

Renewable Energy II: Biofuels, Ethanol, Methanol, and Algae

Ross Salawitch

Class Web Site: <http://www.atmos.umd.edu/~rjs/class/spr2017>

Topic for today:

- **A discussion of the pros and cons of various aspects of meeting the energy needs of society by means of combustion of biomass, biofuels, and biowaste**

Lecture 20
27 April 2017

Course Logistics

Only assigned to students in 433:

4. Plan for The U.S. To Meet Its Future Energy and Needs (60 points)

Ross & Pam will read each reply carefully and make an assessment based on our view of how well material presented throughout the class, or perhaps gleaned from other sources, is integrated into a coherent, thoughtful reply. We look forward to learning from your replies 😊.

You are the Energy Advisor of a candidate for preparing for the 2020 election for President of the United States. The candidate has asked you to present a plan for the nation to meet its future energy needs, taking into account climate change, air quality, and the candidate's long-term vision for a high quality of life for US citizens. Specifically, the candidate has asked you to address the Nation's future *electricity supply* and *energy* needs in a manner that is both environmentally friendly and cost effective over the long-term, even if the plan requires significant initial investment.

The candidate's parting words when describing this request were "when dealing with energy, it is hard to separate the charlatan from the prophet".

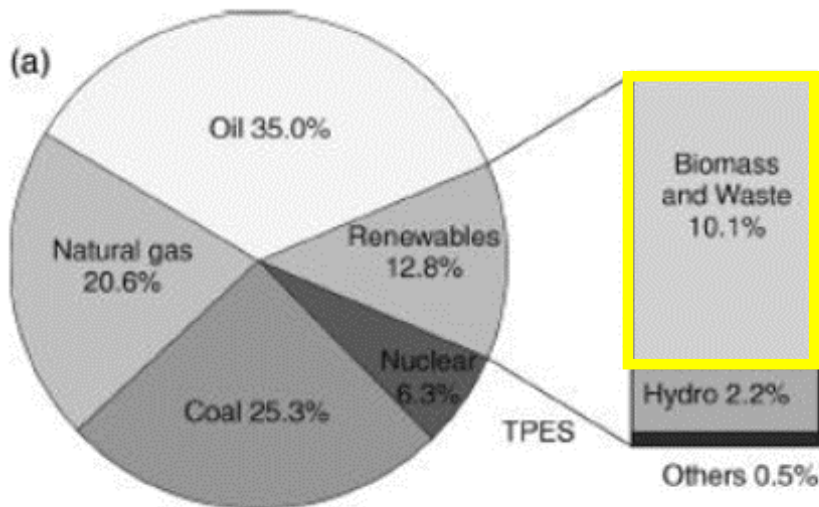
As part of your plan to gain advocacy for your vision of America's energy future, you have decided to produce a "one page" briefing paper for the candidate that highlights the plan.

Please share your *one-page* plan for America's energy future. Your reply can take whatever format you'd like: i.e., paragraphs, bullet statements, etc are all fine. Your reply can be produced using Word, Powerpoint, etc. The only requirement is that your plan *fit onto a single piece of paper (one side)* 😊

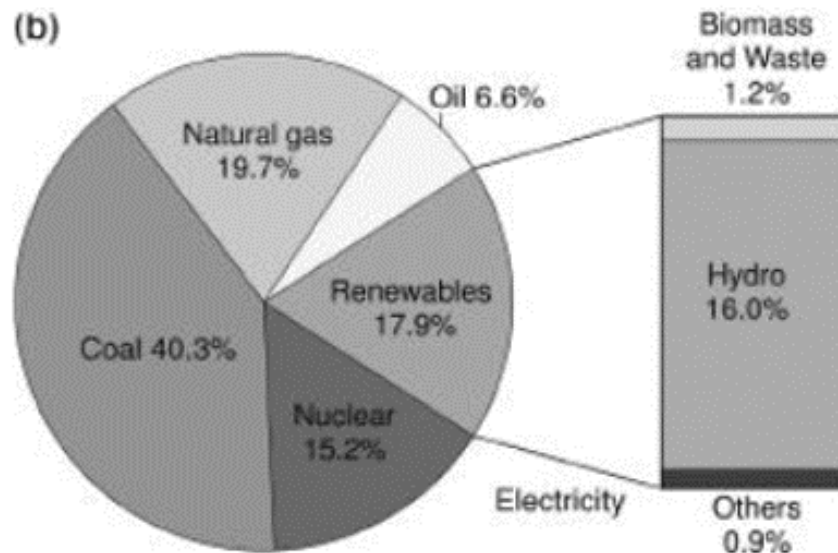
Please write your name on the back, so that we can read your response without knowing by whom it was written (use a pencil if you think your name will show through the paper).

World Energy & Electricity Supply

World Energy



World Electricity



[Figure 8.1](#) (a) Share of renewables in the world total primary energy supply (TPES) in 2005; (b) share of renewables in world electricity production in 2005. (Source: IEA Renewables Information 2007.)

Olah *et al.*, *Beyond Oil and Gas: The Methanol Economy*, 2009

Largest energy source that does not involve combustion of fossil fuels is **Biomass and Waste**

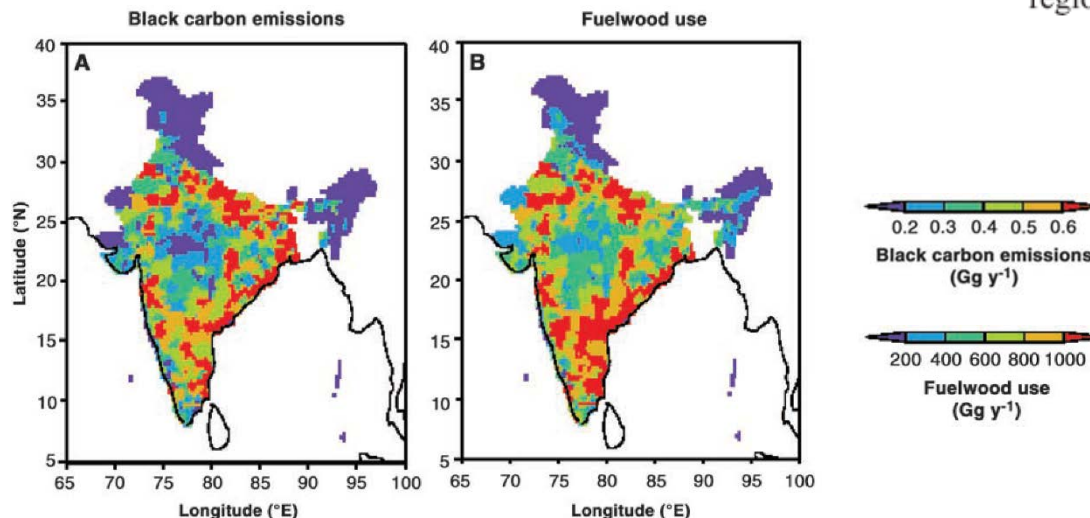
Residential Biofuels in South Asia: Carbonaceous Aerosol Emissions and Climate Impacts

C. Venkataraman,^{1*} G. Habib,¹ A. Eiguren-Fernandez,²
A. H. Miguel,² S. K. Friedlander³

High concentrations of pollution particles, including "soot" or black carbon, exist over the Indian Ocean, but their sources and geographical origins are not well understood. We measured emissions from the combustion of biofuels, used widely in south Asia for cooking, and found that large amounts of carbonaceous aerosols are emitted per kilogram of fuel burnt. We calculate that biofuel combustion is the largest source of black carbon emissions in India, and we suggest that its control is central to climate change mitigation in the south Asian region.

