

# Inaugural Address on the Impact of Biofuel on the Environment

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**THE  
UNIVERSITY OF  
ILLINOIS  
AT  
CHICAGO**



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# Introduction



- University of Illinois at Chicago has 29,000 students
- One of the largest research universities in the state.
  - We conduct a lot of international research projects
  - Students from India are the largest foreign student population in our college.
  - I am managing the Bioenergy and Land Use Research Center

# Introduction

- In this talk I argue that biofuels in general, and ethanol as the largest global biofuel by volume are set to see a significant global expansion in use.
- The reason for this is a large new body of scientific insights and technical developments that support ethanol use in support of our environment.

# Ethanol Environmental Impact

Ethanol can provide significant contributions to both:

1) Mitigating climate change as well as

2) Improving air quality by

- Reducing combustion emissions from on-road vehicles and
- Avoided combustion of field residues: instead field residue removal for 2G ethanol production

Let me elaborate some more on these two topics and the latest science.



# Mitigating Climate Change - Reducing GHG Emissions

# Climate Change: Greenhouse Gas Life Cycle Assessment

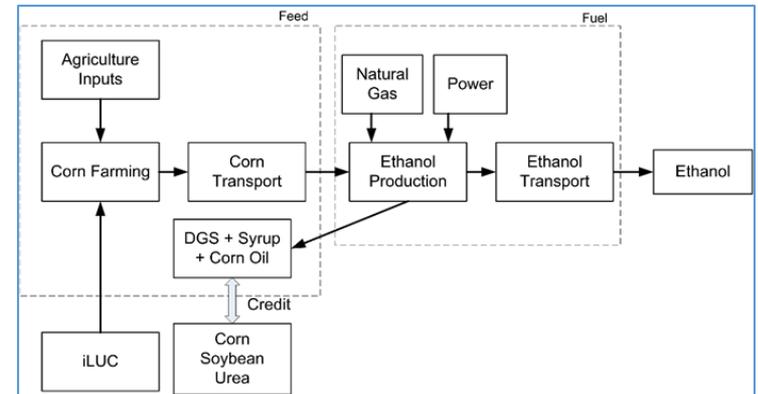
- When comparing the energy and emissions impact of different fuels and vehicle technologies researchers around the world use what is called life cycle models.
- In the US the dominant and most updated life cycle model is the GREET model developed by Argonne National Laboratory. While several different life cycle models exist around the world the basic concept is always the same:
- We look at the individual emissions released during the different production stages to make a fuel followed by the emissions incurred during the combustion of this fuel.



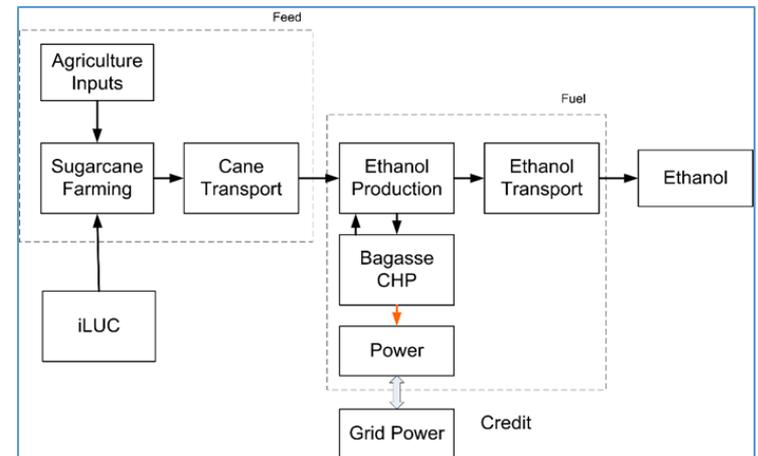
# Corn Ethanol

- For ethanol, for example, we look at the emissions
  - incurred during the growing of the corn or sugarcane feedstock including
    - tractor emissions,
    - nitrogen and other nutrient emissions,
    - emissions from feedstock conversion at the ethanol plant and
    - emissions from combustion of ethanol in the vehicle.
- However, emissions credits are given for
  - co-products produced at the biorefineries such as
    - animal feed produced with corn ethanol
    - and cogenerated electricity often produced at sugarcane ethanol plants.

