.4
27.1
10.6
27.6
10.1
US EPA 2022
CA GREET 2019
DOE GREET 2020
DOE GREET Minnesota
CA GREET BD 2019
DOE GREET BD 2020
CA GREET RD 2019
DOE GREET RD 2020
CA GREET BD 2019
DOE GREET BD 2020
CA GREET RD 2019
DOE GREET RD 2020
Corn Starch Ethanol
Soybean Oil Bio and Renewable Diesel
Corn Oil Bio and Renewable Diesel

Details of Corn Ethanol Carbon Intensity

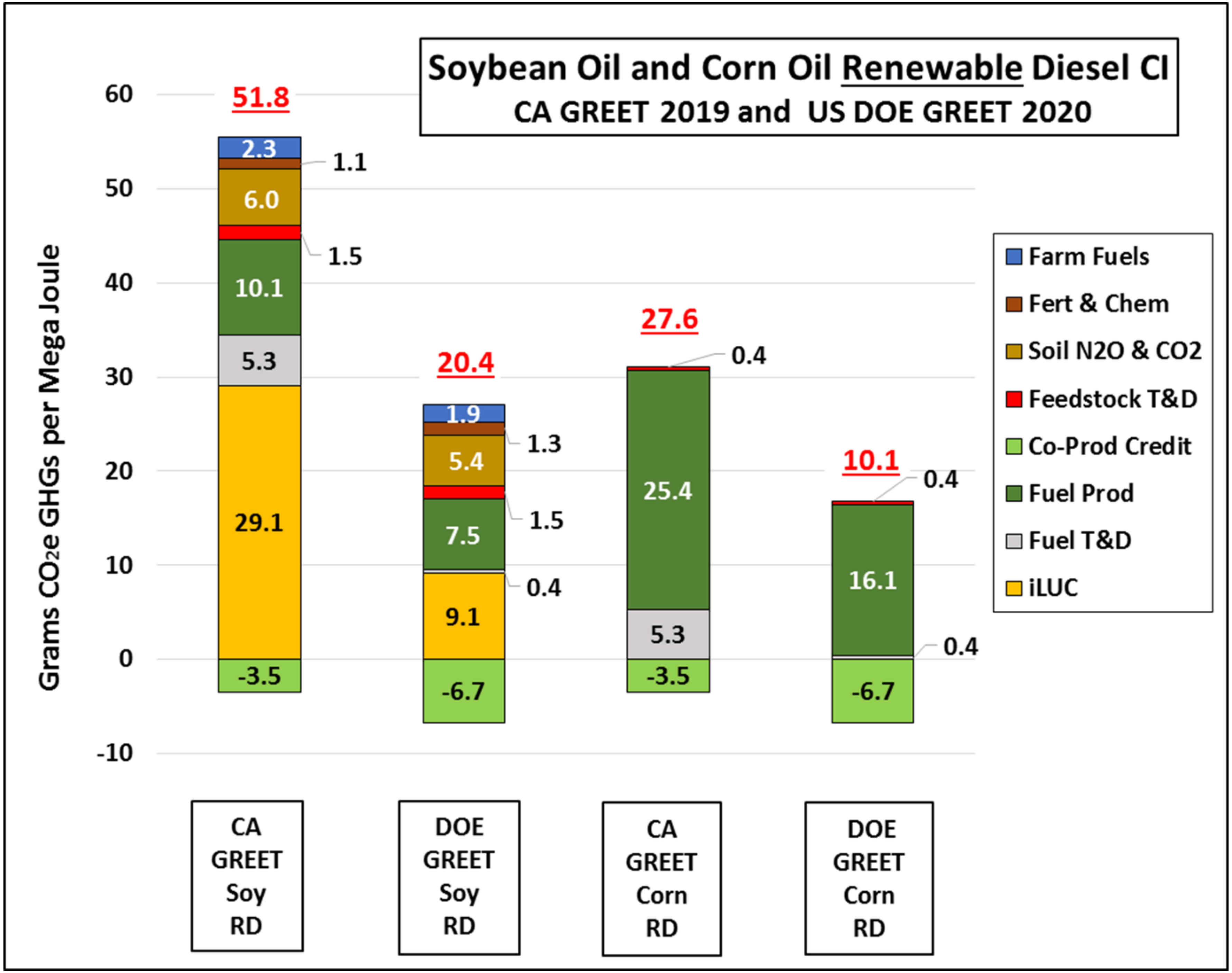
US EPA, California LCFS, and US Dept. of Energy GHG Models



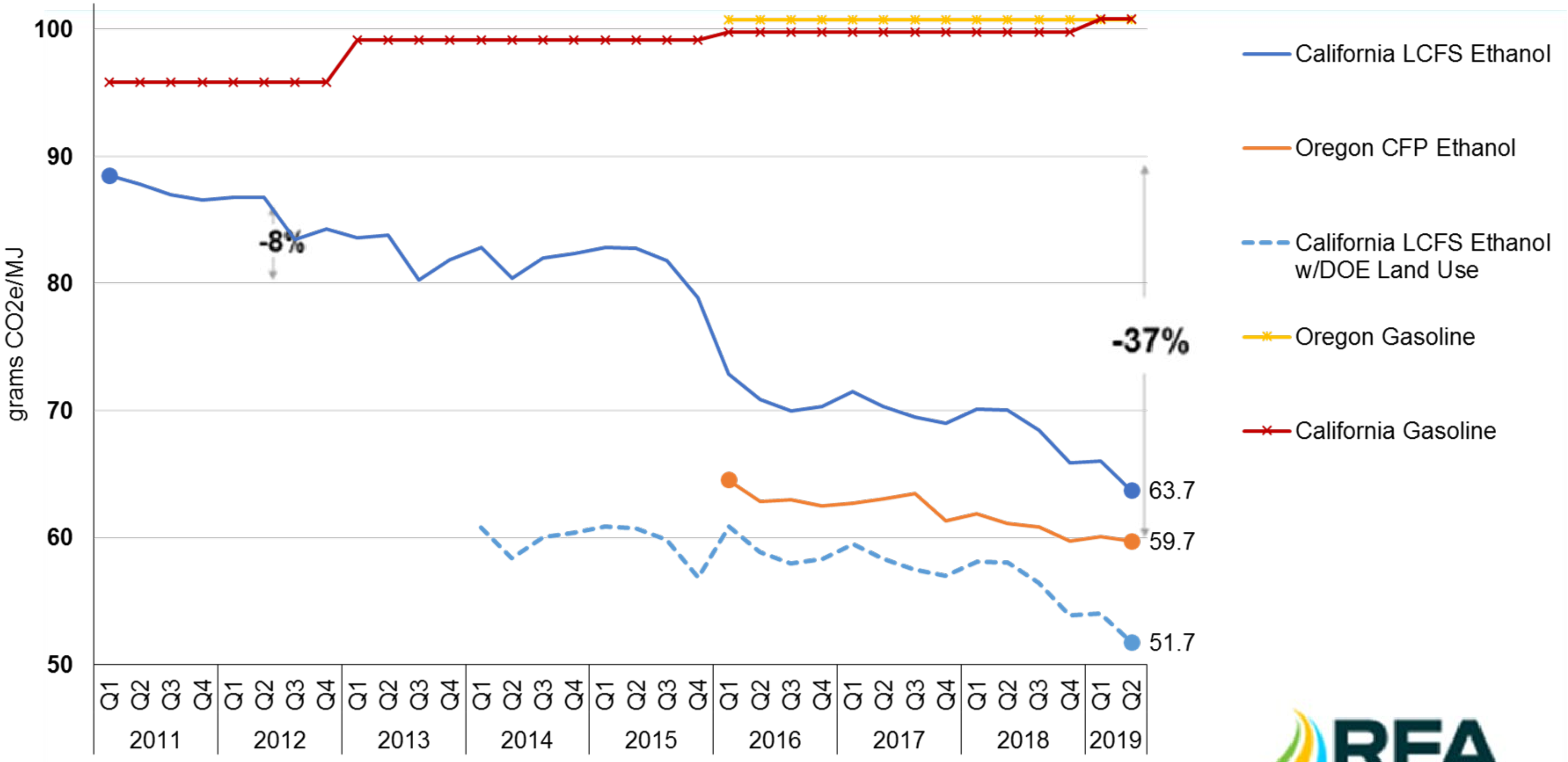
Details of Soy Oil and Corn Oil <u>Bio Diesel</u> Carbon Intensity



Details of Soy Oil and Corn Oil Renewable Diesel Carbon Intensity



Average Carbon Intensity of Corn Ethanol in the California LCFS and Oregon CFP Markets



Steady Reductions in Corn Ethanol CI in the CA LCFS Program

Carbon Intensity Calculation Basics

(Grams CO_2 Equivalent GHG Emissions per Mega Joule of Energy Production)

CA-GREET Model

Energy Production	
Corn Yield (bu/ac)	166
EtOH Yield (gal/bu)	2.88
Mega Joules/gal EtOH	80.5
Mega Joules/Acre	38,527

Corn Production GHG Emissions		Grams CO_2e Emissions	Grams CO_2e per Mega Joule
Nitrogen (lbs/ac)	140	296,269	7.69
P2O5 (lbs/ac)	50.9	33,133	0.86
K2O (lbs/ac)	53.5	14,640	0.38
Lime (pH control) (lbs/ac)	472	48,543	1.26
Herbicides (lbs a.i./acre)	2.14	16,566	0.43
Insecticides (lbs a.i./acre)	0.01	39	0.001
Diesel Fuel (gals/acre)	9.1	110,956	2.88
Gasoline (gals/ac)	1.43	15,796	0.41
Natural Gas (cu.ft./acre)	158	14,640	0.38
Propane (gals/acre)	2.45	19,263	0.5
Electricity (kWh/acre)	15.47	5,008	0.13
Soil N_2O from N fertilizer		470,024	12.2
Soil CO_2 from N fertilizer		57,790	1.5
Total Corn Production Emissions/Acre		**1,102,667**	**28.6**

CA-GREET Model

	Grams CO_2e Emissions	Grams CO_2e per Mega Joule
Total Corn Production Emissions	**1,102,667**	**28.6**
Co-Product Credits	**(477,729)**	**(12.4)**
Land Use Change	**762,825**	**19.8**
Ethanol Plant GHG Emissions		
Natural Gas	1,040,216	27
Electrical Energy	169,517	4.4
Chemicals	68,346	1.8
Ethanol Transportation	37,294	0.97
Denaturant	42,379	1.1
Total	**1,357,752**	**35.3**
Total Corn Ethanol Emissions	**2,745,515**	**71.3**

How does Minnesota Corn Production Compare to Mid-West Average?

Source:
USDA National Agriculture Statistics Service

Comparing California GREET Mid-west Average Corn Production Emissions with US DOE GREET 2020 Minnesota Avg. Corn Production Emissions	California GREET Mid-West Avg.	Grams CO_2e/ Mega Joule	US DOE GREET 2020 Minnesota	Grams CO_2e/ Mega Joule	Notes:
Corn Yield (bu/ac)	166		186		
Corn to EtOH Conversion (gal/bu)	2.882		2.955		
Mega Joules per gallon EtOH	80.53		80.53		15% More Mega Joules per Acre
Mega Joules per Acre of EtOH	**38,527**		**44,262**		(higher corn and ethanol yields)
Nitrogen Fertilizer (lbs/ac)	140	7.69	131.9	5.1	2018 USDA NASS Avg. Fertilizer
P_2O_5 Fertilizer (lbs/ac)	50.9	0.86	58.6	0.86	application rates for Minnesota
K_2O Fertilizer (lbs/ac)	53.5	0.38	65.5	0.40	
Lime (pH control) (lbs/ac)	472	1.26	235	0.55	
Herbicides (lbs a.i./acre)	2.14	0.43	2.0	0.42	
Insecticides (lbs a.i./acre)	0.01	0.001	0.01	0.001	
Diesel Fuel (gals/acre)	9.1	2.88	6.1	1.82	Reduced corn transportation distances
Gasoline (gals/ac)	1.43	0.41	1.43	0.26	and use of biofuel blends in Mn.
Natural Gas (cu.ft./acre)	158	0.38	158	0.34	
Propane (gals/acre)	2.45	0.50	2.45	0.44	
Electricity (kWh/acre)	15.47	0.13	15.47	0.11	
Soil N_2O from N fertilizer		12.2		8.3	Lower N rates & leaching losses, some
Soil CO_2 from N fertilizer		1.5		1.3	4R N Mgmt. and Nitrification Inhibitors
Total Corn Production Emissions		**28.6**		**19.9**	

Biofuel Carbon Modeling Improvements…

Currently, Biofuel Carbon Modelers do not account for Individual Biofuel Feedstock
"Soil Carbon Effects"

Modelers assume Biofuel Feedstock Crops such as Corn, Soybeans and Sugar Cane all have the same effect on Soil Carbon Stocks - ZERO

Biofuel Carbon Modelers say there is too much uncertainty regarding feedstock soil carbon effects

Soil Carbon Models aren't "good enough", it has been said?

Yet, biofuel carbon modelers use these very same soil carbon models to determine Biofuel Land Use Change soil carbon effects?