An analysis of the climate response of soot emissions from fossil fuel and biofuel combustion has suggested that control of soot, in addition to greenhouse gases, is an important measure to slow global warming, especially on short time scales (6, 7). Our results suggest that biofuel combustion could significantly affect atmospheric BC concentrations in the south Asian region. The climate effects of biofuel combustion aerosols have been combined with the effects of open biomass burning in the scientific consensus reports of the Intergovernmental Panel on Climate Change (29). We suggest that biofuel combustion needs to be addressed as a distinct source, and that cleaner cooking technologies not only could yield significant local health and air quality benefits but also could have an important role in climate change mitigation in the south Asian region.

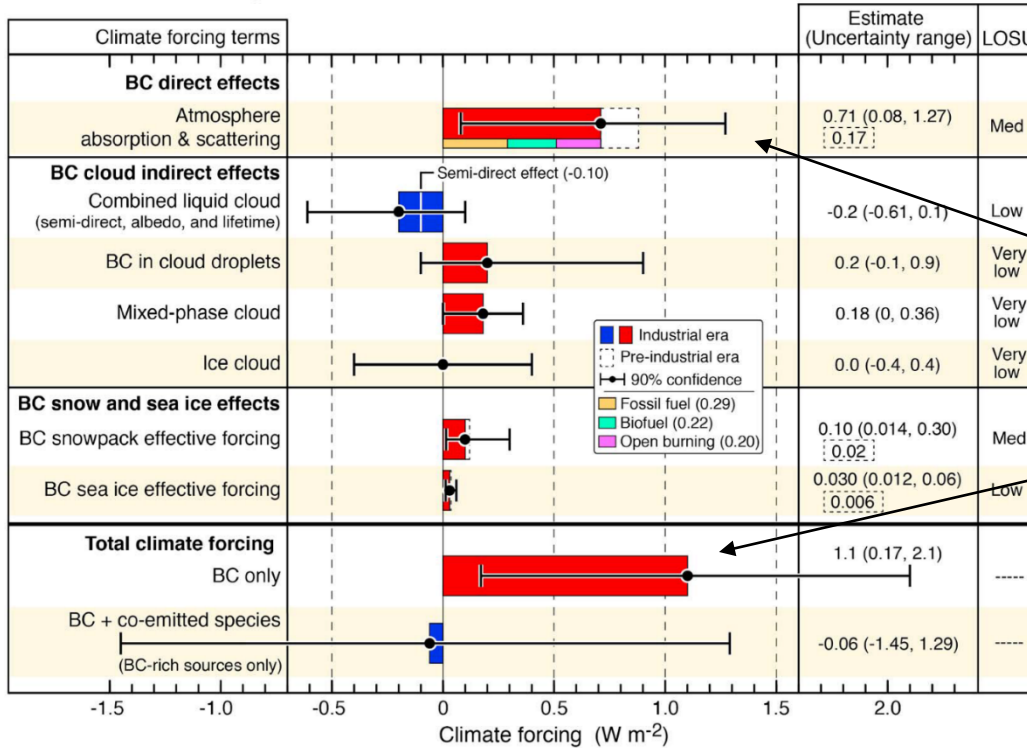
4 MARCH 2005 VOL 307 SCIENCE



Black Carbon & Climate

BOND ET AL.: BLACK CARBON IN THE CLIMATE SYSTEM

Global climate forcing of black carbon and co-emitted species in the industrial era (1750 - 2005)



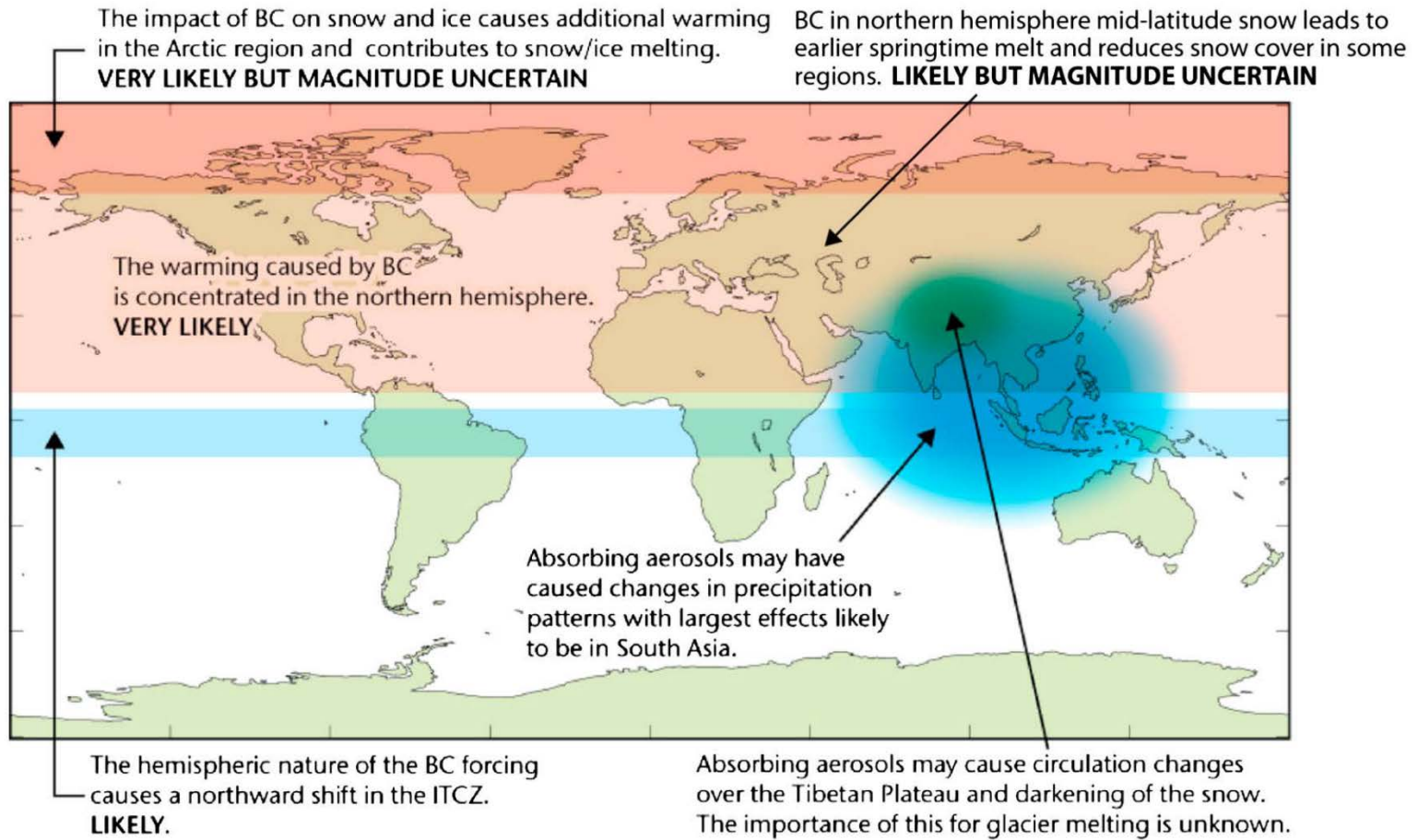
New Estimate:

BC causes 0.7 W m⁻² RF
Direct, warming

& 1.1 W m⁻² RF
Total, also warming

Bond *et al.*, JGR, 2013

Black Carbon & Climate



Bond *et al.*, JGR, 2013

Aerosol Direct RF of Climate, IPCC

Box & Whisker: Climate Models

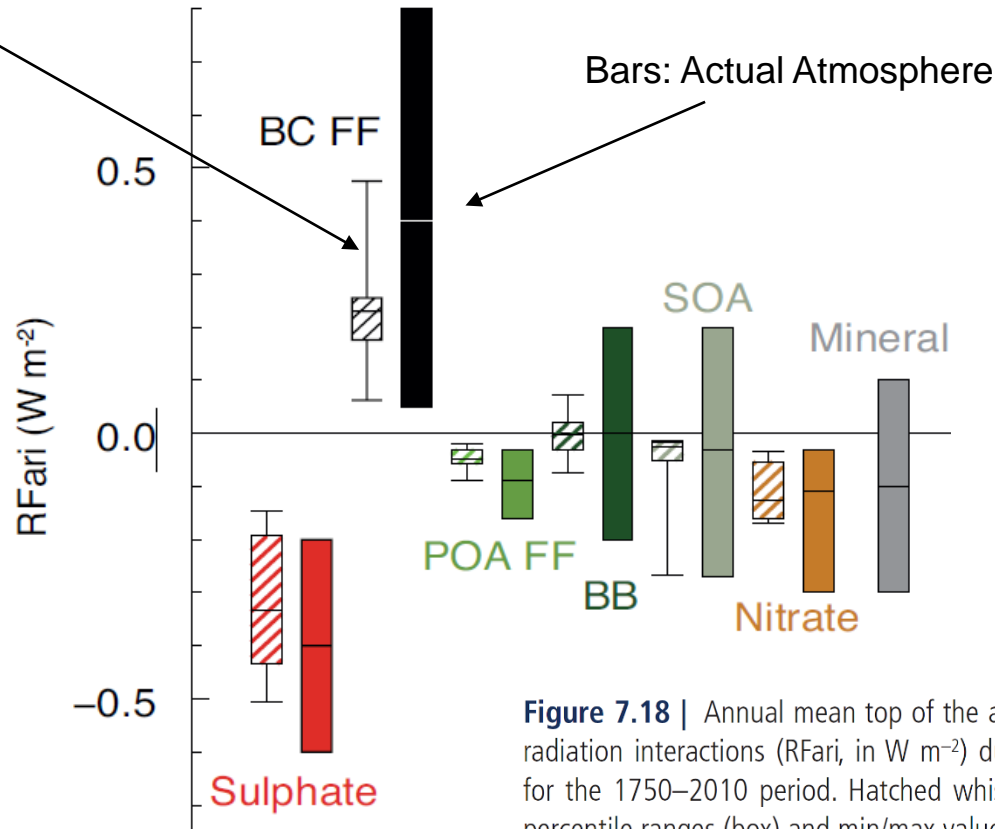
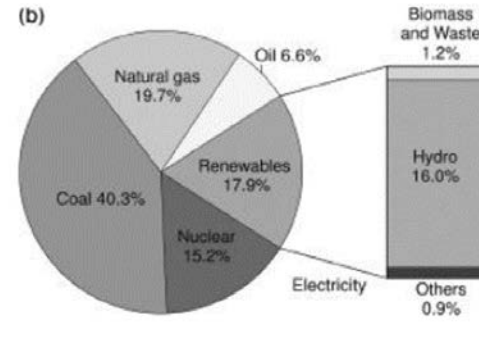
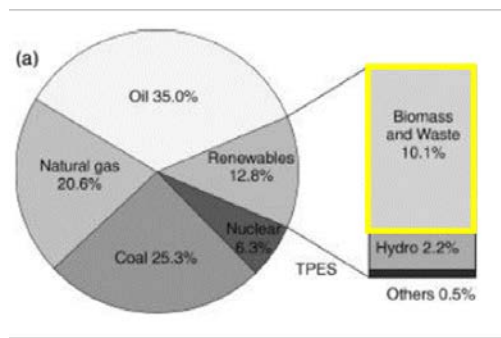


Figure 7.18 | Annual mean top of the atmosphere radiative forcing due to aerosol–radiation interactions (RFari, in W m^{-2}) due to different anthropogenic aerosol types, for the 1750–2010 period. Hatched whisker boxes show median (line), 5th to 95th percentile ranges (box) and min/max values (whiskers) from AeroCom II models (Myhre et al., 2013) corrected for the 1750–2010 period. Solid coloured boxes show the AR5 best estimates and 90% uncertainty ranges. BC FF is for black carbon from fossil fuel and biofuel, POA FF is for primary organic aerosol from fossil fuel and biofuel, BB is for biomass burning aerosols and SOA is for secondary organic aerosols.

IPCC (2013)



Surya – Sanskrit for Sun

- 65 villages (6500 homes) covering 1500 km², where most residents use wood for cooking, will be provided with either solar and/or biogas burners
- Air quality, soot, and particulates will be monitored for 6 months prior to installation of alternate cookers and for at least 1 year subsequent
- Indoor air quality will be measured in selected homes
- Outdoor air quality will also be monitored using NASA satellite instruments
- PI: V. Ramanathan, Scripps

<http://www.projectsurya.org>

Surya – Pilot Phase Findings

- **Pilot village included 485 households**
- **Cooking drives local outdoor black carbon concentrations**
- **New stove technologies could reduce emissions of PM_{2.5} and CO by factors of 4 to 5**
- **Demonstrated an ultra low power wireless cell phone approach for measuring black carbon**

<http://www.projectsurya.org/storage/prospectusinsert.pdf>

EXPECTED OUTCOME

REGIONAL

Increase food and water supply, decrease mountain glacier melt, decrease deforestation and aid in poverty alleviation.

GLOBAL

Contribute to the delay of the DAI threshold by up to few decades and saving 2 million lives yearly.

BACKGROUND

Global warming of more than 2°C is considered to be the threshold for dangerous anthropogenic interference (DAI).

Black carbon (BC) & non-CO₂ gases such as methane, ozone, halocarbons account for half of global warming and can be removed from the air 10x-100x faster than CO₂.

Biomass cooking (using dung, firewood, crop residues) is a major source of BC & ozone and leads to CO₂ emission by deforestation; it leads to severe air pollution which is the root cause of millions of cardiovascular & respiratory related deaths.

Surya will introduce cleaner cooking methods.



Photo Credit: Adam Ferguson, New York Times

GLOBAL POLICY

2020 - 2025

\$20 Billion

Target: 3 Billion people worldwide

Funded and sustained by carbon credits, micro-financing, Global Environment Facility funds and foundations.

REPLICATION

2014 - 2020

\$200 Million

Target: 10-20 Million people in Africa, Asia and Latin America.

PILOT PHASE

2009 - 2010

\$ 0.8 Million

2,500 People

COMPLETED

DEMONSTRATION

2011 - 2013

\$13.7 Million

Target: 50,000 people in North India

IMPLEMENTATION

Replace stoves in 10,000 homes with aid of multi-national team of scientists, engineers, health professionals and village leaders.

VALIDATION

Use data collected from cell phones, satellites and other cutting-edge technologies to quantify impacts on climate and health. Develop metrics for carbon credits.