Life Cycle Boundaries of Corn Ethanol Production

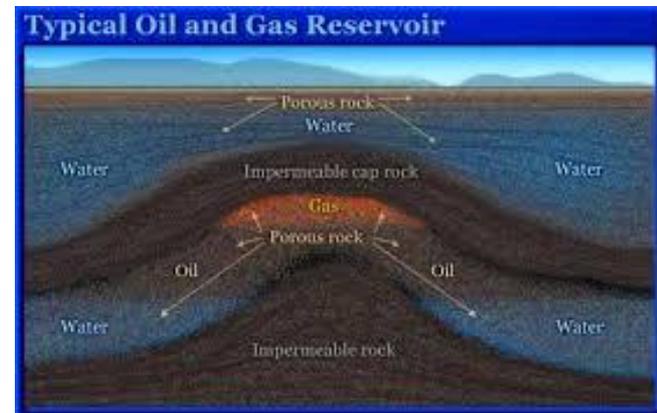


Life Cycle Boundaries of Sugarcane Ethanol Production



# Petroleum Based Fuels

- Then we compare the emissions from ethanol to emissions from petroleum based fuels which include
  - emissions from crude oil extraction and
  - emissions from oil refining.
- While crop based ethanol production takes more steps than gasoline production one must keep in mind that the carbon in the biofuel is carbon neutral, which refers to the fact that it was absorbed during plant growth and it is released to the atmosphere during combustion;
- All emissions from ethanol production are due to the individual production process for a particular quantity of fuel.
- This is not the case for petroleum based fuels where the fuel carbon extracted from the ground is not carbon neutral but a net addition of geological carbon to the atmosphere.