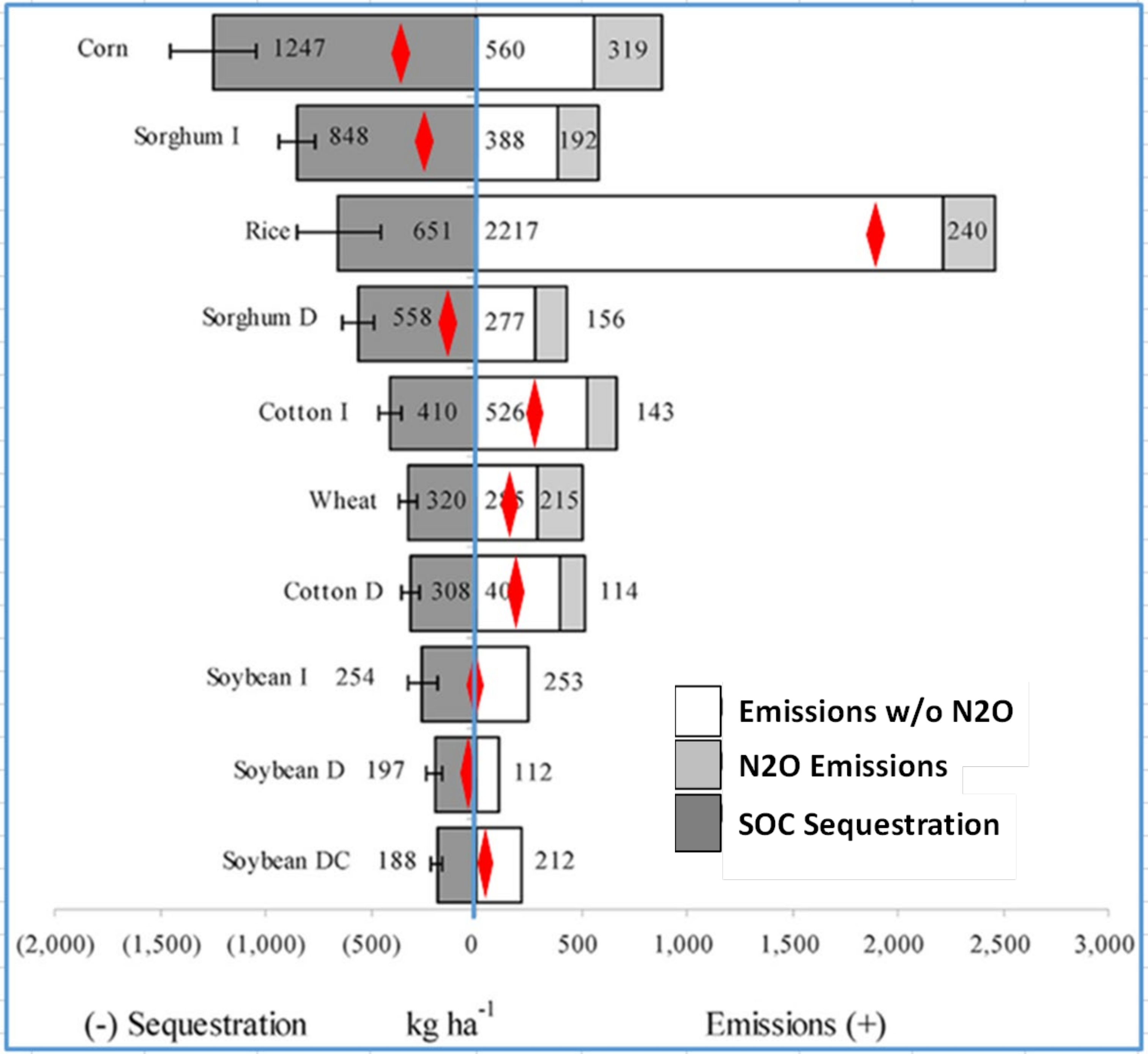
Why this double standard?

What do Crop and Soil Scientists say?
Are crops different, with respect to their effects on SOC?

Popp et al. 2011

Estimating Crop Net Carbon Emissions and Agricultural Response to Potential Carbon Offset Policies

Fig. 1. Carbon equivalent emissions and sequestration by crop including variation in C sequestration due to yield, soil, and tillage effects; I = irrigated, D = unirrigated or dryland, DC = double cropped. Error bars on the sequestration side include variation due to yield, soil type, and tillage effects but exclude expected variation in harvest index and root/shoot ratio. Also note that soybean production entailed no N fertilizer application and hence no N2O emissions. Additional uncertainty, especially pertaining to N2O emissions, exists and is not shown here.



Michigan State University Cropland GHG Calculator

http://surf.kbs.msu.edu/

(The effects of crops, yield, and tillage intensity on Soil Organic Carbon)

SOC sequestration - Mg CO_2 per acre per year (negative values indicate SOC sequestration, positive numbers SOC losses)

National Avg. Yields

Corn Yield

Tillage	90	100	110	120	130	140	150	160	170	180	190	200	210	220	230	240	250	260	270	World Yield Records 616.19
No-till	-0.14	-0.19	-0.24	-0.28	-0.33	-0.38	-0.42	-0.47	**-0.52**	-0.56	-0.61	-0.66	-0.70	-0.75	-0.80	-0.84	-0.89	-0.93	-0.98	-2.62
Reduced	0.01	-0.02	-0.05	-0.08	-0.11	-0.14	-0.17	-0.20	**-0.23**	-0.26	-0.29	-0.32	-0.35	-0.38	-0.41	-0.44	-0.47	-0.50	-0.53	-1.56
Conventional	0.08	0.06	0.03	0.01	-0.01	-0.03	-0.06	-0.08	**-0.10**	-0.13	-0.15	-0.17	-0.19	-0.22	-0.24	-0.26	-0.28	-0.31	-0.33	-1.09

Soy Yield

Tillage	26	29	32	35	38	41	44	47	50	53	56	59	62	65	68	71	74	77	80	190.23
No-till	0.10	0.05	0.05	0.03	0.01	-0.02	-0.04	-0.06	**-0.09**	-0.11	-0.13	-0.16	-0.18	-0.20	-0.23	-0.25	-0.27	-0.30	-0.32	-1.17
Reduced	0.18	0.15	0.15	0.14	0.12	0.11	0.09	0.08	**0.06**	0.05	0.03	0.02	0.00	-0.01	-0.03	-0.04	-0.06	-0.07	-0.09	-0.61
Conventional	0.21	0.19	0.19	0.18	0.17	0.16	0.15	0.14	**0.13**	0.11	0.10	0.09	0.07	0.07	0.06	0.05	0.04	0.03	0.02	-0.36

Wheat Yield

Tillage	26	29	32	35	38	41	44	47	50	53	56	59	62	65	68	71	74	77	80	249.68
No-till	0.07	0.04	0.02	-0.01	-0.03	-0.06	-0.08	-0.10	**-0.13**	-0.15	-0.18	-0.20	-0.22	-0.25	-0.27	-0.30	-0.32	-0.35	-0.37	-1.74
Reduced	0.15	0.14	0.12	0.11	0.09	0.07	0.06	0.04	**0.03**	0.01	0.00	-0.02	-0.03	-0.05	-0.06	-0.08	-0.09	-0.11	-0.12	-0.96
Conventional	0.19	0.18	0.17	0.15	0.14	0.13	0.12	0.11	**0.10**	0.09	0.08	0.06	0.05	0.04	0.03	0.02	0.01	0.00	-0.01	-0.61

2015 Paris Climate Summit (COP21)

Launch of the 4 Per Thousand Initiative

Goal to Increase Soil Carbon Stocks by .4% annually in 0-40 cm (0-16 inch) soil profiles

(Assuming 2% Organic Matter in 0-40 CM soil profile, this increase is .24 Mg.C/Ha/Yr)

0.4 Mg C/ha/yr results in a 16 gram/mega joule soil carbon sequestration credit to the corn ethanol life cycle!

Soil carbon sequestration potential of US croplands and grasslands: Implementing the 4 per Thousand Initiative. *Journal of Soil and Water Conservation*

Adam Chambers, Rattan Lal, and Keith Paustian

Adam Chambers is a co-leader of the Energy and Environmental Markets Team at the USDA Natural Resources Conservation Service, West National Technology Support Center, Science and Technology Deputy Area, Portland, Oregon. Rattan Lal is director of the Carbon Management and Sequestration Center, The Ohio State University, Columbus, Ohio. Keith Paustian is professor of Soil Ecology, Department of Soil and Crop Sciences and Senior Research Scientist, Natural Resource Ecology Laboratory, Colorado State University, Fort Collins, Colorado.

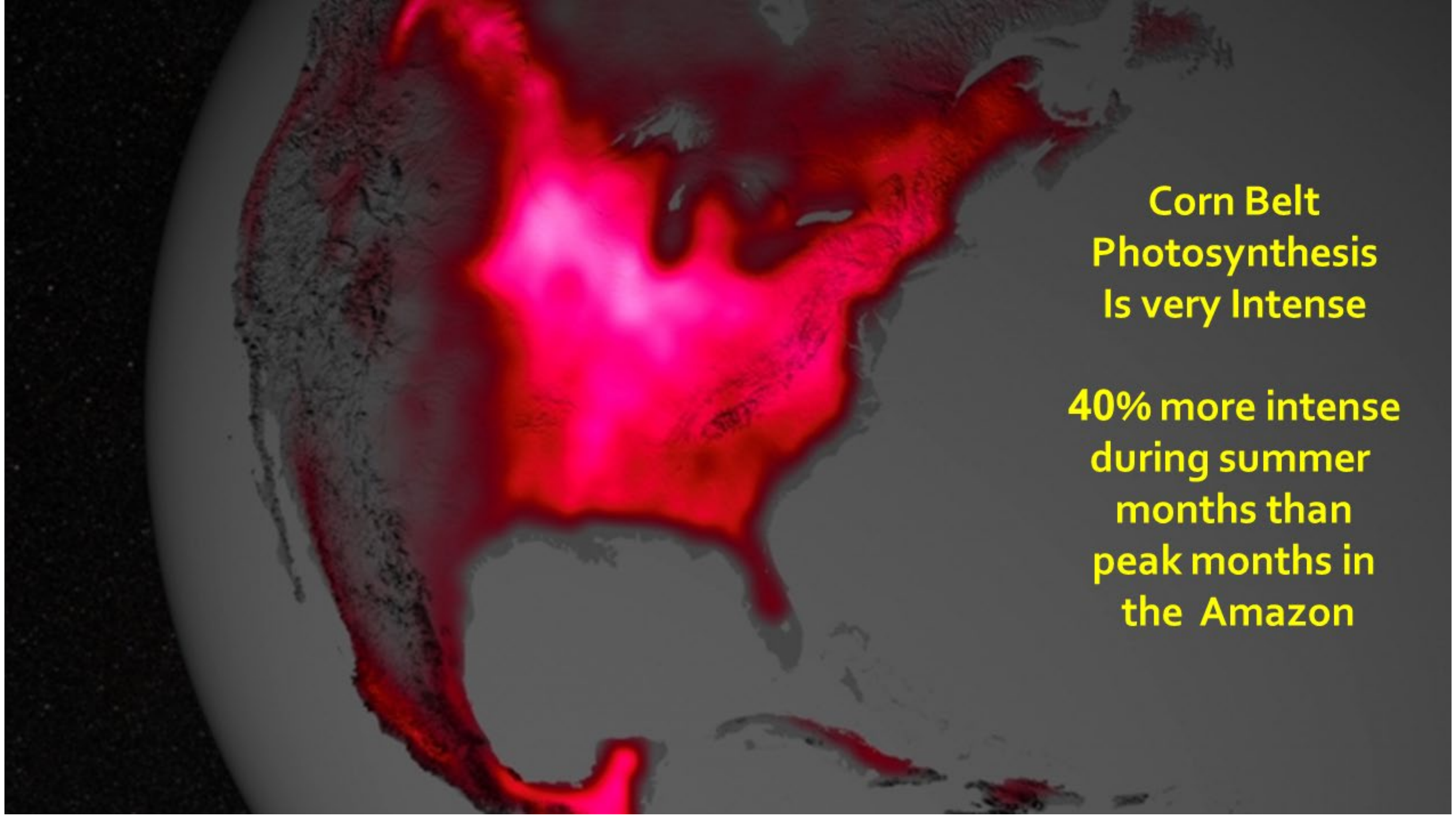
Table 1

Potential of US soils to sequester carbon (C) and mitigate climate change.

	Land area*	Rate	Total potential	
Ecosystem	(Mha–1)	(Mg C ha–1 y–1)	(Tg C y–1)	Reference
Cropland	156.9	0.3 to 0.5	45 to 98	Lal et al. (1998c)
Grazing land	336.0	0.04 to 0.21	13 to 70	Follett et al. (2001)
Forest land	236.1	0.11 to 0.43	25 to 102	Kimble et al. (2002)
Land conversion	16.8	0.125 to 0.46	21 to 77	Lal et al. (2003)
Soil restoration	498.4	0.05 to 0.12	25 to 60	Lal et al. (2003)
Other land use	166.0	0.09 to 0.15	15 to 25	Lal et al. (2003)
Total			144 to 432 (288)	Lal et al. (2003)

*Land area under different uses cannot be added because of the overlap with total area where "soil restoration" practices could be implemented.

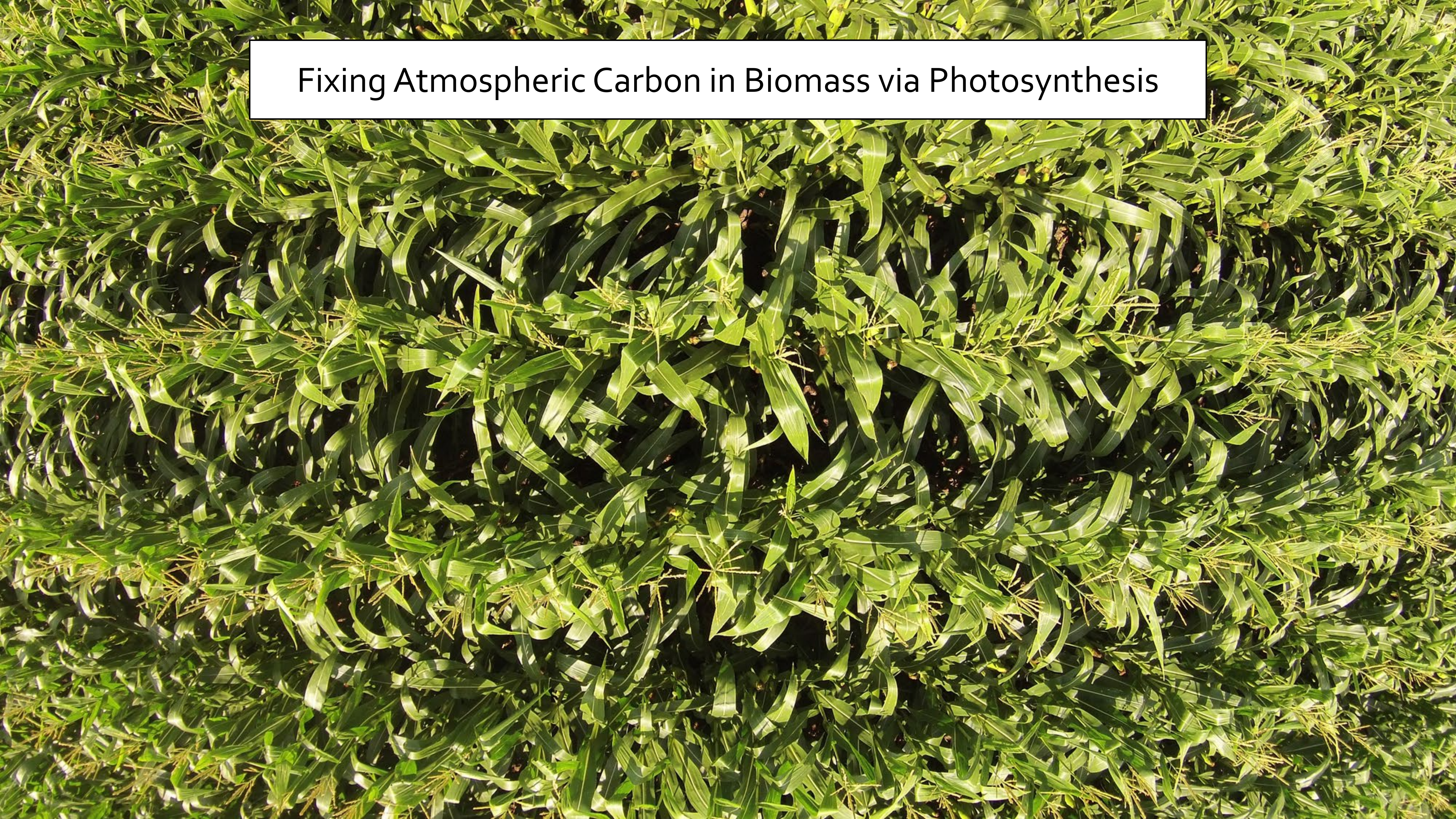
NASA and Jet Propulsion Laboratory Satellite Based Detection of Photosynthesis Intensity