<http://www.projectsurya.org/storage/ProjectSuryaWEB-Feb23.pdf>

Project Surya: April 2015

HOME OVERVIEW ABOUT SURYA THE CHALLENGE CO-BENEFITS PRESS PAPERS CONTACT STATUS DOWNLOADS

 **project surya**
Fighting Climate Change Now

C2 P2 Launch of 5,000 stoves with McQuown donation

You Can Help [Give Now](#)

You can directly aid Project Surya expand into new homes. Your \$70 donation will provide a household with a clean cookstove. At \$30, your donation will provide a solar light.

Please make checks payable to "UC Regents" with a memo of "Project Surya."

Mail to:
Project Surya Office
9500 Gilman Drive MC 0221
La Jolla, CA 92093

Project Surya making a bold entry towards the Voluntary Carbon Credit Market
[Team of cook stove suppliers, solar lamp manufacturers, NGOs, Rural Bank and academics is pioneering a new approach for getting climate credit directly to women using the renewable technologies.](#)

UN.org: "A cooking stove improves lives in Kenya"

Project Surya is:

- exploring how to include Short Lived Climate Pollutants including BC and O₃ producing gases (CO & VOCs) into carbon credit calculations, which will lead to more revenue for climate credits.
- distribute the funds from carbon credits directly to the participant women instead of the stove distributors or manufacturers

<http://static1.1.sqspcdn.com/static/f/316880/20886420/1352224604787/ProjectSuryaLaunchesPilotCarbonCreditMarket.pdf>

Wireless sensors linked to climate financing for globally affordable clean cooking

Tara Ramanathan¹, Nithya Ramanathan^{1*}, Jeevan Mohanty², Ibrahim H. Rehman², Eric Graham¹ and Veerabhadran Ramanathan³

Affordability of cleaner stoves is one of the major barriers addressed in this study through a breakthrough approach, hereafter referred to as SCF for sensor-enabled climate financing, described below and further detailed in the Methods and Supplementary Methods A–H. SCF differs from traditional approaches to rural cookstove interventions in the following ways: data collected from wireless sensors are used to measure and verify daily cooking duration in each household in near real time; sensor data are converted into climate credits to pay each woman directly for her role in climate change mitigation. Rewarding users is at the heart of the proposed model and to date, we know of no other study

The results demonstrate the potential of widespread monitoring via wireless sensors to produce unprecedented insights into energy access, science-based measurements for carbon mitigation and financing for distributed and decentralized energy access in rural areas. Results-based financing models such as SCF are relevant today, as they can provide a solid basis for understanding how best to apply the approximately US\$100 billion per year of pledged climate financing from UN signatory nations that backed the 2015 Paris Agreement²², declaring the protection of vulnerable populations in developing countries a primary goal.

<http://projectsurya.squarespace.com/storage/Nclimate3141.pdf>

Wireless sensors linked to climate financing for globally affordable clean cooking

Tara Ramanathan¹, Nithya Ramanathan^{1*}, Jeevan Mohanty², Ibrahim H. Rehman², Eric Graham¹ and Veerabhadran Ramanathan³

Three billion of the world's poorest people mostly rely on solid biomass for cooking, with major consequences to health¹ and environment². We demonstrate the untapped potential of wireless sensors connected to the 'internet of things' to make clean energy solutions affordable for those at the bottom of the energy pyramid. This breakthrough approach is demonstrated by a 17-month field study with 4,038 households in India. Major findings include: self-reported data on cooking duration have little correlation with actual usage data from sensors; sensor data revealed that the distribution of high and low users varied over time, and the actual mitigation of climate pollution was only 25% of the projected mitigation; climate credits were shown to significantly incentivize the use of cleaner technologies.

<http://projectsurya.squarespace.com/storage/Nclimate3141.pdf>

Electricity from Biomass

Table 8.1 Production of electricity from biomass and waste in 2006.

Data source: EDF and IEA key statistics.

Country	Production (TWh)	Percentage of world electricity production from biomass	Percentage of the country's total electricity production
United States	58.7	29.3	1.5
Germany	19.7	9.9	3.4
Brazil	14.6	7.3	3.9
Finland	11.8	5.9	14.0
Japan	11.6	5.8	1.1
United Kingdom	9.3	4.6	2.5
Canada	9	4.5	1.6
Spain	8.2	4.1	3.1
Rest of the world	57.2	28.6	0.6
World	200.1	100	1.2

Olah et al., Beyond Oil and Gas: The Methanol Economy, 2009.

Electricity from Biomass: Overview

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Courtesy A. Truman Schwartz

Fig 4.24, *Chemistry in Context*

- Plant size average 20 MW
- Efficiencies range from 15 to 30% (electricity only) to 60% (electricity + heat)
 - co-firing uses biomass to supplement fossil fuel
- Use wood, agricultural residues, and municipal waste
- 85 plants in U.S generate some type of energy from waste
- Addresses energy need and growing “mountain of waste”:
 - waste converted to CO₂ and water; unburned residue about 10% of initial volume
 - iron-containing metals often recovered and recycled