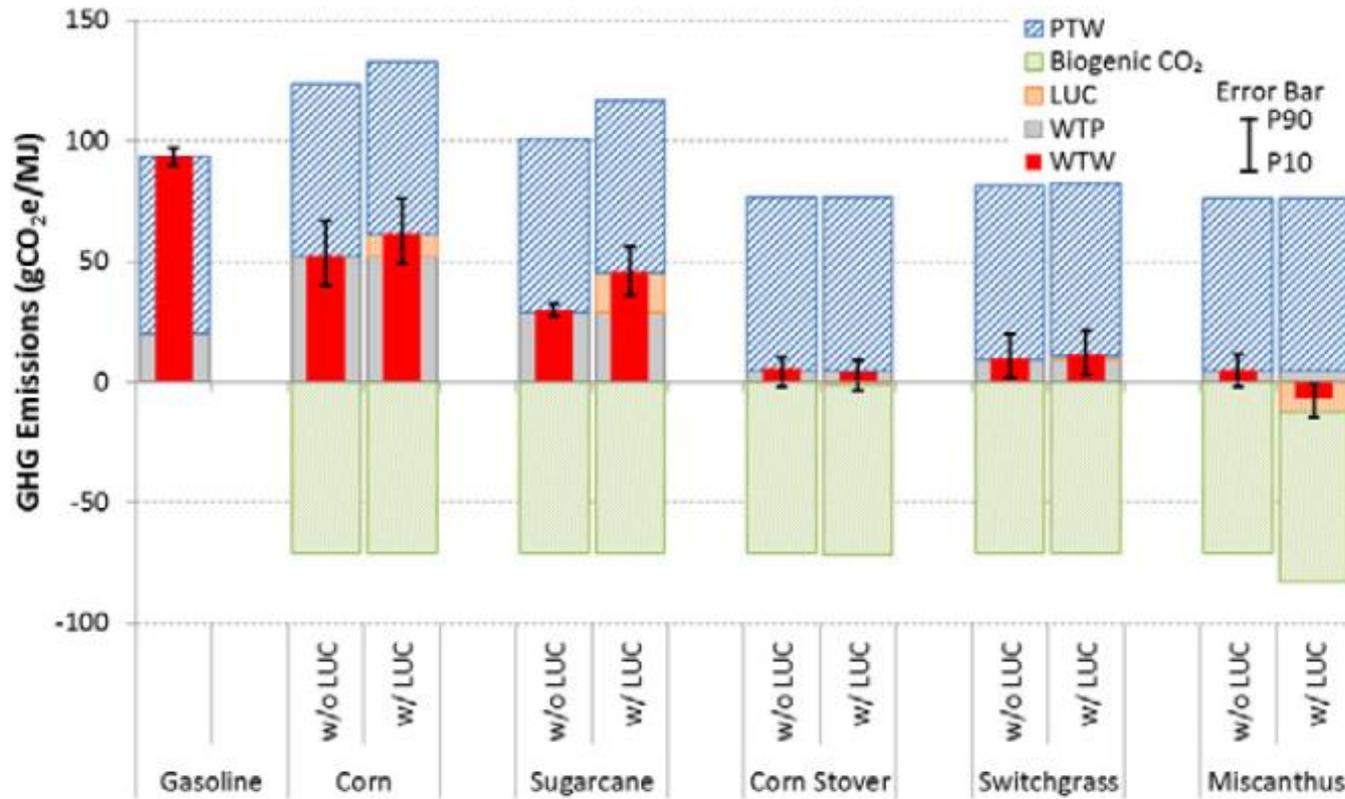


# Ethanol Helps to Mitigate Climate Change



- So, what is the latest science regarding life cycle modeling of the climate impact of ethanol.
- Life cycle analysis has shown that, depending on the individual plants, ethanol from corn and sugarcane provides a one third to two third reduction of greenhouse gases over gasoline and even higher reductions for residue based ethanol
- GHG reductions go a long way in meeting Paris Climate Commitments.

# GHG Life Cycle Emissions



Source: Argonne National Laboratory

# Modern Ethanol Production: 1G and 2G Technologies Merge

- Several technologies are responsible for the significant lower greenhouse emissions of ethanol compared to gasoline, a trend which will only continue in the future.
- A modern ethanol plant of today is much different from a plant only 10 years ago.
  - Incorporates 2G technologies

# Modern Ethanol Production: 1G and 2G Technologies Merge

- Corn ethanol plants today produce multiple products from the same corn feedstock which means that the same production inputs result in more products and therefore reduced emissions.
- Almost all corn ethanol plants now also extract corn oil which goes into animal feed as well as biodiesel production.
  - In fact about 14% of all biodiesel feedstocks come from corn ethanol plants.
- Furthermore, the animal feed coproduced at ethanol plants is included in more and more animal feed rations and its global price reflects its high feeding value
- Research has produced better enzymes to convert cellulose sugars from corn kernels
- Many plants now capture CO<sub>2</sub> released as part of the fermentation process and sell it for beverage production; and finally,
- More and more growers are adopting conservation management practices such as reduced tillage practices.
- We have published widely in the peer reviewed literature to demonstrate how these management practices increase soil carbon and thereby reduce carbon from the atmosphere.

# Modern Ethanol Production: 1G and 2G Technologies Merge

- Sugarcane ethanol is being produced with:
  - higher levels of mechanization,
  - higher yielding varieties and excess electricity co-product fed back to the local electricity grid.
- Second generation ethanol takes advantage of first generation know-how including the R&D in enzyme production and fermentation systems.



# New Technologies

- Information Technology has entered production agriculture and growers can use software tools to optimize nutrient inputs on their fields and sustainably intensify their yields.
- New equipment technologies by companies like Mahindra and AGCO provide precision farming applications and reduce tractor fuel consumption making agriculture more efficient and thereby reducing the overall greenhouse gas life cycle emissions.