Quotes from research paper:

"Data showed that photosynthesis fluorescence from the Corn Belt, which extends from Ohio to Nebraska and Kansas, peaks in July at levels 40 percent greater than those observed in the Amazon" "The analysis also revealed that carbon cycle models – which scientists use to understand how carbon cycles through the ocean, land and atmosphere over time – underestimate the productivity of the Corn Belt by 40 to 60 percent." **"Corn plants (C4 grasses) are very productive in terms of assimilating carbon dioxide from the atmosphere. <u>This needs to be accounted for</u> going forward in trying to predict how much of the atmospheric carbon dioxide will be taken up by crops in a changing climate."**

Fixing Atmospheric Carbon in Biomass via Photosynthesis



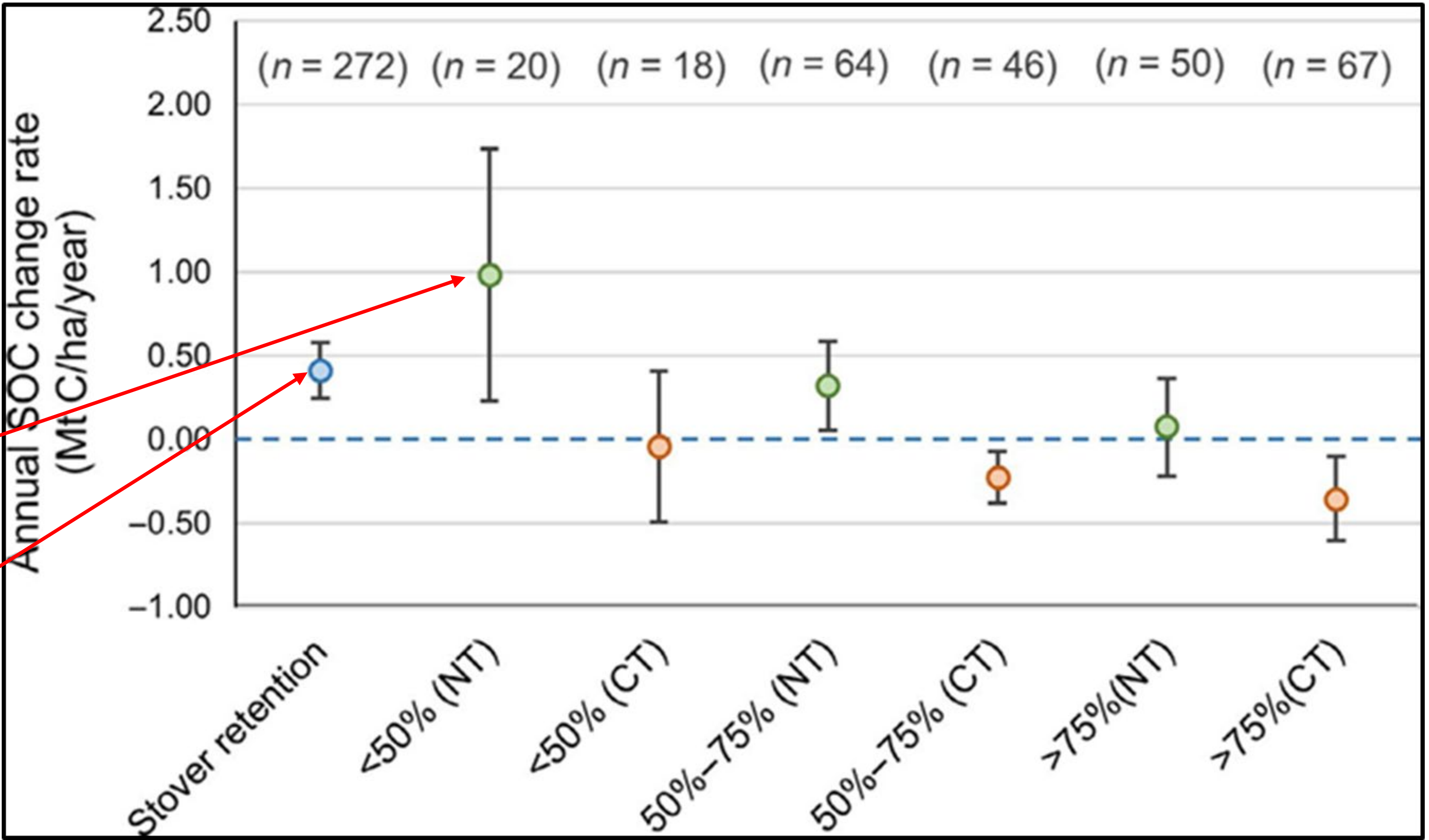
<u>Xu et al. 2019</u>, *"A global meta-analysis of soil organic carbon response to corn stover removal"*

Hui Xu, U.S. DOE Argonne Labs; Heidi Sieverding, SDSMT; Hoyoung Kwon, US DOE; David Clay, SDSU; Catherine Stewart, USDA ARS; Jane M. F. Johnson, USDA ARS; Zhangcai Qin, Douglas L. Karlen, USDA ARS; Michael Wang, US DOE. https://greet.es.anl.gov/publication-soc_corn_stover

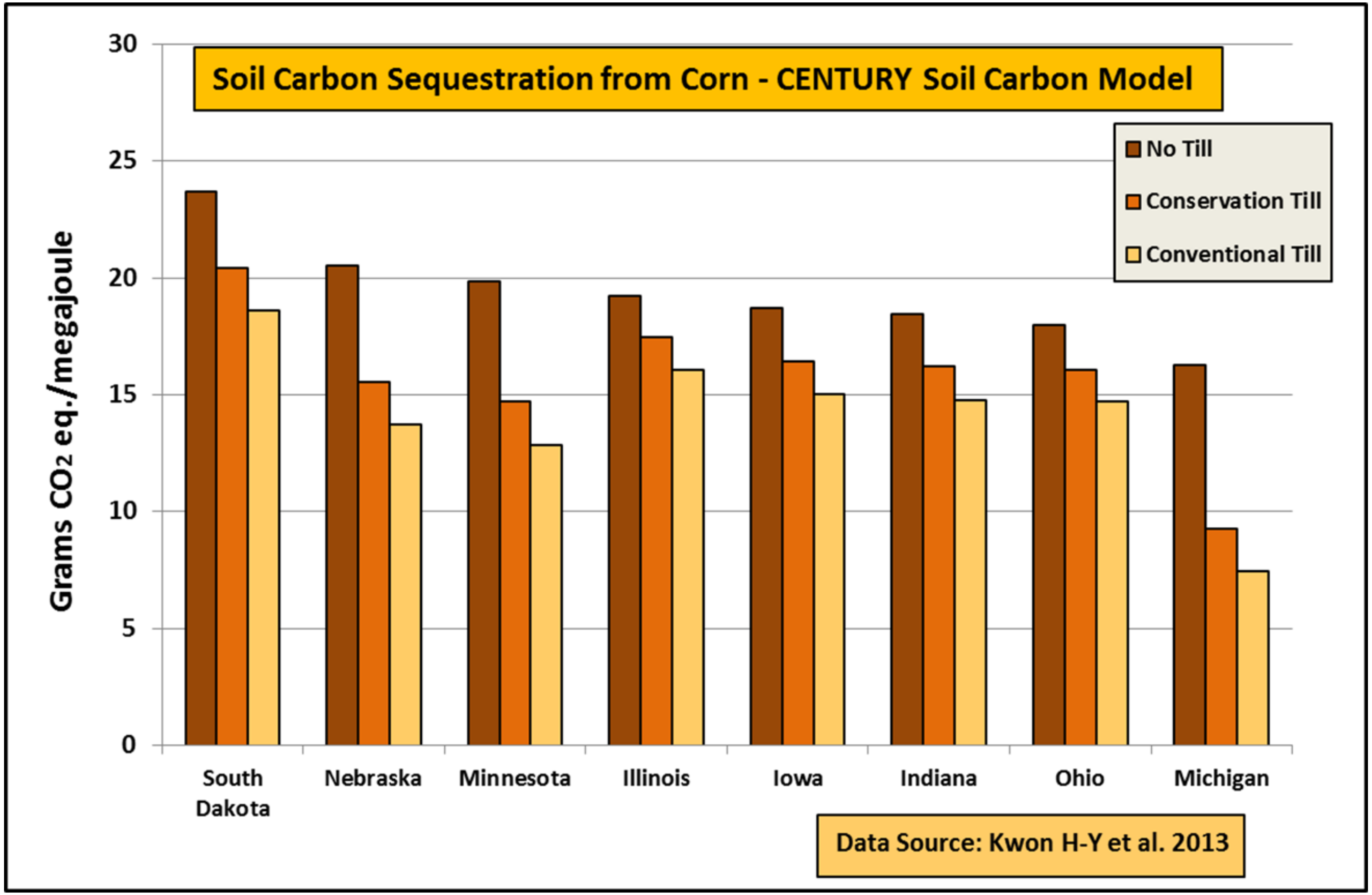
409 data points from 74 corn world-wide corn stover harvest experiments

No-till = 38 grams/mega joule SOC Sequestration

Avg. of all tillage methods = 16 grams/MJ SOC Seq.



Colorado State University – CENTURY Soil Carbon Model



Corn Should Get a Significant Soil Carbon Sequestration Credit!

Other "Low Hanging Fruit" to Improve Corn CI Modeling-

Nitrogen (fertilizer & biomass) **Induced N_2O Emissions**

Some of the N_2O Emission Modeling Factors that the EPA, CARB & GREET use are Archaic!

Nitrous Oxide Emission Factors-

Models assume that 30% of the Nitrogen Fertilizer and Nitrogen in Crop Residues is lost due to Leaching and Runoff

CA-GREET Nitrous Oxide Emission Calculation		
	%	Grams/bu
Nitrogen Fertilizer Rate (grams/bu)		383
Direct N_2O Emissions (%)	1%	3.83
Indirect N_2O Emissions		
Leaching and runoff losses (%)	30%	
% of leached N converted to N_2O	0.75%	0.86
Volatilization losses (%)	10%	
% of volatilized N converted to N_2O	1%	0.38
Root and Residue Nitrogen (grams/bu)		141.6
Direct N_2O Emissions (%)	1%	1.42
Leaching and Runoff Losses (%)	30%	
% of leached N converted to N_2O	0.75%	0.32
Total Nitrogen converted to N_2O (grams/bu)		6.81
N_2O Global Warming Potential (265X CO_2)		265
Total CO_2 equivalent N_2O emissions (grams/bu)		1,804
Nitrogen to Nitrous Oxide Mole Weight Adjustment (44/28)		1.57
Total CO_2e emissions (grams/bu)		2,836
Mega Joules of Energy in Ethanol from One Bushel Corn		232.1
Total Grams CO_2e GHGs per MJ from Corn Nitrogen		12.22

The Mississippi River Watershed Receives about 24 Million Tons of Nitrogen Annually

(7-8 Million Tons from Fertilizer)

