



We will begin momentarily at 2pm ET



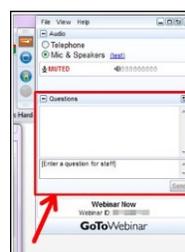
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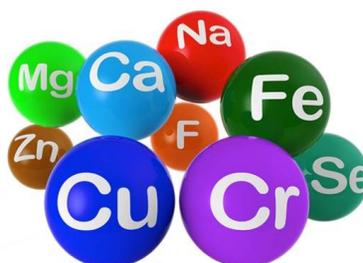
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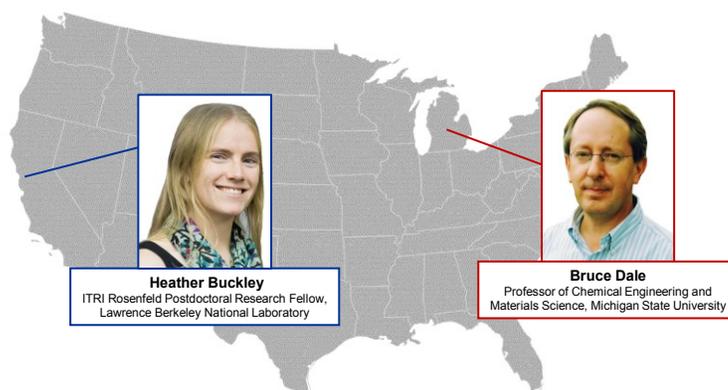
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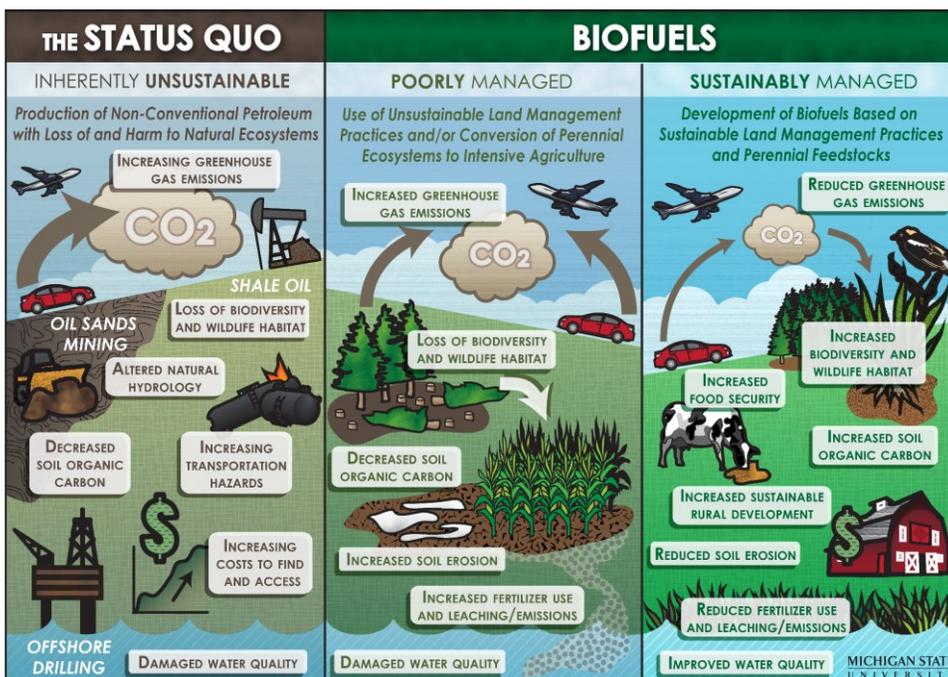
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Sustainable Bioenergy Systems: Unlocking the Power of Renewable Plant Biomass

Bruce E. Dale, University Distinguished Professor
Michigan State University



Some Thoughts on the Sustainability Transition

- The world is in the early stages of a profound transition in how it will be fueled & fed— *we cannot continue forever along our current pathways (oil & fossil fuel dependent), we must change & the sooner the better*
- The changes required will be far reaching, profound, revolutionary, upsetting, painful, exciting...(and they must also be “profitable”)
- *Liquid fuels from plant matter (biofuels) are an essential part of the sustainability transition—this will cause a huge impact on the economic, physical & social “landscapes”*
- We should be seeking large, complementary, beneficial changes: *we need food (actually feed) and fuel and better environmental performance and rural economic development and better social outcomes*
- This will not happen by accident—we must envision (use our heads), and design (do the R&D) sustainable systems to achieve multiple objectives...then implement these systems
- **For many reasons, we do not have a lot of time to make this transition—it must happen in the next few decades**