**FUSE**  
AGCO Connecting Your Farm



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# Improving Air Quality

# Improvements in Air Quality: Reduction in Combustion Emissions

- Actual emissions from ethanol blends depend on engine type, fuel specification, altitude etc. However, selected publications show that
  - Ethanol can reduce PM emissions. PM emissions are correlated with double bond equivalent number of fuel components. Aromatic hydrocarbons have high DBE number whereas ethanol has DBE number of 0. (Aikawa&Jetter, 2014, Honda Model)
  - Potential reduction in NOx emissions: "Ethanol's high heat of vaporization (920 kJ/kg fuel vs ~350 for gasoline) results in charge cooling (particularly with DI engines)" Stein et al SAE 2013.
  - The latest research also shows a consistent reduction in several key pollutants including, for example, 1,3 butadiene which has a high cancer risk and a high rating to form ozone.
- At my research center we assess the impact of different ethanol blends for the air quality in an urban area taking a region or country's vehicle age, driving conditions, and weather patterns into account.
  - In recent study we have shown how ethanol blends can reduce ozone in Mexico City

# Improvements in Air Quality: Reduction in Combustion Emissions

- Researchers now understand how important it is to create the right blend of hydrocarbons in a fuel to fully take advantage of ethanol's high octane number.
- The US Department of Energy is currently funding the “Co-Optimization of Fuels & Engines (Co-Optima) initiative”.
  - High octane fuels including E25 are at the center of this initiative.
- Automakers and auto suppliers in the US, Brazil, and elsewhere have created substantial research programs in the area of high octane fuels as a technology of the future.

# Improvements in Air Quality: Avoided Emissions from Crop Residue Burning

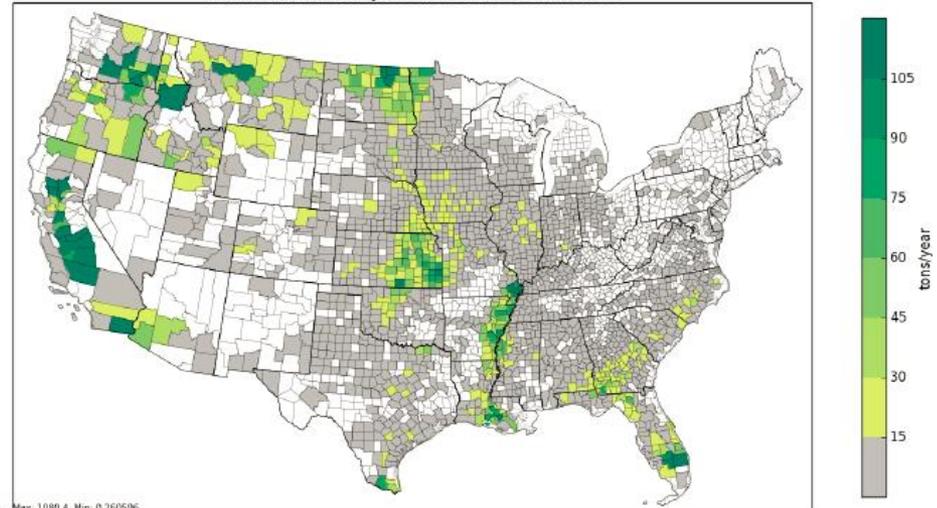
- Additional air quality benefits incur from second generation ethanol produced from, for example, rice and wheat straws.
- The removal of these residues for conversion into fuel avoids emissions from burning.

## Crop Residue Burning in the 2014 National Emissions Inventory



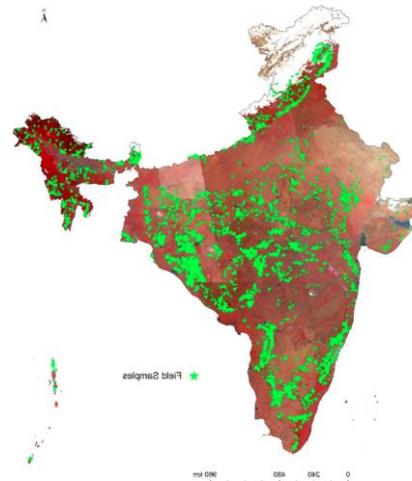
### Draft 2014 Crop Residue PM2.5 Emissions