Source: Goolsby et al. 1999

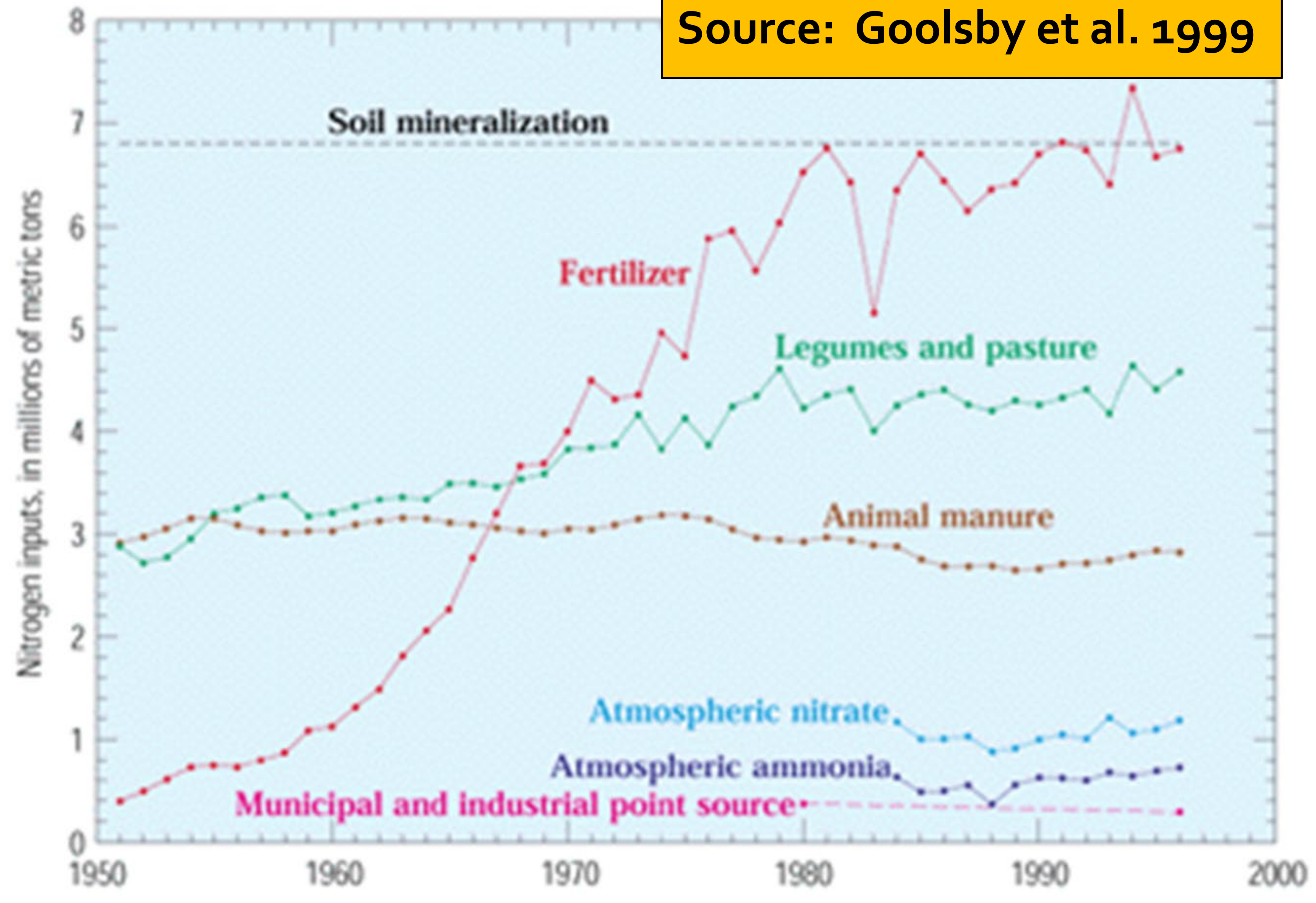
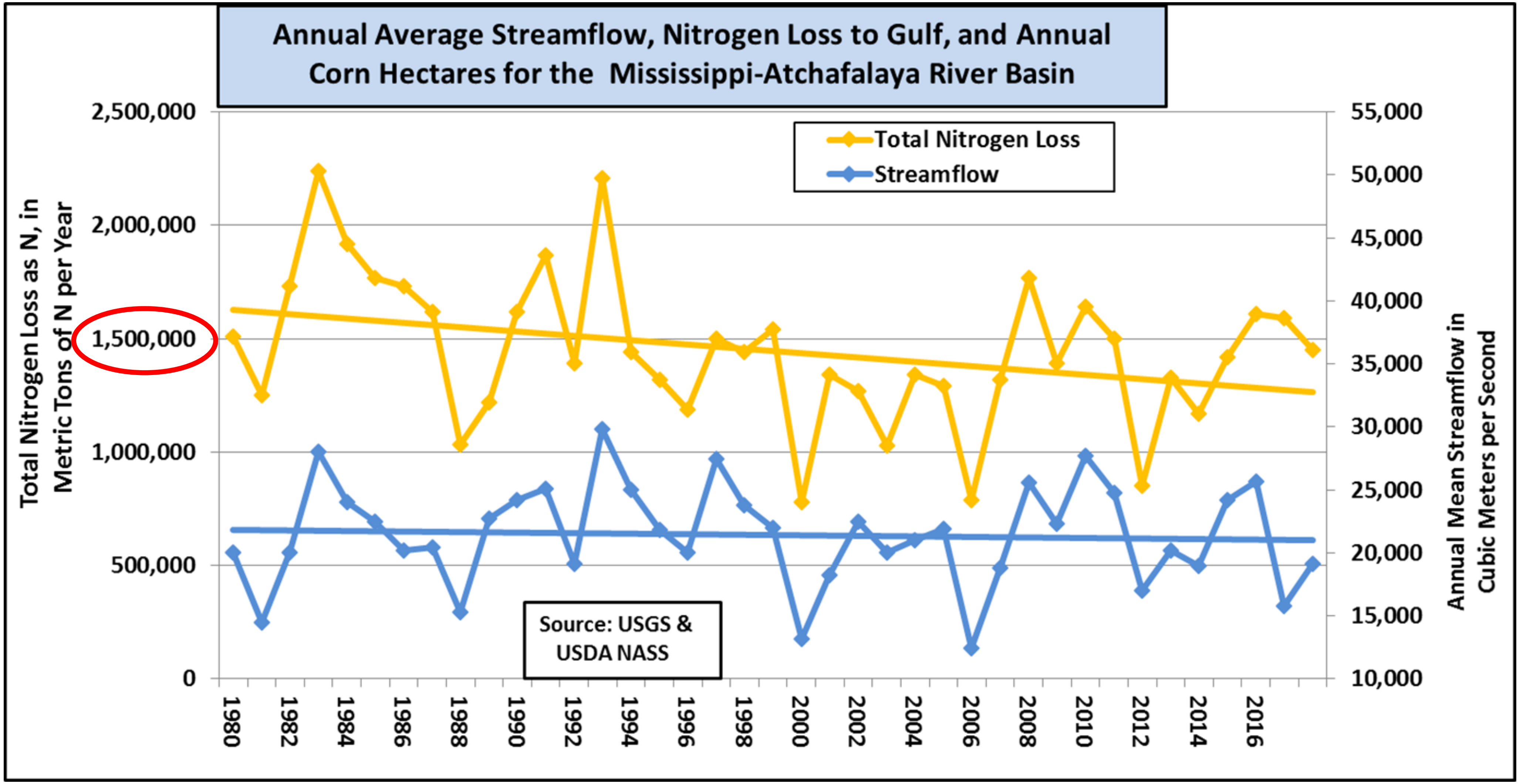


Figure 5. Annual nitrogen inputs to the Mississippi Basin from major sources.

How much Nitrogen Is Discharged Into the Gulf of Mexico each Year from the Mississippi Watershed?

<u>1,500,000</u> Metric Tons Avg. Per Year



These USGS data imply about 6% of Total N inputs to the Watershed is lost (1.5 million tons of loss divided by 24 million tons of inputs)

"4R"

Nitrogen Fertilizer Management

(Right Type, Right Rate, Right Placement, Right Timing)

30% Lower Runoff/Leaching Losses

And 30% Lower N2O Emissions

Published October 12, 2017

Soil & Water Management & Conservation

Fertilizer Management and Environmental Factors Drive N_2O and NO_3 Losses in Corn: A Meta-Analysis

Alison J. Eagle*
Environmental Defense Fund
4000 Westchase Blvd.
Suite 510
Raleigh, NC 27607

formerly at:
Nicholas Institute for Environmental Policy Solutions
Duke Univ.
Box 90335
Durham, NC 27708

Lydia P. Olander
Katie L. Locklier
Nicholas Institute for Environmental Policy Solutions
Duke Univ.
Box 90335
Durham, NC 27708

James B. Heffernan
Nicholas School of the Environment
Duke Univ.
Box 90328
Durham, NC 27708

Emily S. Bernhardt
Department of Biology
Duke Univ.
Box 90338
Durham, NC 27708

Effective management of nitrogen (N) in agricultural landscapes must account for how nitrate (NO_3) leaching and nitrous oxide (N_2O) emissions respond to local field-scale management and to broader environmental drivers such as climate and soil. We assembled a comprehensive database of fertilizer management studies with data on N_2O (417 observations, 27 studies) and NO_3 (388 observations, 25 studies) losses associated with 4R fertilizer N management in North American corn-cropping systems. Only one study measured both losses, and studies of N_2O and NO_3 differed by location, time period, and management practices. Meta-analysis of side-by-side comparisons found significant yield-scaled N_2O emission reductions when SUPERU replaced urea or UAN, and when urea replaced anhydrous ammonia. Hierarchical regression models found near-equivalent magnitude effects on N_2O emissions of 1°C rise in average July temperature (+), increase in soil C by 10 g kg^{-1} (+), nitrification inhibitors (–), side-dressed fertilizer timing (–), broadcast fertilizer (–), and 100 kg N ha^{-1} decrease in fertilizer rate (–). Average NO_3 leaching response to 100 kg N ha^{-1} reduction in fertilizer rate (–) were comparable to effects of 100 mm less annual precipitation (–), 10 g kg^{-1} more soil C (–), or replacing continuous corn with corn-soybean rotations (–). The large effects of climate and soil, and the potential for opposite reactions to some management changes, indicate that more simultaneous measurements of N_2O and NO_3 losses are needed to understand their joint responses to management and environmental factors, and how these shape tradeoffs or synergies in pathways of N loss.

Inorganic N in excess of plant demand creates high potential for export of unused N from farm fields. Worldwide, N fertilizer recovery as crop biomass varies considerably (Dinnes et al., 2002), but is usually less than 50% (Fageria and Baligar, 2005); the remainder accumulates in soils, is exported to the atmosphere (from nitrification, denitrification, and volatilization), or is lost to surface and groundwater (leaching and erosion). Agriculture is a major source of nitrate

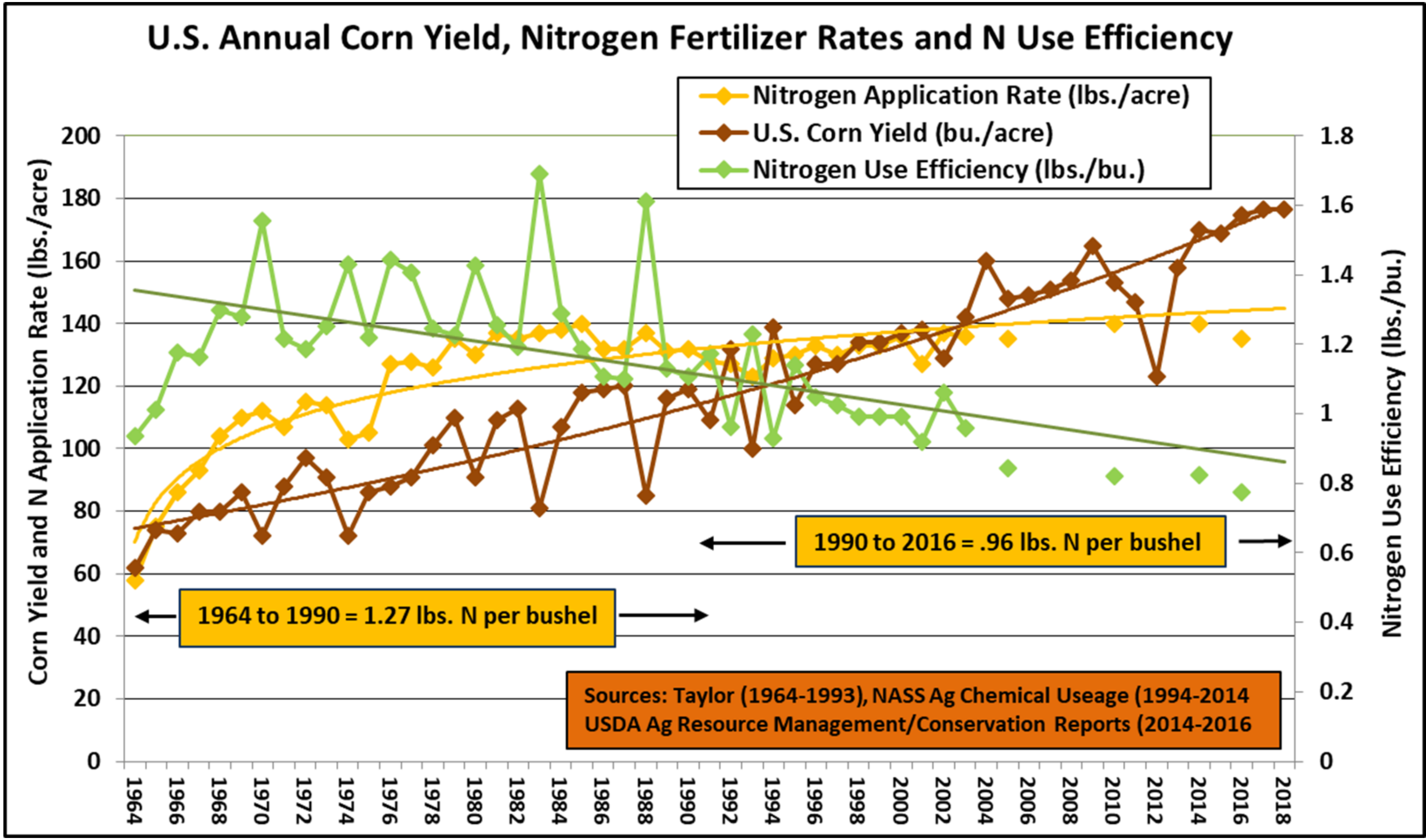
“4 R”