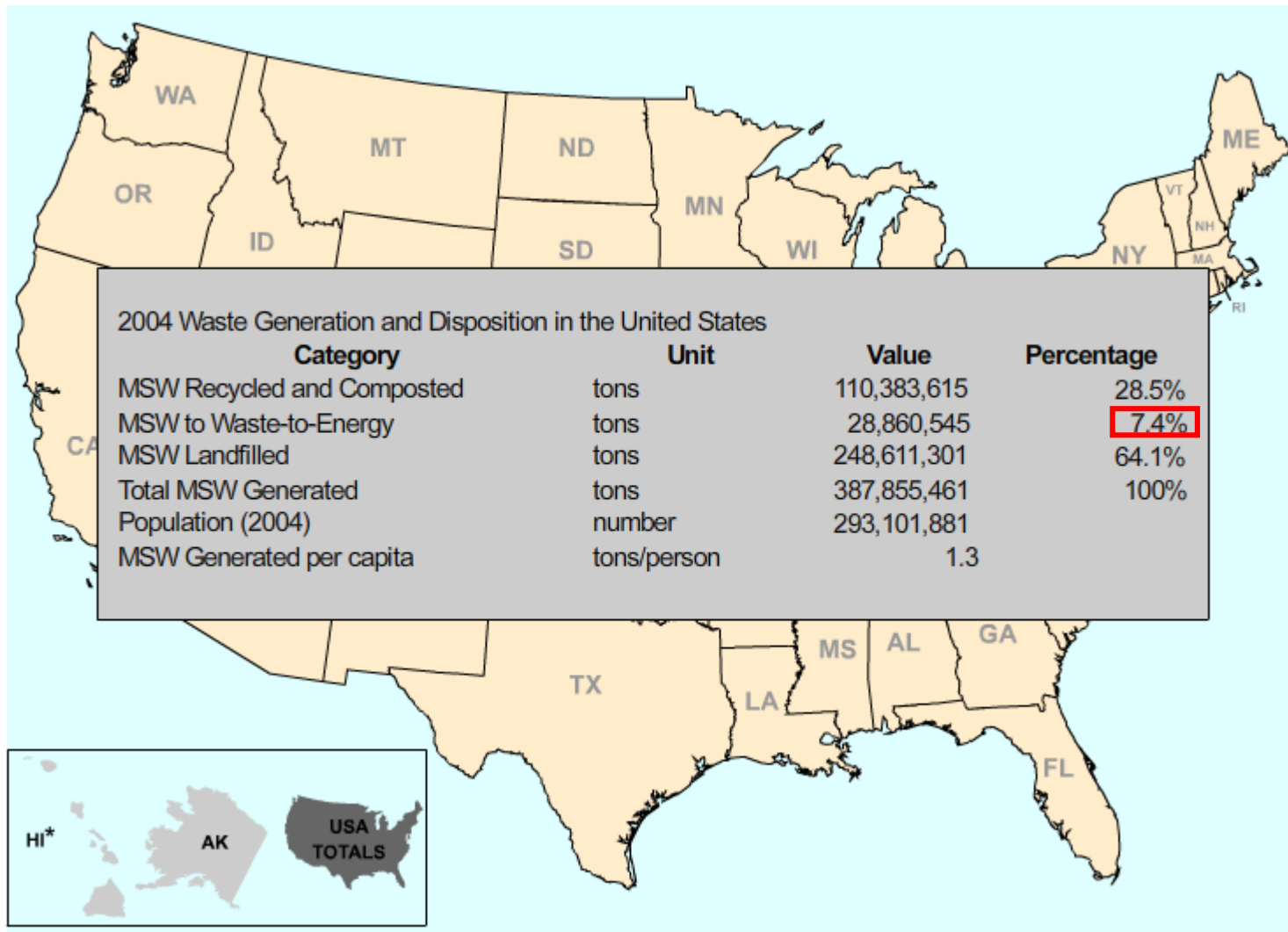
Electricity from Waste



Baltimore RESCO (Refuse Energy Systems Company) Plant
Russell Street & U.S Interstate 95 (shadow of Ravens Stadium)

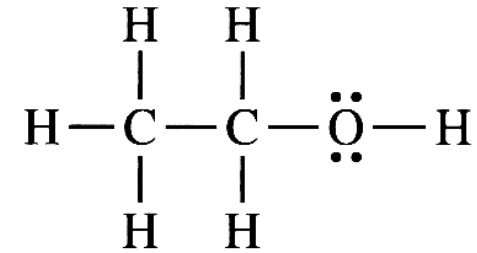
- Opened in 1984
- Site of old pyrolysis plant
- Burns 2,250 tons of trash per day
- Metals recovered; volume of trash reduced by factor of 10
- Can generate 60,000 kW of electricity \Rightarrow 60 MW (2700 \times size of UP solar array but only 6% typical nuclear plant)
- Heat used for direct steam heating / cooling downtown Baltimore
- One of 16 such plants in the U.S. http://www.eia.doe.gov/kids/energy.cfm?page=RESCOE_Plant

Energy from Waste



<http://www.seas.columbia.edu/earth/recycle/>

Ethanol



- Ethanol : $\text{C}_2\text{H}_5\text{OH}$
- Alcohol
- $\text{C}_6\text{H}_{12}\text{O}_6 \rightarrow 2 \text{C}_2\text{H}_5\text{OH} + 2 \text{CO}_2$ ($\Delta H_f = 228 \text{ kJ/mol}$ or 5 kJ/g)
- Reaction catalyzed by enzymes; theoretically, can be close to carbon neutral
- Ethanol combustion:



Heat release less than combustion of C_8H_{18} (47.8 kJ/g) because $\text{C}_2\text{H}_5\text{OH}$ is already partially oxidized

- However ... ethanol has a higher octane than gasoline

Ethanol Production

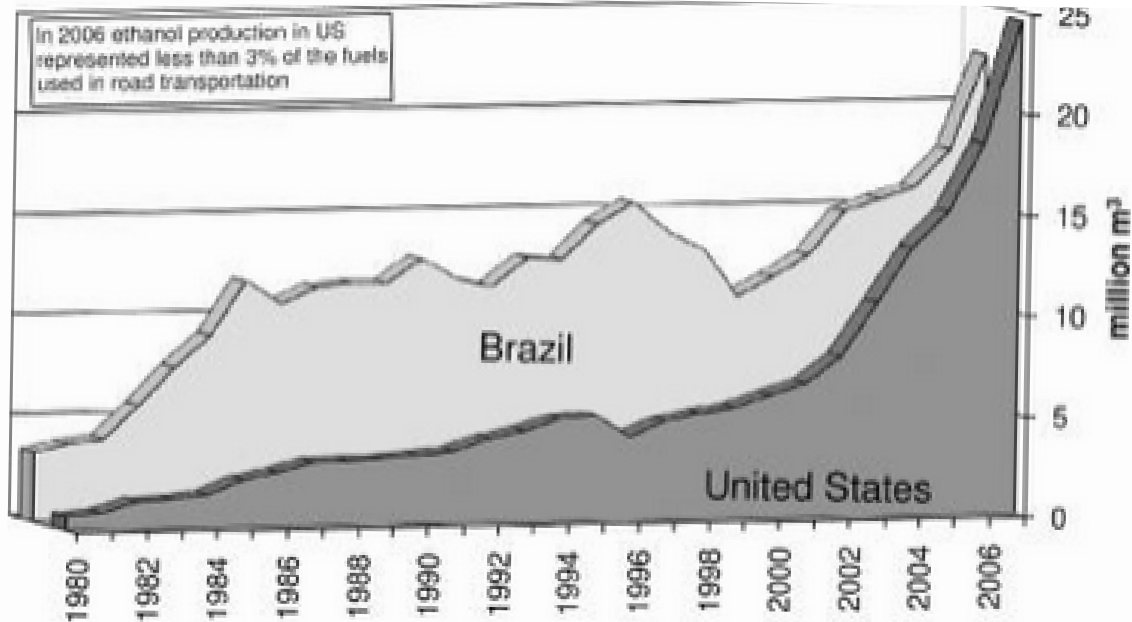


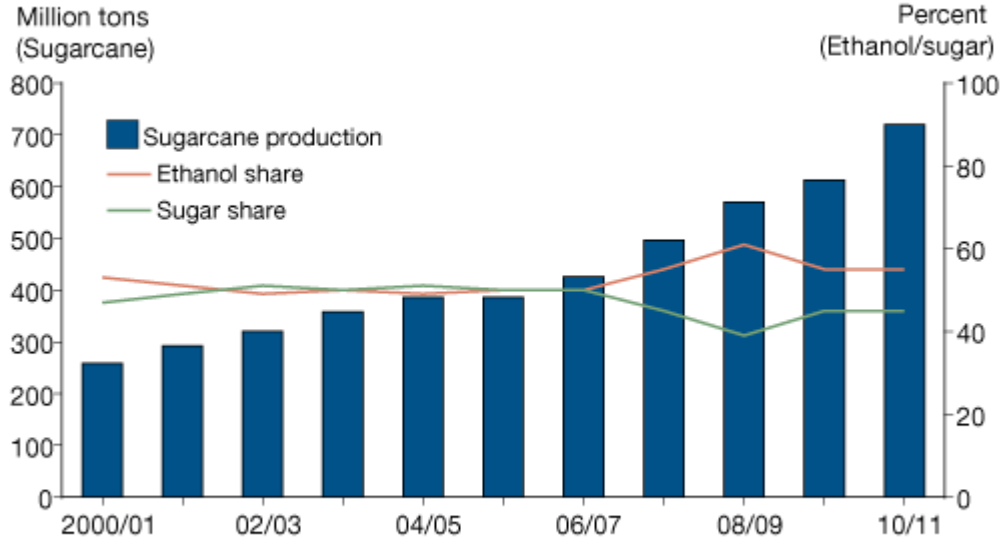
Figure 8.13 Historic production of ethanol in the United States and Brazil. (Based on data from Renewable Fuel Association and Sao Paulo Agroindustry Union (UNICA).)