Draft 2014 NEI Crop Residue PM2.5 Emissions



# Sustainability and Responsibility

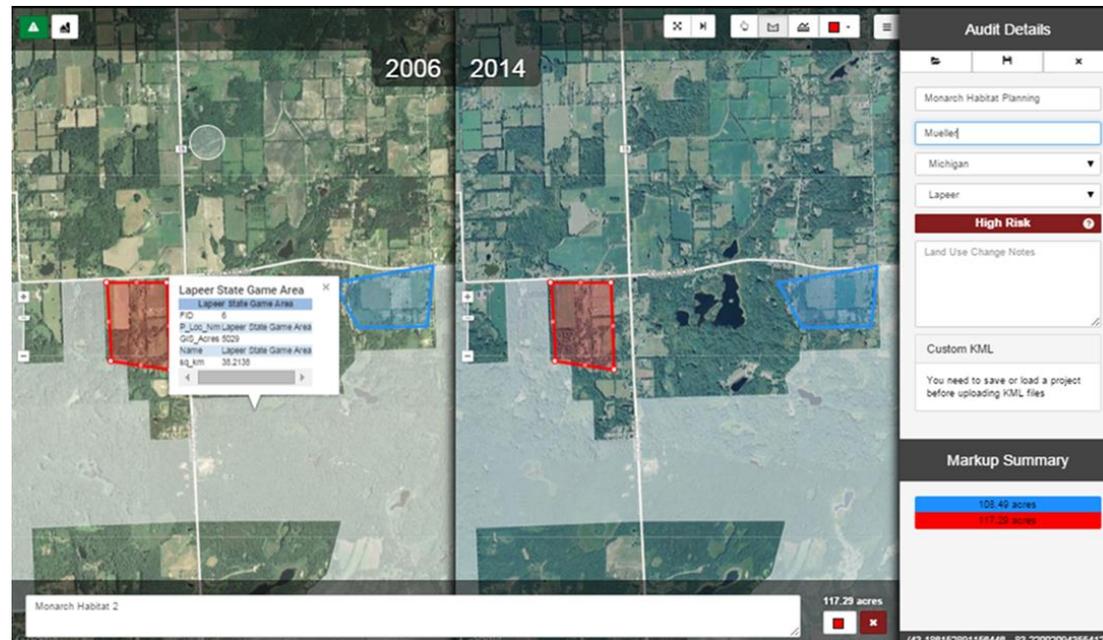
- Responsibility to ensure that we can maintain the high level of sustainability even as we produce more and more of them.
- My final set of thoughts addresses this issue as, again, newly developed technologies can help with this.
- Advanced Wide Field Sensor (AWIFS) satellite technology by the Indian Space Research Organization has long been used to increase the accuracy of the US Department of Agriculture's annual cropland data layer (CDL) which is the extremely essential determination of land planted for each crop each year.
- The CDL allows us to track land expansion and native land conversions



# Sustainability and Responsibility

- At my University Research Center we work extensively with satellite data layers. We have developed tools that allow us to ensure that biofuels feedstocks are grown sustainably and that those feedstocks do not come from deforested lands.
- For example, we have worked with one of the European Union's largest certification protocol developers to develop a satellite based land use verification tool. This tool is now used by the Europeans to certify that none of the biofuels imported into the European Union under the Renewable Energy Directive come from deforested fields or plantations.

Global Risk  
Assessment Services  
GRAS Tool for Land  
Use and Sustainable  
Feedstock  
Assessment



# Sustainability and Responsibility

- So, as scientists we now understand more than ever the benefits that biofuels can provide for our societies and how to quantify these benefits based on the latest models.
- We also understand the sustainable production practices required to optimize the benefits we get from using biofuels in our vehicles.
- In my assessment, ethanol provides a flexible platform for the fuel supply in India.
  - Ethanol from 1G, 2G, Combined 1&2G, Industrial Waste Gas Streams
- You can import ethanol from a variety of feedstocks or make it in India thereby taking advantage of India's existing know-how in farm equipment technology as well as its remote sensing capabilities, two of the key technology fields of the future.

# Contact

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