Fertilizer Management

Right time,
Right placement,
Right rate,
Right formulation

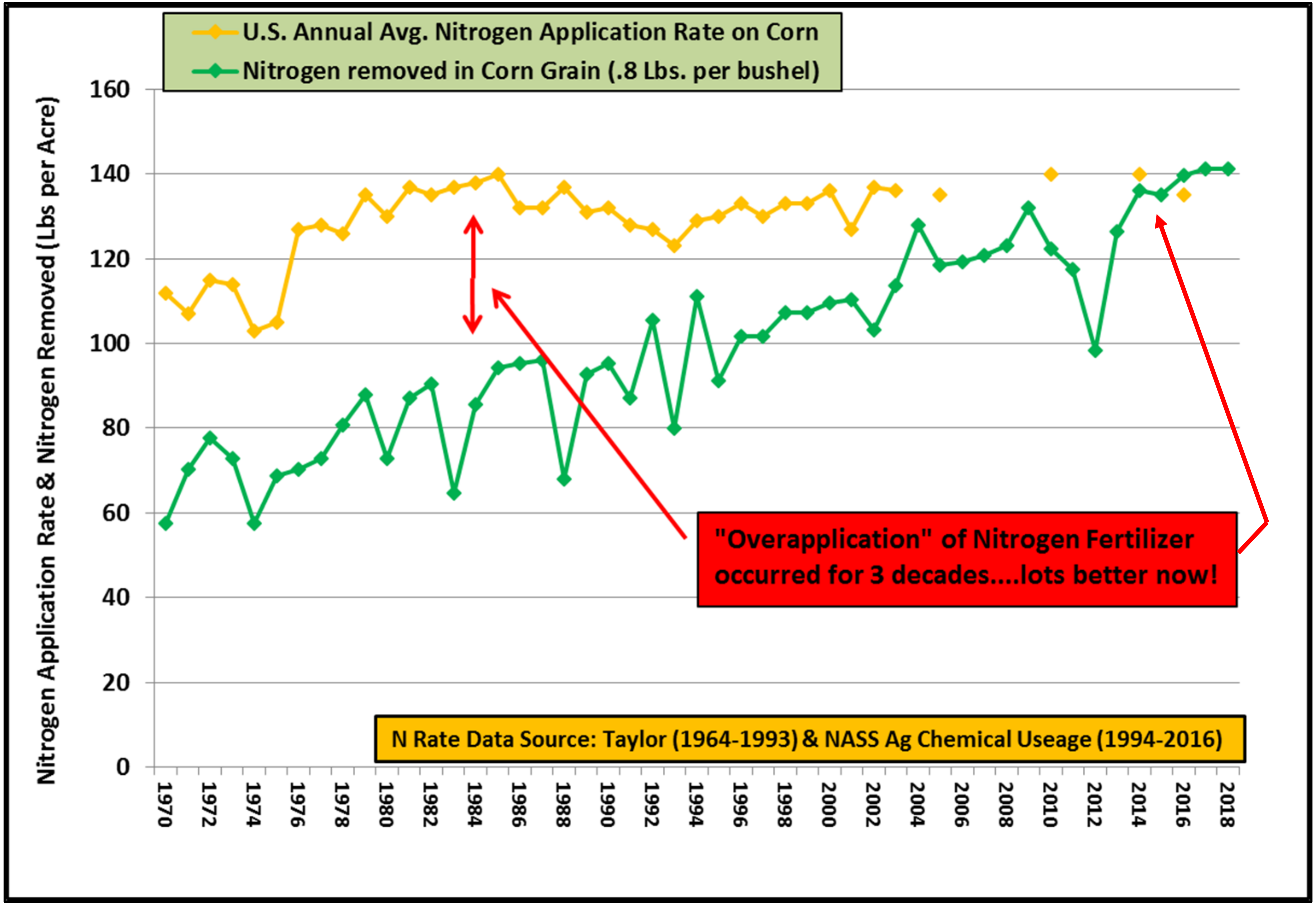
Precision, Variable Rate, Side-dress Nitrogen Fertilizer Application

U.S. Trends In Corn Yield, Nitrogen Fertilizer Application Rates, and Nitrogen Use Efficiency

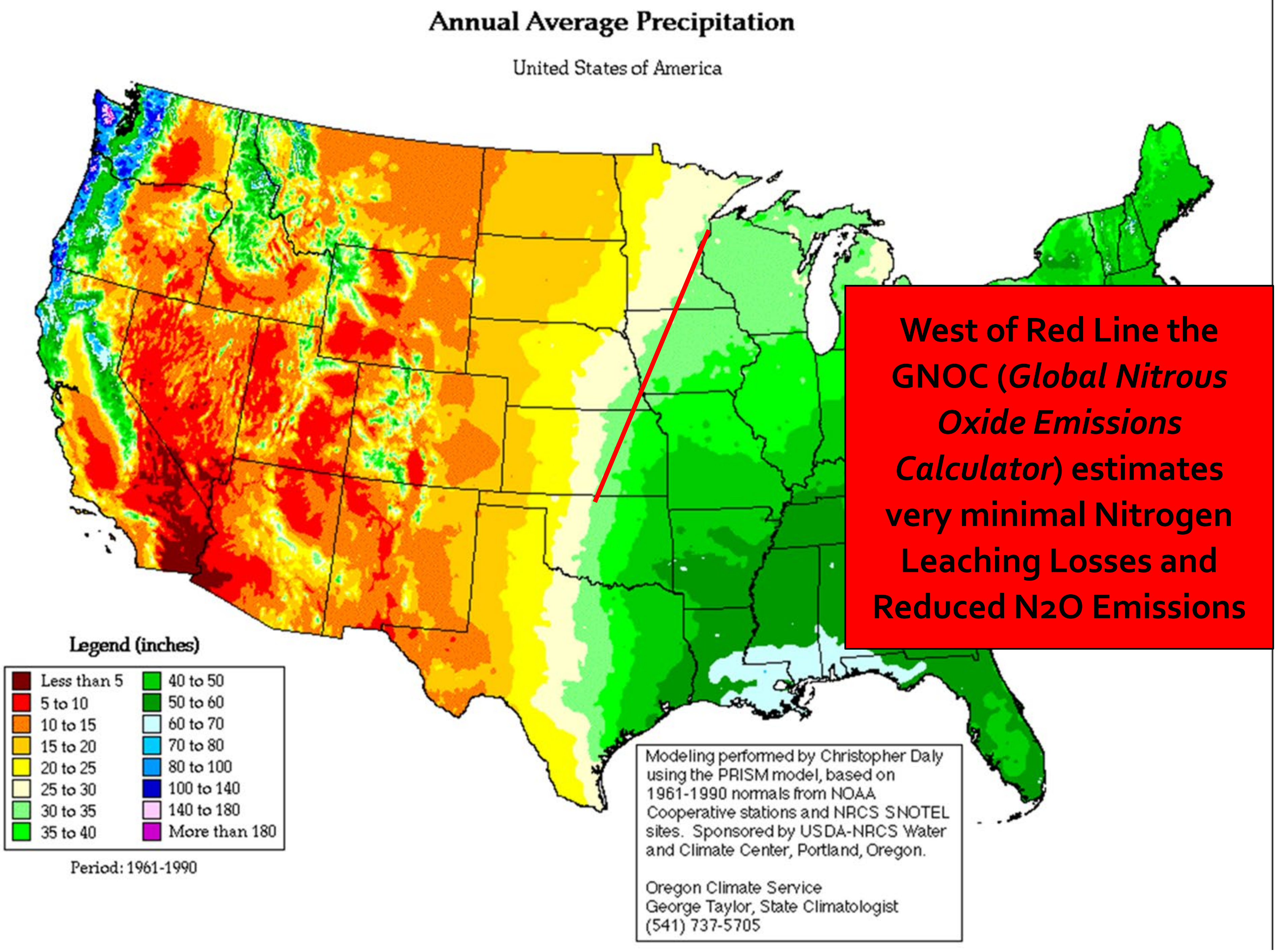


Corn Producers have become much more Judicious users of Nitrogen Fertilizer

Nitrogen application rates are now well balanced with N Removal

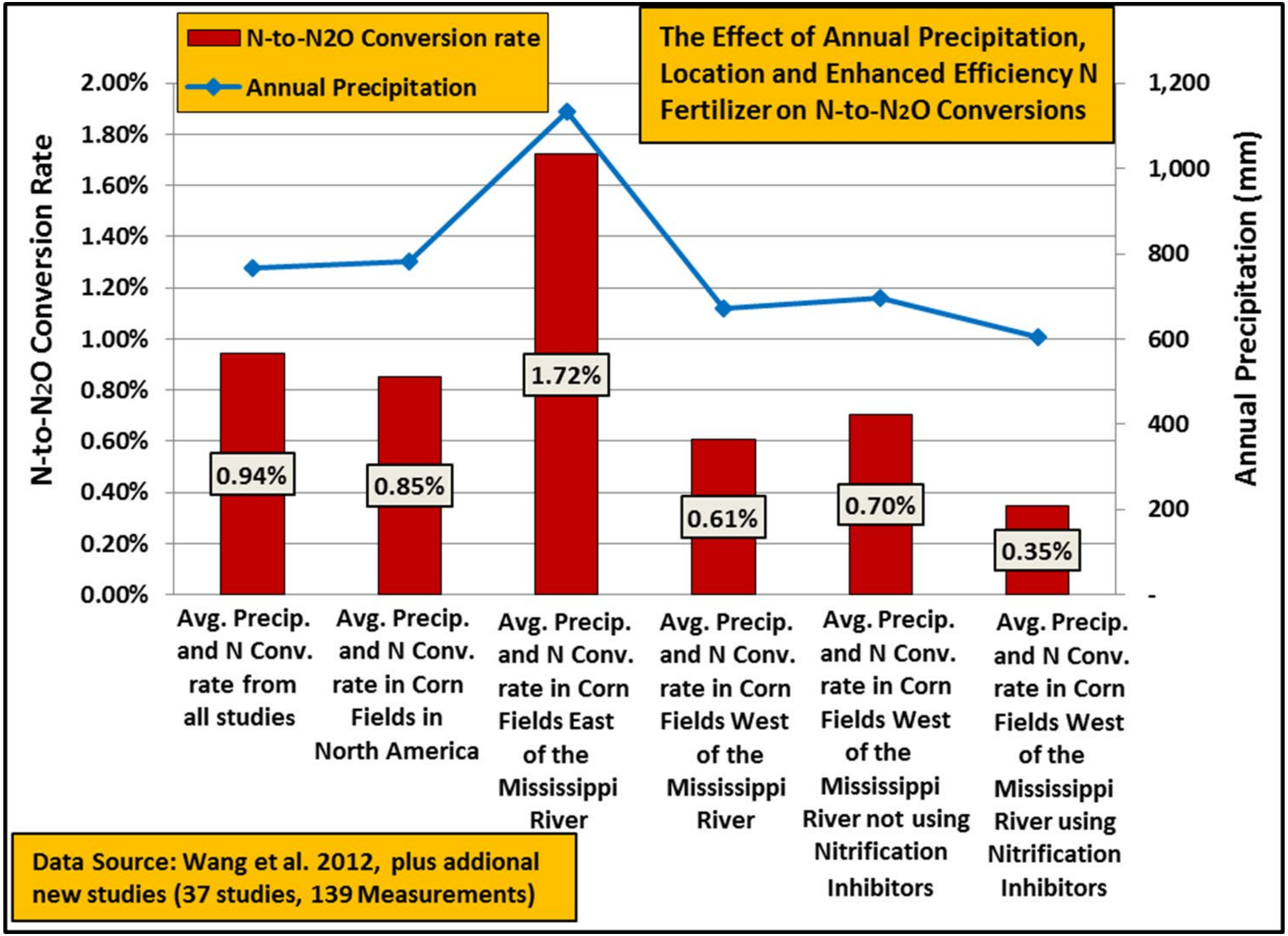


Nitrogen Fertilizer Leaching Losses and N2O Emissions are Highly Correlated with Annual Precipitation



West of Red Line the GNOC (*Global Nitrous Oxide Emissions Calculator*) estimates very minimal Nitrogen Leaching Losses and Reduced N2O Emissions

Precipitation and Enhanced Efficiency Nitrogen Fertilizer Impacts on N_2O Emissions in the U.S. Corn Belt



Land Use Change SOC Effects

A Biofuel
Carbon Footprint
Issue Worth Revisiting

3 factors ….

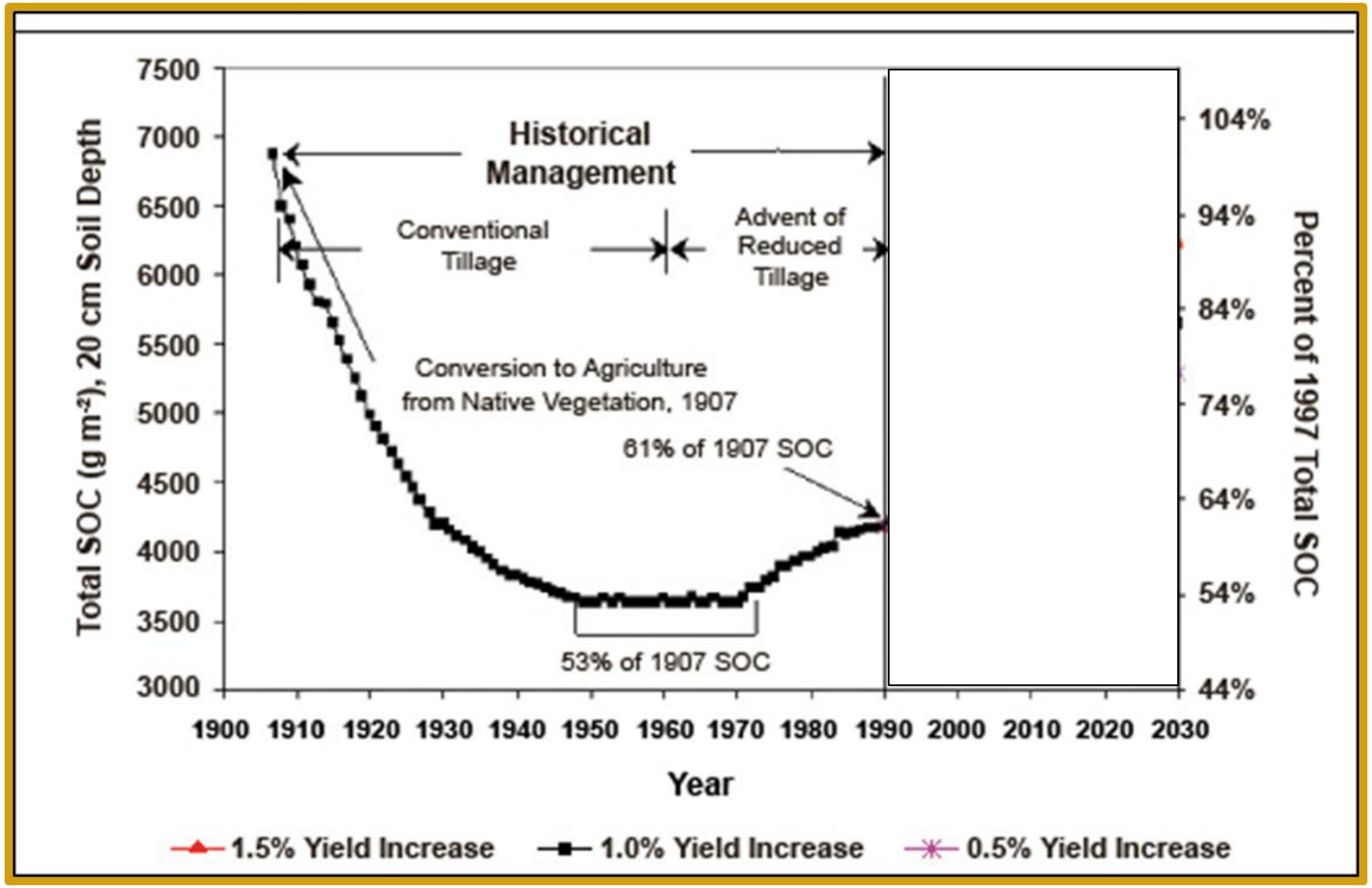
1. Area of forest, grasslands, pastures switched to cropland
2. Which crops are grown
3. How cropland is managed