Olah *et al.*, *Beyond Oil and Gas: The Methanol Economy*, 2009.

- U.S.: Ethanol produced from corn
- Brazil: Ethanol produced from sugar cane, which thrives in tropical climate

Ethanol Production: Good News

In 2010, over 55 percent of Brazil's sugarcane harvest was used for ethanol production



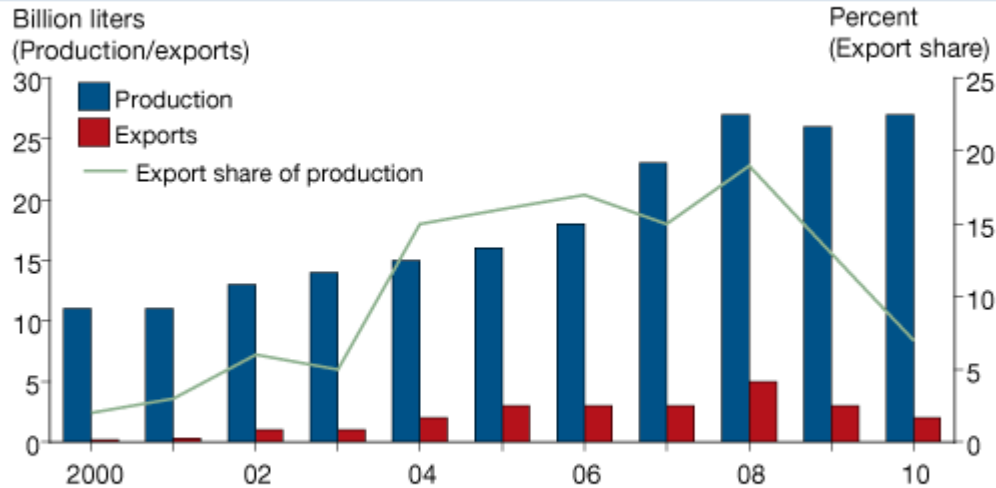
Source: USDA, Economic Research Service using data from Brazil's Ministry of Agriculture, Livestock and Food Supply.

<http://www.ers.usda.gov/amber-waves/2011-december/can-brazil-meet-the-world%E2%80%99s-growing-need-for-ethanol.aspx>

- Brazil: Ethanol produced from sugar cane, which thrives in tropical climate
 - energy to convert sugar to ethanol supplied by burning bagasse (sugar cane husk)
- About half cars in Brazil are “flex fuel vehicles (FFV)”
 - can run on 100 percent ethanol or any ethanol-gasoline mixture.
- Ethanol accounts for ~40% of non-diesel fuel use in Brazil
- 2010: Brazil produces 26% of world ethanol (US produces most)

Ethanol Production: **Bad News**

Brazil's ethanol exports fell after 2008 because of strong domestic demand and a greater diversion of cane to sugar production



Sources: USDA, Economic Research Service using data from Brazil's National Petroleum, Natural Gas, and Biofuels Agency, São Paulo Cane Agricultural Industry Union, and Global Trade Information Services.

<http://www.ers.usda.gov/amber-waves/2011-december/can-brazil-meet-the-world%E2%80%99s-growing-need-for-ethanol.aspx>

- **Annual Brazil ethanol production < 1 day world petroleum consumption**
- **Brazil consumes nearly all the ethanol it produces due to high domestic demand**

Ethanol Production

- McElroy article suggests considering refinement cost, transportation cost, and energy content of ethanol, “the energy captured in the ethanol exceeds the fossil energy consumed in its production by no more than ~25 %”
- McElroy did not consider _____

Ethanol Production

- Raging debate over “green” aspects of both sugar and corn based biofuels:
Excellent point/counterpoint: <http://cen.acs.org/articles/85/i51/Costs-Biofuels.html>

Land Clearing and the Biofuel Carbon Debt

SCIENCE VOL 319 29 FEBRUARY 2008

Joseph Fargione,¹ Jason Hill,^{2,3} David Tilman,^{2*} Stephen Polasky,^{2,3} Peter Hawthorne²

Increasing energy use, climate change, and carbon dioxide (CO₂) emissions from fossil fuels make switching to low-carbon fuels a high priority. Biofuels are a potential low-carbon energy source, but whether biofuels offer carbon savings depends on how they are produced. Converting rainforests, peatlands, savannas, or grasslands to produce food crop–based biofuels in Brazil, Southeast Asia, and the United States creates a “biofuel carbon debt” by releasing 17 to 420 times more CO₂ than the annual greenhouse gas (GHG) reductions that these biofuels would provide by displacing fossil fuels. In contrast, biofuels made from waste biomass or from biomass grown on degraded and abandoned agricultural lands planted with perennials incur little or no carbon debt and can offer immediate and sustained GHG advantages.

¹The Nature Conservancy, 1101 West River Parkway, Suite 200, Minneapolis, MN 55415, USA. ²Department of Ecology, Evolution, and Behavior, University of Minnesota, St. Paul, MN 55108, USA. ³Department of Applied Economics, University of Minnesota, St. Paul, MN 55108, USA.

Ethanol Production

- Raging debate over “green” aspects of both sugar and corn based biofuels:
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SCIENCE VOL 319 29 FEBRUARY 2008

Use of U.S. Croplands for Biofuels Increases Greenhouse Gases Through Emissions from Land-Use Change

Timothy Searchinger,^{1*} Ralph Heimlich,² R. A. Houghton,³ Fengxia Dong,⁴ Amani Elobeid,⁴
Jacinto Fabiosa,⁴ Simla Tokgoz,⁴ Dermot Hayes,⁴ Tun-Hsiang Yu⁴

Most prior studies have found that substituting biofuels for gasoline will reduce greenhouse gases because biofuels sequester carbon through the growth of the feedstock. These analyses have failed to count the carbon emissions that occur as farmers worldwide respond to higher prices and convert forest and grassland to new cropland to replace the grain (or cropland) diverted to biofuels. By using a worldwide agricultural model to estimate emissions from land-use change, we found that corn-based ethanol, instead of producing a 20% savings, nearly doubles greenhouse emissions over 30 years and increases greenhouse gases for 167 years.

¹Woodrow Wilson School, Princeton University, Princeton, NJ, USA. German Marshall Fund of the U.S., Georgetown

Environmental Law and Policy Institute. ²Agricultural Conservation Economics, Laurel, MD, USA. ³Woods Hole Research Center,

Falmouth, MA, USA. ⁴Center for Agricultural and Rural Development, Iowa State University, Ames, IA, USA.

Ethanol Production

- Raging debate over “green” aspects of both sugar and corn based biofuels:
Excellent point/counterpoint: <http://cen.acs.org/articles/85/i51/Costs-Biofuels.html>

The New York Times

Biofuels Threaten Fertilizer

By KEITH BRADSHER and ANDREW MARTIN

Published: April 30, 2008

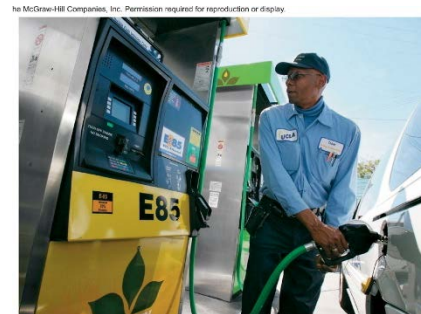
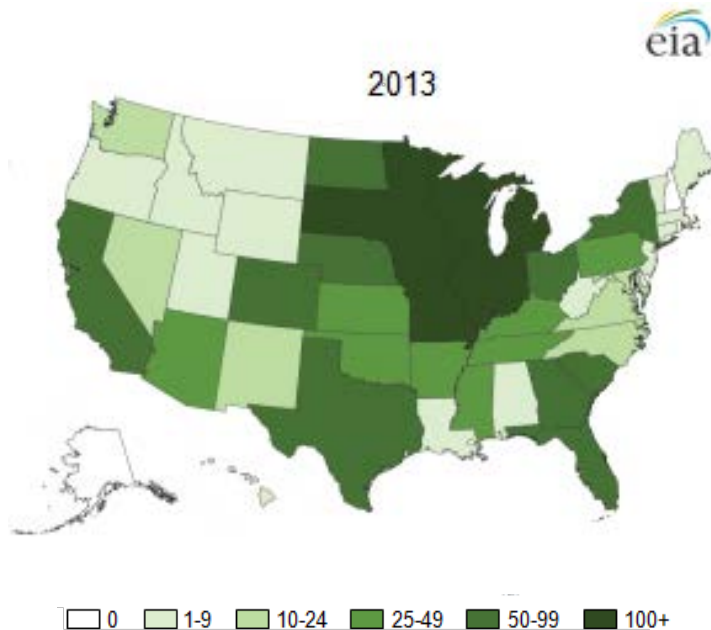
The squeeze on the supply of fertilizer has been building for roughly five years. Rising demand for food and biofuels prompted farmers everywhere to plant more crops. As demand grew, the fertilizer mines and factories of the world proved unable to keep up.

Some dealers in the Midwest ran out of fertilizer last fall, and they continue to restrict sales this spring because of a limited supply.

“If you want 10,000 tons, they’ll sell you 5,000 today, maybe 3,000,” said W. Scott Tinsman Jr., a fertilizer dealer in Davenport, Iowa. “The rubber band is stretched really far.

Ethanol Production: US

- Despite these debates the “show goes on”
 - US produced 14×10^9 gallons of ethanol in 2014
 - 83 million acres (**20% of cultivated land area**) harvested for corn
 - ~40% of US corn produced goes to ethanol production
 - US govt subsidy of ethanol, \$0.45/gallon, expired Jan 2012 leading to rise in fuel prices:
<http://green.autoblog.com/2012/01/18/u-s-ethanol-subsidy-expiration-may-be-driving-up-gas-prices>
 - Present debate focused on Renewable Fuel Standard:
<http://www.washingtonpost.com/news/energy-environment/wp/2015/04/10/epa-says-it-will-get-back-on-schedule-in-issuing-rules-for-biofuels>



*Chemistry
in Context*



McElroy, Ethanol Illusion,
Harvard Magazine,
Nov-Dec 2006.

<http://www.eia.gov/todayinenergy/images/2014.03.07/main.png>

<http://www.forbes.com/sites/jamesconca/2014/04/20/its-final-corn-ethanol-is-of-no-use>

Ethanol Subsidies: Obama

Good News For Corn, Bad News For You

The corn ethanol lobby gets a big break in Obama's 2015 budget proposal.

So it was great news that the (otherwise terrible) 2014 farm bill (officially the Agricultural Act of 2014) prevents the mature corn ethanol industry from receiving subsidies to purchase pumps dispensing higher blends of corn ethanol.

Now for the bad news. Less than a month after signing the farm bill into law, the president proposed new subsidies for ethanol blender pumps in his [FY 2015 budget proposal](#). The overall budget was released last Tuesday, with detailed back up documents following in the last few days. Buried on page 158 of the "Analytical Perspectives" document, released Monday, is up to \$200 million in new advanced energy manufacturing tax credits for the "construction of infrastructure that contributes to networks of refueling stations that serve alternative fuels," or in other words, more subsidies for corn ethanol blender pumps and other alternative fuel infrastructure projects. Such is the power of the [corn ethanol lobby](#).

<https://www.usnews.com/opinion/economic-intelligence/2014/03/11/obamas-2015-budget-backs-costly-corn-ethanol-subsidies>

See also <http://www.taxpayer.net/library/article/federal-subsidies-for-corn-ethanol-and-other-corn-based-biofuels>

Ethanol Subsidies: Trump TBD

Ethanol future murky in Trump era

Patrick Anderson, panderson@argusleader.com

Published 10:22 a.m. CT April 10, 2017 | Updated 12:13 p.m. CT April 10, 2017

President Donald Trump's White House is less predictable when it comes to the future of ethanol policy. Growers and producers in South Dakota are watching Washington D.C. to see what happens. Wochit

A Donald Trump White House means a new, uncertain political landscape. Some of the Trump administration's leaders have deep ties to the oil industry. The seismic political transition raises questions and concerns for the benefactors of a multi-billion dollar industry that also happens to drive South Dakota's economy.

Ethanol was far from a major talking point for Trump on the campaign trail. Even after touring a Poet plant in Iowa, he uttered just a few sentences about renewable fuel and its impact on Midwestern jobs.

"I went out to see some of the folks on the ethanol," Trump said at the 2015 rally in Fort Dodge. "And good stuff and great people. Put a lot of people to work out here too, I want to tell you. I just want to tell you that."

The president never mentioned ethanol on Twitter. He has since expressed support for upholding the renewable fuel standards. But people on his team have allegiances elsewhere. Some have been outspoken critics of ethanol and federal biofuel regulations.

<http://www.argusleader.com/story/news/business-journal/2017/04/10/ethanol-future-murky-trump-era/100127048>

One Last Comparison:

In prior lectures, we have looked at market forces such as:

- Cost of Fossil Fuel ↑
- Cost of Electricity from Renewables ↓

as well as complete life cycle effects of various options:

- Carbon release (early) and methane release (late) from areas flooded for hydro
- N₂O associated with fertilizer production for biofuels

There is one more comparison that could be vital for society to consider, for large-scale transition to energy production from some means other than combustion of fossil fuel

Biofuels and Diesel

- Fuels made from recycled restaurant waste have a CH ratio conducive for use in **diesel** engines and not **gasoline** engines
- Gasoline engine: spark plug ignites fuel/air mixture (Otto cycle)
- Diesel engine: compression ignites fuel in combustion chamber (Diesel cycle)
- Gasoline: C_8H_{18}
- Diesel fuel: $C_{10}H_{20}$ to $C_{15}H_{28}$ (average $C_{12}H_{23}$)
- Main advantage of diesel: better fuel economy due to higher engine efficiency
- Disadvantages:
 - past fuel has contained high amounts of sulfur
 - past engines have released large amounts of NO_x
 - fuel gels in cold weather!
- Diesel cars much more common in Europe than the U.S. but: diesel cars making a comeback in the U.S.