The Ups, and Downs, and Ups of Mid-West Soil Carbon Stocks

Prior to Settler's arrival, carbon (C) fixed by prairie grasses (photosynthesis) accumulated in Mid-west soil.
All fixed C remained in the Region
And the C balance of the Region was Positive

Settlers plowed the prairies to produce food for people living outside of the Mid-west

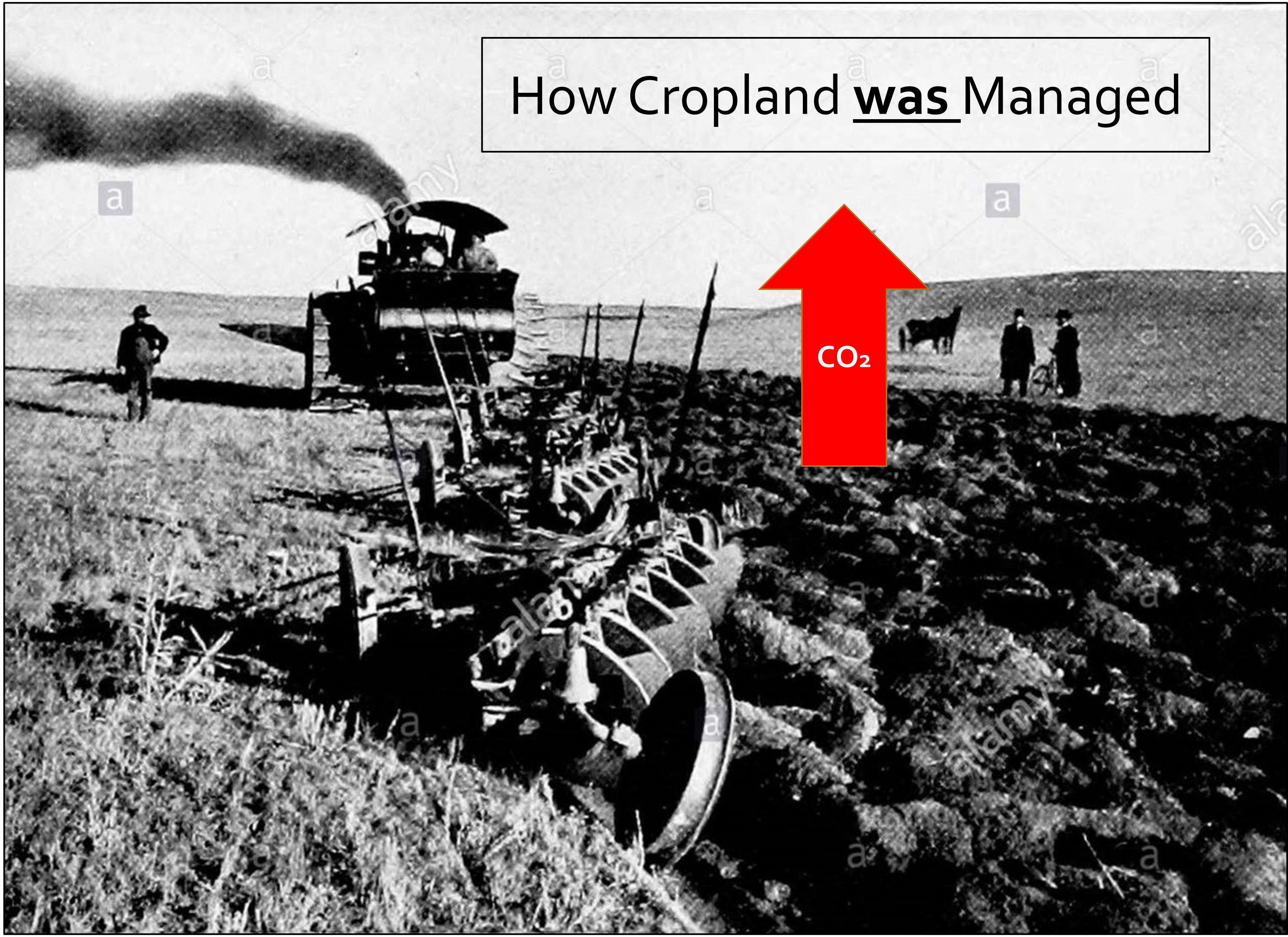
The C in the food left the Mid-west, Intense tillage (to control weeds) decomposed soil C, and Low crop yields reduced annual C fixation (photosynthesis) turning the C Balance of the Mid-west Negative



Early to Mid 1900s Land Use Change Soil Carbon Losses

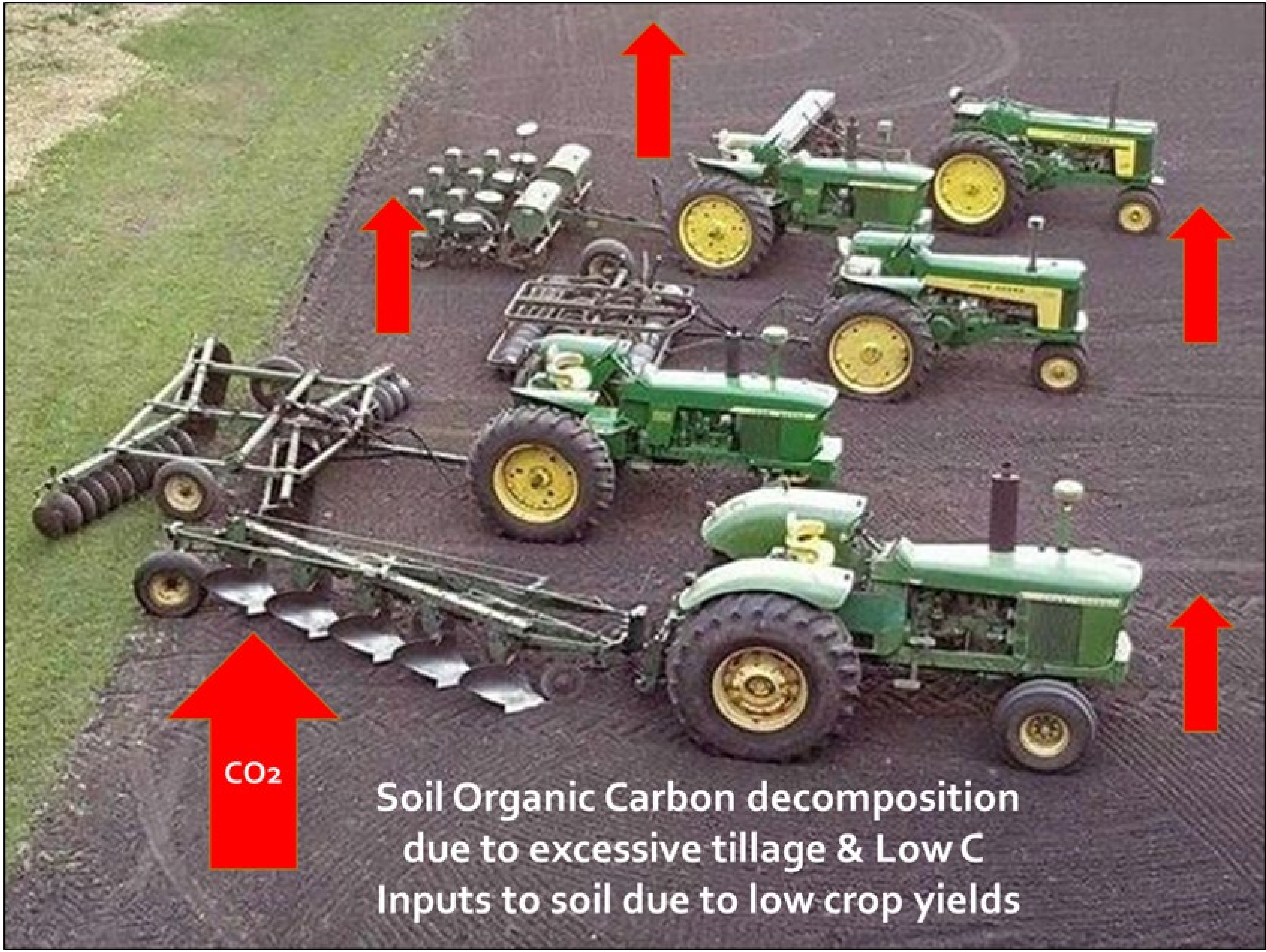
Intense tillage plus low crop yields = large annual SOC losses

.4 Metric Tons C/ha/year for 50+ years.



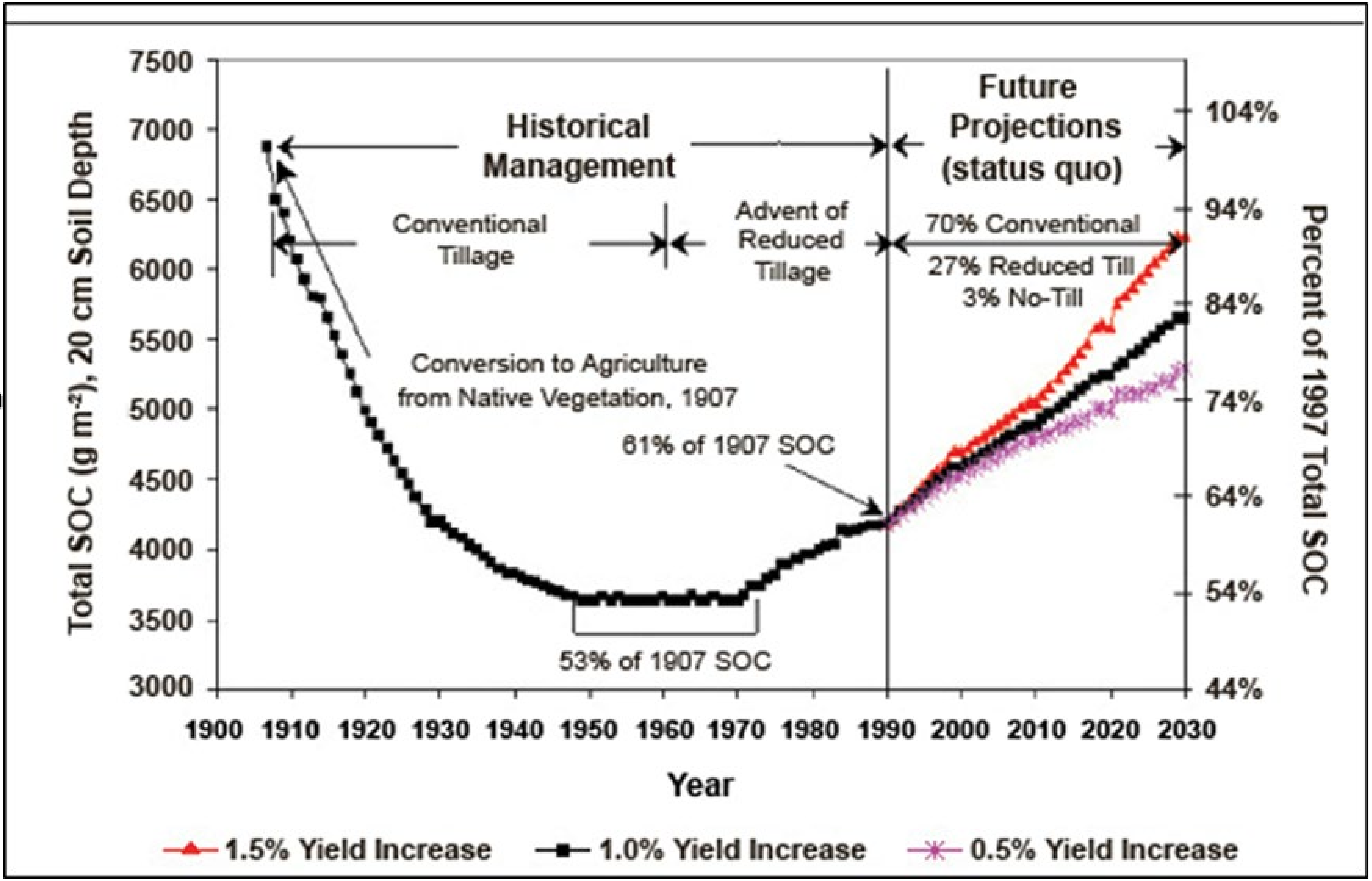
Up until the development of Herbicides in the 60s & 70s, crop production practices were very destructive to our soil and environment

No herbicides meant intensive tillage to control weeds



Historic Loss of Soil Organic Carbon Stocks in the Mid-west

38 Billion Tons CO2



Source:

Matson et al. 1997

38 Billion Tons of CO2 Emissions is Equal to 280 Million Car CO2 Emission for 29 years!

But tillage methods have changed..

2017 USDA Census of Agriculture Midwest Cropland Tillage Practices

No-till 37%

Reduced = 35%

Intensive = 28%

Many still consider Land Use Change Soil Carbon losses a major issue with Corn Ethanol Carbon Footprints

Let’s revisit the conditions just prior to the first LUC modeling efforts in **2007-2010**…..

Revisiting 2007 Conditions……..
Prior to the first Modeling Estimations of iLUC

New EISA Legislation - Required 15 Billion gallons of conventional biofuels by 2015 (corn starch ethanol qualified because the current modeling indicated that it's LCA GHG emissions met the 20% reduction threshold relative to fossil gasoline)

2007 U.S. corn starch ethanol production = **6.5** billion gallons. In the next 8 years, the US needed to increase biofuel production by **8.5** B Gals! This would require **3.15** billion bushels more corn! (assumes 2.7 gallons Ethanol/bu)

2007 Conditions:

Land Use, Corn and Ethanol Statistics	5 Year Avg.
	2003-2007
Total U.S. Cropland Planted Acres (Millions)	320.4
U.S. Corn Planted Acres (Millions)	82.6
U.S. Corn Yield (Bushels/acre)	150
U.S. Corn Production (Billion bushels)	11.3
U.S. Ethanol Production (Billion gallons in 2007)	6.5
U.S. Corn Exports (Billion bushels)	2.08
U.S. Corn Price (Cash price $/bushel)	2.74
U.S. Meat and Milk Production (Billion lbs.)	264.7
U.S. Food Price Inflation (%)	2.90%

It was widely speculated that to increase corn production by 3.15 billion bushels, it would require an additional 21 million acres of corn *(No corn yield increases were assumed because these new corn plantings would be on less productive land)*

Many top Agriculture and Commodity Supply/Demand Economists were very skeptical that the U.S. could ramp up corn production fast enough to meet the EISA ethanol production requirements.