<http://www.practicalenvironmentalist.com/automobiles/2011-diesel-cars-usa.htm>

Sources:

http://en.wikipedia.org/wiki/Diesel_engine

http://en.wikipedia.org/wiki/Diesel_fuel

\$mart Power by William H. Kemp, Hushion House Publishing

<http://www.scientificamerican.com/article.cfm?id=why-european-diesel-cars>

Biofuels and Diesel

- Fuels made from recycled restaurant waste have a CH ratio conducive for use in **diesel** engines and not **gasoline** engines

Advantages of biodiesel:

- Low sulfur
- Biodegradable
- Climate friendly (C that is combusted recently pulled from atmosphere!)
- Can be “brewed” at home



FuelMeister II™
Personal Biodiesel Processor!
Azure Biodiesel Company
Sully, Iowa 50251

<http://www.azurebiodiesel.com/contact.shtml>

Disadvantage of biodiesel:

- Weak solvent that could soften rubber hoses, seals, and gaskets over time
- Supposedly, B20 blends (20% biodiesel) combined with modern use of synthetic materials minimize risk ... nonetheless, **vehicle warranty could be compromised by use of biofuels**

For more info see:

<http://www.makebiodiesel.com>

<http://www.biodiesel.org>

<http://www.biodiesel-canada.org>

The Methanol Economy[®]

- Methanol: CH₃OH
- Alcohol
- Methanol combustion:



Heat release considerable more than ethanol (29.7 kJ/g) and close to that of C₈H₁₈ (47.8 kJ/g)

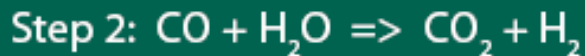
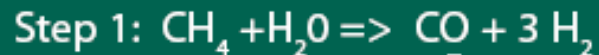
- Octane of 107
- Very clean burning: little or no CO, NO_x, or particulates
- Can be used in “clean diesels”
- Presently used in Indy 500 race cars !

The Methanol Economy[®]

- Methanol production from atmospheric CO₂:
 - $\text{CO}_2 + 3 \text{H}_2 \rightarrow \text{CH}_3\text{OH} + \text{H}_2\text{O}$
 - Exothermic by 49.3 kJ/mol ; nonetheless, need a catalyst
 - Need to capture CO₂ out of atmosphere (tall order!)
 - Need supply of H₂ that is “carbon neutral” (i.e., not from CH₄ !)

Today, 95% of the hydrogen produced in the U.S., roughly 9 million tons per year, uses a thermal process with natural gas as the feedstock. This process, called steam methane reformation (SMR), consists of two steps: 1) reformation of the feedstock with high temperature steam supplied by burning natural gas to obtain a synthesis gas, and 2) using a water-gas shift reaction to form hydrogen and carbon dioxide from the carbon monoxide produced in the first step.

STEAM METHANE REFORMATION



http://www.hydrogenassociation.org/general/factSheet_production.pdf

The Methanol Economy[®]

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 - Need to capture CO₂ out of atmosphere (tall order!)
 - Need supply of H₂ that is “carbon neutral” (i.e., not from CH₄ !)
 - If electrolysis of seawater to yield H₂ could be powered by solar energy, and an energy efficient way to capture and concentrate atmospheric CO₂ could be devised (i.e., using KOH or MEA-monoethanolamine (CH₂CH₂OH)NH₂), then $\text{CO}_2 + 3 \text{H}_2 \rightarrow \text{CH}_3\text{OH} + \text{H}_2\text{O}$ would simulate photosynthesis and could provide a fuel that could be used in cars without major changes to present infrastructure

NOTE: methanol is corrosive to aluminum, zinc, and magnesium, and reactive with some plastics and rubber, so some systems specific to methanol would be needed

Algae as a Biofuel

Pros:

- High oil content
- Absorbs atmospheric CO₂
- Can use waste as fertilizer
- Not a food staple



Cons:

- Need sunny, warm conditions; certain areas preferred
- Growth limited by “self shading” effect; challenge to exploit entire volume of pond
- Water intensive (rules out many warm, sunny environs for large scale production)
- Efficient processing method still being researched
- Fertilizer intensive
- Water intensive

The promise of algae as an economically viable clean source of fuel is leading many groups to research the large scale viability of this potential resource.

<http://www3.signonsandiego.com/stories/2009/apr/29/1n29biofuels005337-new-center-focus-algae-biofuels>

http://cosmiclog.msnbc.msn.com/_news/2011/04/14/6471719-is-algae-biofuel-too-thirsty

<http://stateimpact.npr.org/texas/2012/12/17/the-downside-of-using-algae-as-a-biofuel>

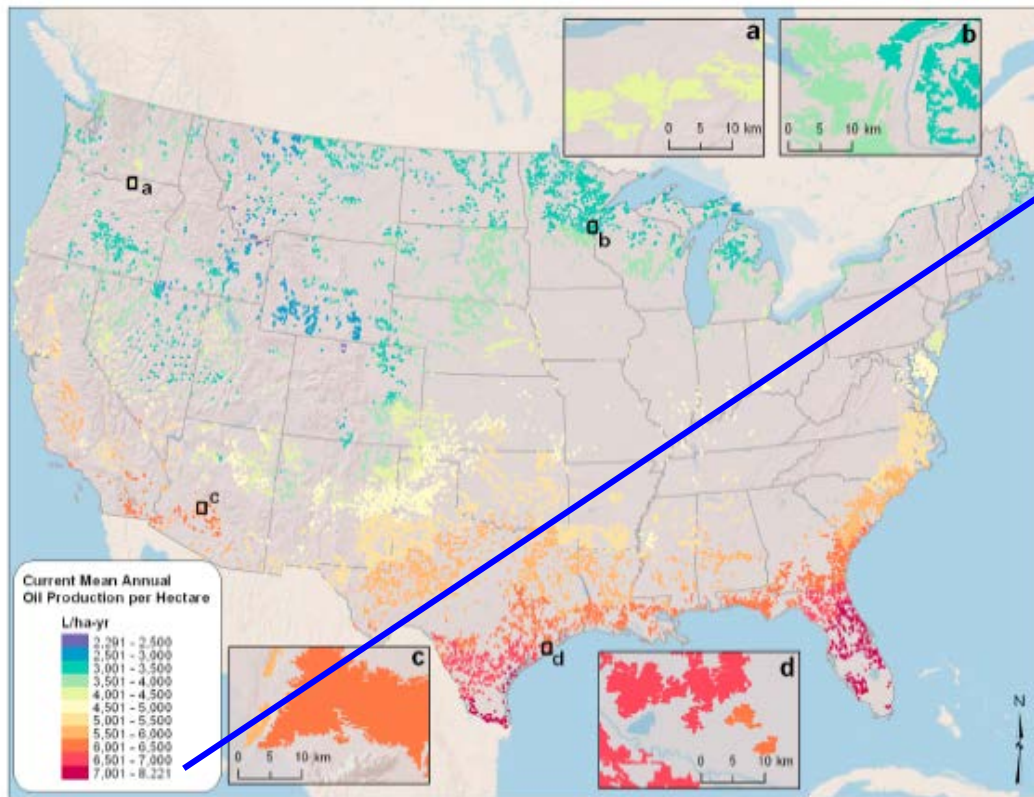
Algae as a Biofuel

Wigmosta *et al.*, *Water Resources Res*, 13 April 2011 conclude:

Using current technology, 48% of petroleum needed for US transportation can be produced using:

- 5.5% of U.S. land area (lower 48)
- 3 times the total amount of water used for irrigation

Optimal placement of algae production facility in the humid Gulf Coast, southeastern seaboard, and Great Lakes regions would considerably reduce the water needed



High yield: 8000 L/ha/year:

U.S. uses 5.2×10^{11} L/year

**Hence, need 6.5×10^7 ha
or 2.5×10^5 mi²**

**500 x 500 miles
(7% land area, lower 48)**



<http://www.eia.gov/tools/faqs/faq.cfm?id=23&t=1>

Figure 3. Mean annual biofuel production ($\text{L ha}^{-1} \text{yr}^{-1}$) under current technology plotted at the centroid of each pond facility.