(Doug Jackson - FC Stone, Bill Hudson - Pro Exporter)

Experts said…." Corn price might skyrocket, corn exports might plunge, livestock producers might suffer and food prices might skyrocket"!

It was under these conditions and with these expert opinions and analysis', that the first Land Use Change models were developed after EISA was passed

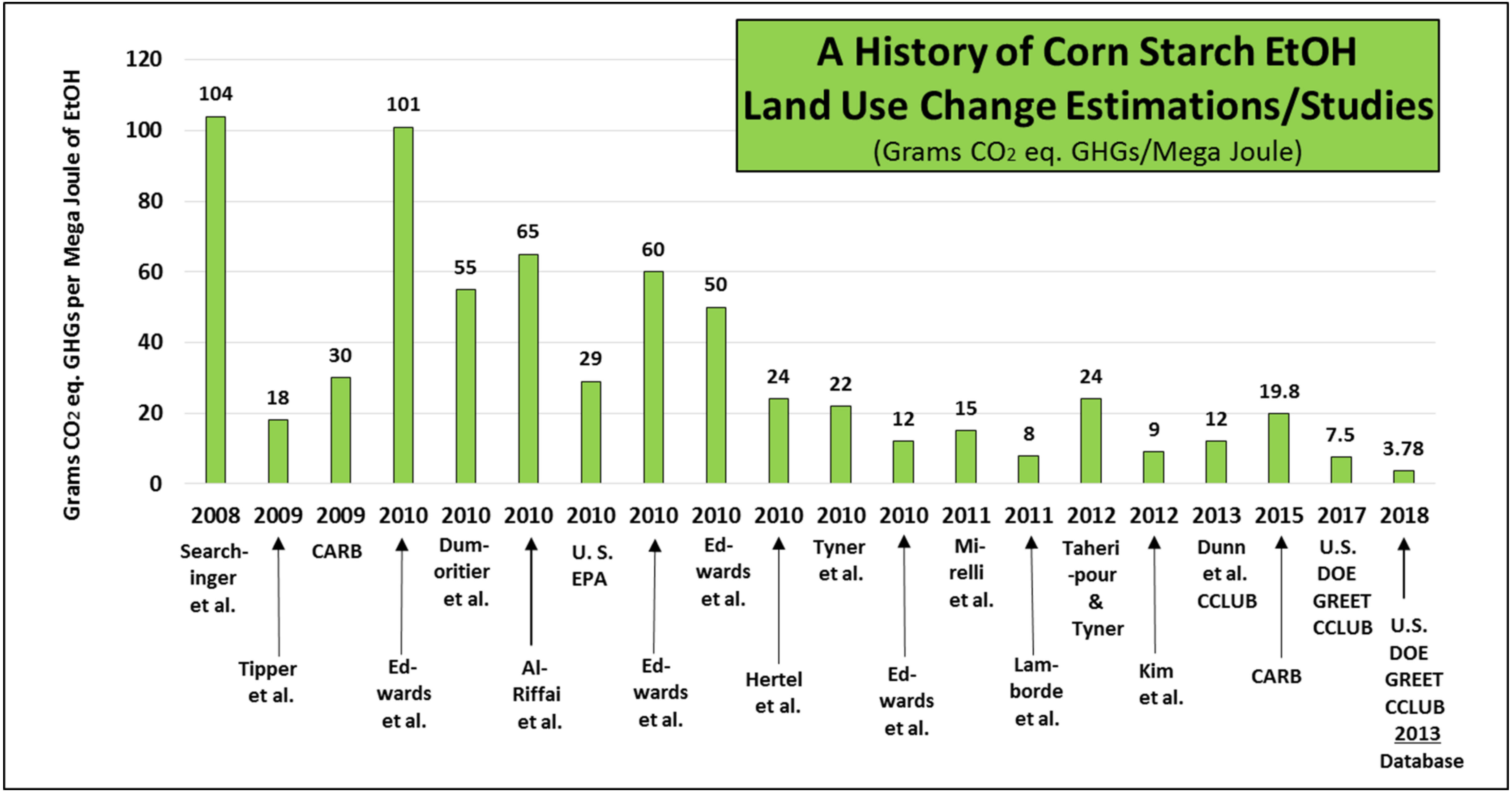
Modelers predicted millions of acres of forest and grasslands would be converted to cropland and rapid losses of SOC would occur from these converted lands.

After much analysis and expert testimony, the US EPA estimated that LUC SOC emissions were 30 grams CO2 per mega-joule for corn based ethanol.

The California Air Resources Board also estimated about 30 grams per mega-joule LUC for corn ethanol in their Low Carbon Fuel Standard program.

The addition of this LUC SOC emissions factor meant that corn ethanol had about the same carbon intensity as fossil fuel derived gasoline!

Public & Environmental group support evaporated almost overnight for corn starch ethanol!


A History of Corn Starch EtOH
Land Use Change Estimations/Studies
(Grams CO2 eq. GHGs/Mega Joule)
Grams CO2 eq. GHGs per Mega Joule of EtOH
120
100
80
60
40
20
0
104
18
30
101
55
65
29
60
50
24
22
12
15
8
24
9
12
19.8
7.5
3.78
2008
2009
2009
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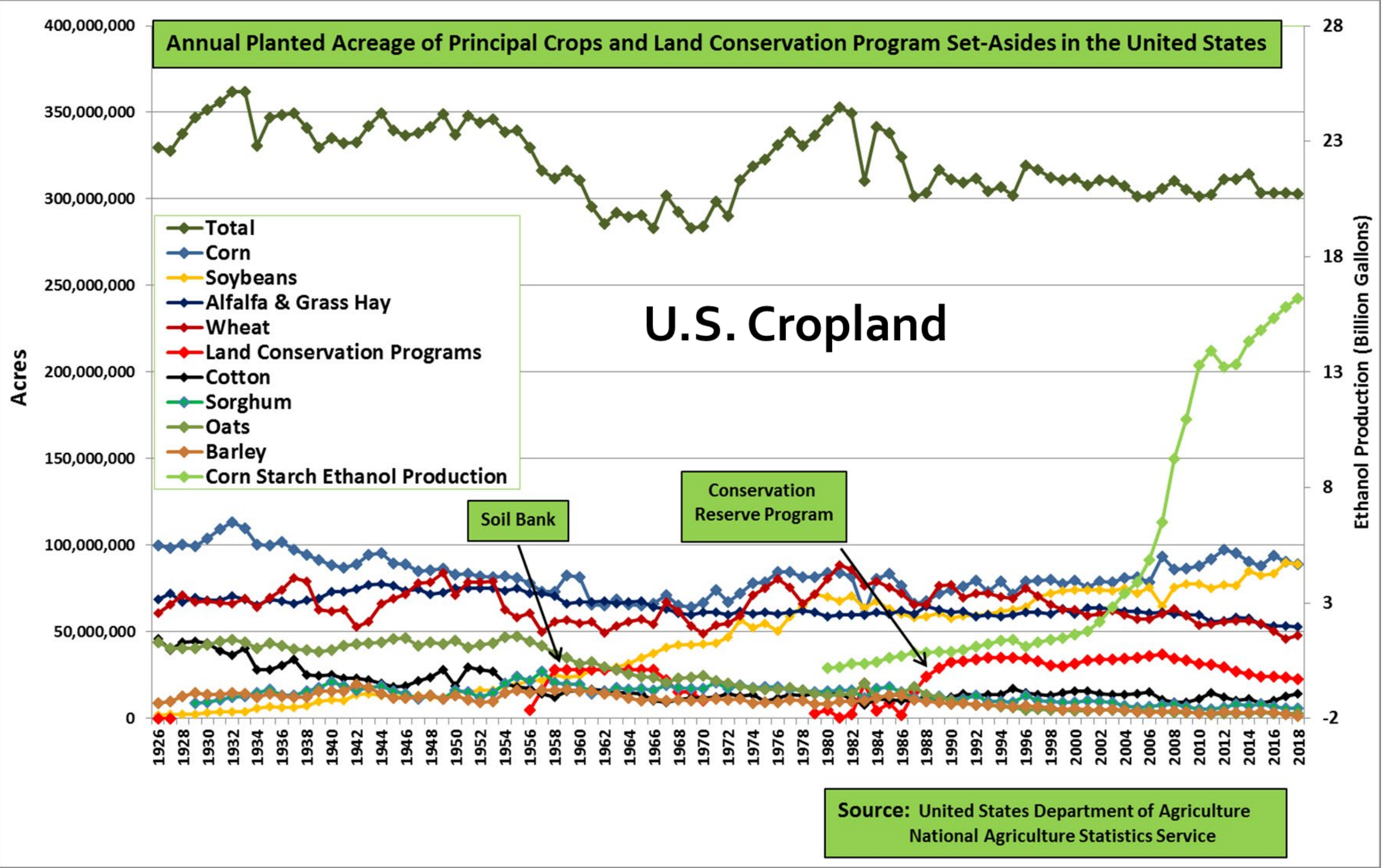
2011
2012
2012
2013
2015
2017
2018
Search-inger et al.
Tipper et al.
CARB
Ed-wards et al.
Dum-oritier et al.
Al-Riffai et al.
U. S. EPA
Ed-wards et al.
Ed-wards et al.
Hertel et al.
Tyner et al.
Ed-wards et al.
Mi-relli et al.
Lam-borde et al.
Taheri-pour & Tyner
Kim et al.
Dunn et al. CCLUB
CARB
U.S. DOE GREET CCLUB
U.S. DOE GREET CCLUB 2013 Database

So..., how did all those dire 2007 warnings turn out?

Land Use, Corn and Ethanol Statistics	5 Year Avg. 2003-2007	5 Year Avg. 2014-2018
Total U.S. Cropland Planted Acres (Millions)	320.4	320.5
U.S. Corn Planted Acres (Millions)	82.6	90.3
U.S. Corn Yield (Bushels/acre)	150	173.4
U.S. Corn Production (Billion bushels)	11.3	14.4
U.S. Ethanol Production (Billion gallons in 2007)	6.5	16.1
U.S. Corn Exports (Billion bushels)	2.08	2.09
U.S. Corn Price (Cash price $/bushel)	2.74	3.53
U.S. Meat and Milk Production (Billion lbs.)	264.7	309.4
U.S. Food Price Inflation (%)	2.90%	1.40%

LUC Modeling in 2007-2008 was highly theoretical……

We now know how much land use change has occurred



Annual Planted Acreage of Principal Crops and Land Conservation Program Set-Asides in the United States
U.S. Cropland
Acres
Ethanol Production (Billion Gallons)
Total
Corn
Soybeans
Alfalfa & Grass Hay
Wheat
Land Conservation Programs
Cotton
Sorghum
Oats
Barley
Corn Starch Ethanol Production
Soil Bank
Conservation Reserve Program
Source: United States Department of Agriculture
National Agriculture Statistics Service

Thoughts on Future Biofuel iLUC Modeling/Accounting

A Very Basic Question?..

Would there be less corn and soy grown
in the absence of demand for Biofuels from
corn starch and oil, and soybean oil?

BIODIESEL
America's Advanced Biofuel

PROTEIN

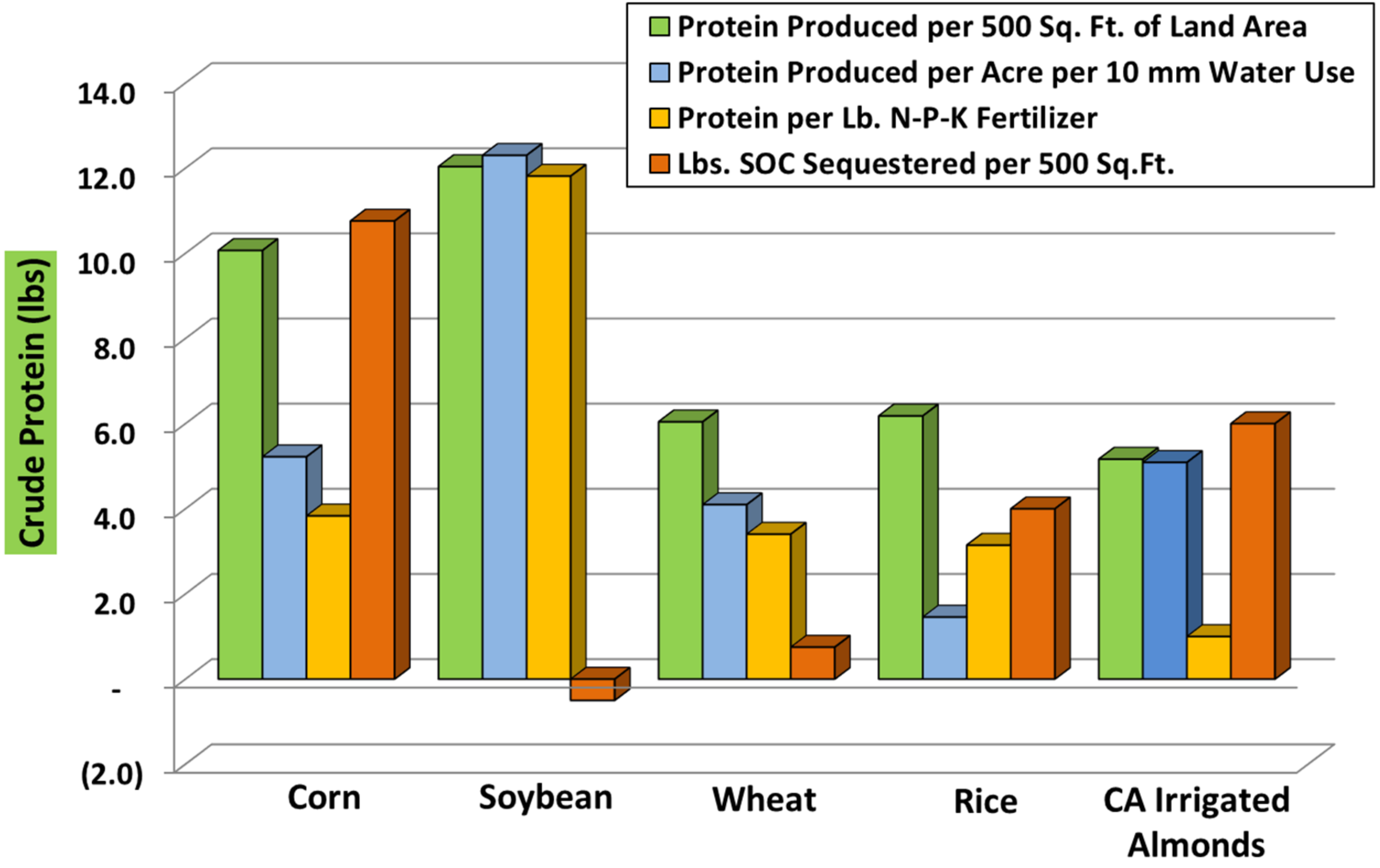
The Missing Link to

Understanding the Impact of Biofuels on the Landscape

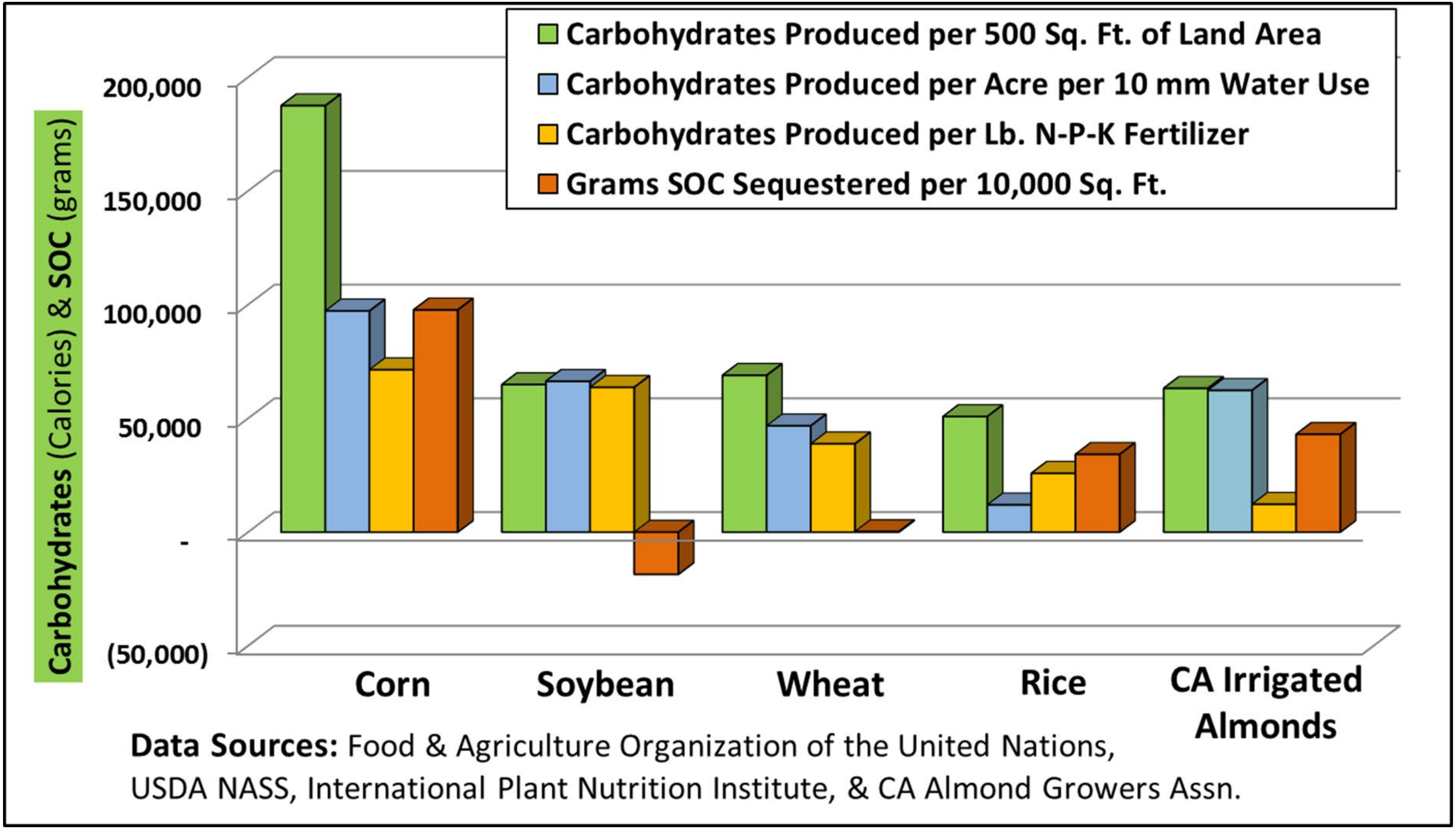
Don Scott, Director of Sustainability, National Biodiesel Board

When we grow protein to feed the world, we get more carbohydrates and fat than we can eat.

The Planet's Most Prolific and Efficient Protein Producing Crops



Data Sources: USDA NASS, International Plant Nutrition Institute, Food & Agriculture Organization of the United Nations, CA Almond Growers Assn.


Carbohydrates Produced per 500 Sq. Ft. of Land Area
Carbohydrates Produced per Acre per 10 mm Water Use
Carbohydrates Produced per Lb. N-P-K Fertilizer
Grams SOC Sequestered per 10,000 Sq. Ft.
Carbohydrates (Calories) & SOC (grams)
200,000
150,000
100,000
50,000
-
(50,000)
Corn
Soybean
Wheat
Rice
CA Irrigated Almonds
Data Sources: Food & Agriculture Organization of the United Nations, USDA NASS, International Plant Nutrition Institute, & CA Almond Growers Assn.

When we grow protein to feed the world, we get more carbohydrates and fat than we can eat.

One Rational Way to Utilize These Excess Carbs and Oils are Biofuels!

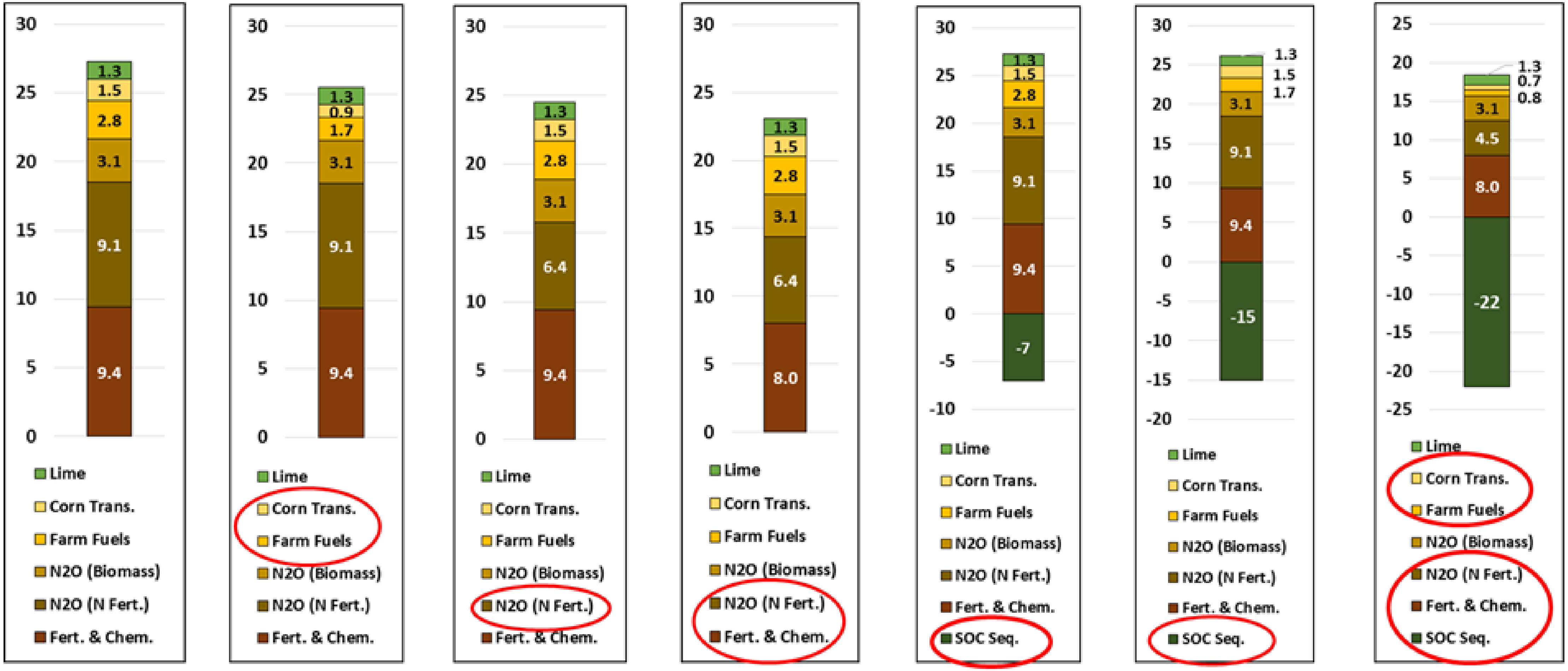
Future Corn Ethanol Carbon Footprints……

Applying all the best practices
while producing Corn and Ethanol

Low Carbon Crop Production Management Practices Effects on Corn Prod. Carbon Intensity

Net

GREET 2020 Baseline	Low C Farming Fuels	Nitrification Inhibitors	4R Fertilizer Management	Cover Crops	Minimal Tillage	All Practices	Net
27.3	-1.8	-2.8	-4.2	-7	-15	-30.8	-3.5



GREET 2020 Baseline

Low C Farming Fuels

Nitrification Inhibitors

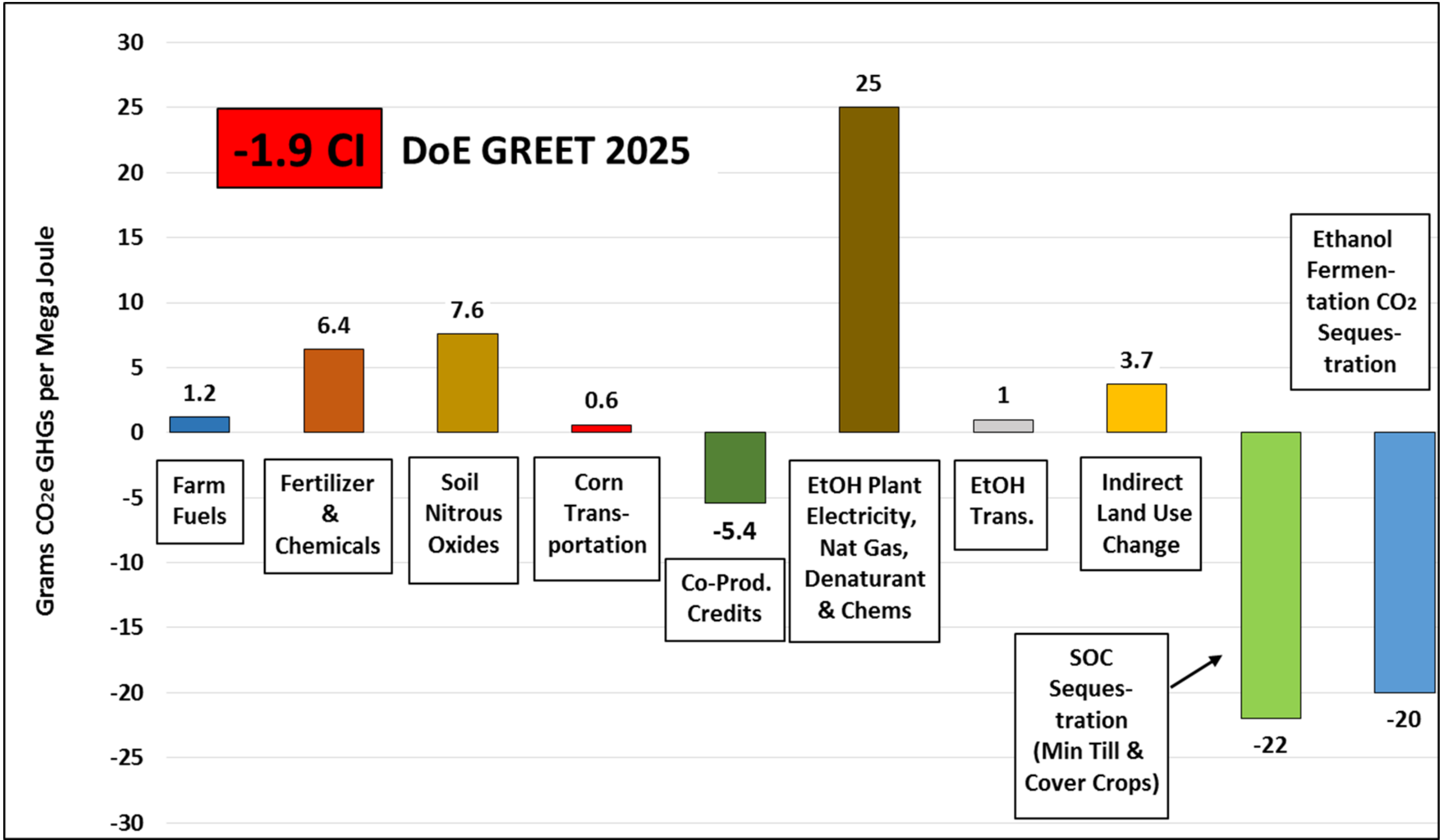
4R Fertilizer Management

Cover Crops

Minimal Tillage

All Practices

2025 Best Corn and Ethanol Producers



Summarizing:

"Low Carbon Fuel Standard" markets are growing, are beneficial and working, and appear to have "Staying Power"

Biofuel GHG accounting is improving – but is still a "Young" science

Biofuel Carbon Intensity has dropped and continues to drop

To Maximize GHG Reductions, LCFS Programs need to account for and incentivize Low Carbon Biofuel Feedstock Management

In the coming years, the Federal Renewable Fuels Standard should transition to a Federal Low Carbon Fuel Standard

To learn more about our Farm's Sustainability Practices....

Please visit www.carbonharmony.org