Audience Survey Question

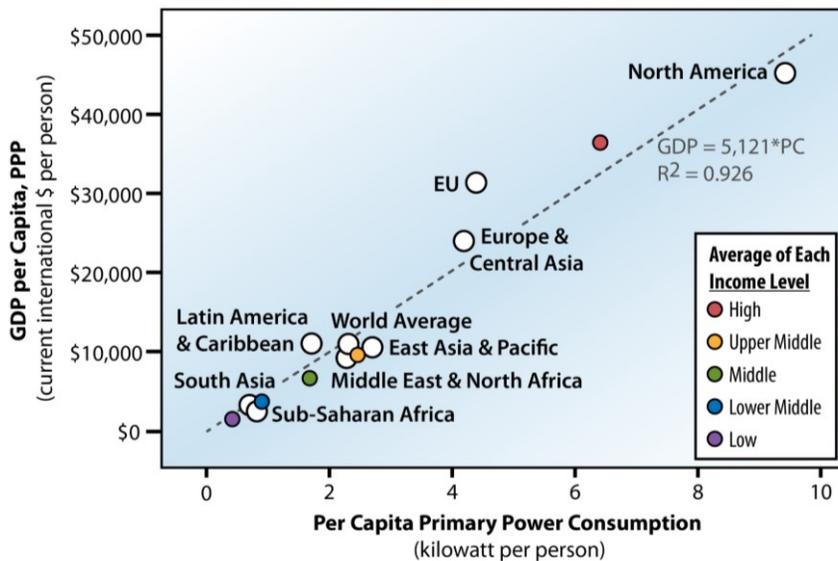
ANSWER THE QUESTION ON BLUE SCREEN IN ONE MOMENT



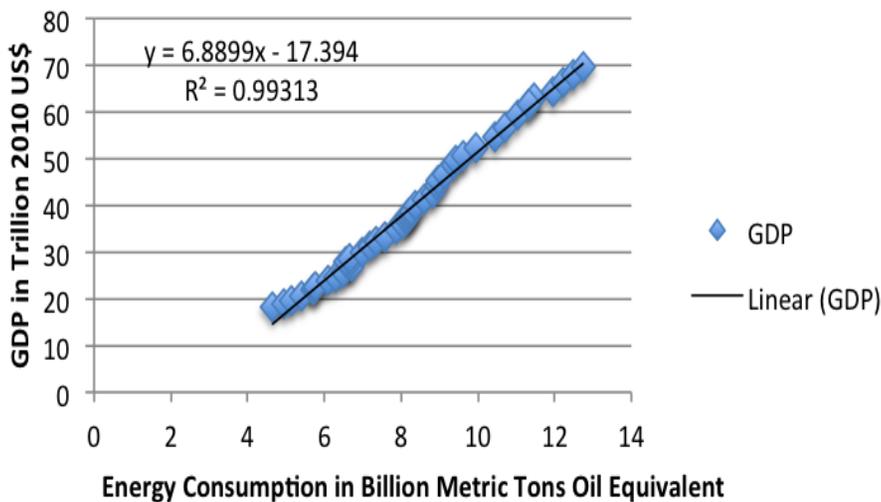
What is the relationship between power consumption and GDP?

- There is none (most mainstream economists think this or ignore the question entirely)
- There is a weak relationship between the two
- Power consumption is directly proportional to GDP with a very high degree of correlation
- There is a negative correlation between the two

Power Consumption and GDP (World Regions)



World GDP Compared to Energy Consumption 1969 to 2013



<https://ourfiniteworld.com/author/gailtheactuary/>

Audience Survey Question

ANSWER THE QUESTION ON BLUE SCREEN IN ONE MOMENT



Of the total world energy consumption, what fraction comes from non-renewable energy sources (oil, coal and natural gas)?

- Less than ten percent
- Around twenty-five percent
- Around fifty percent
- Greater than eighty percent

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Energy Consumption & Human Well Being are Linked: How Much Energy is "Enough"?

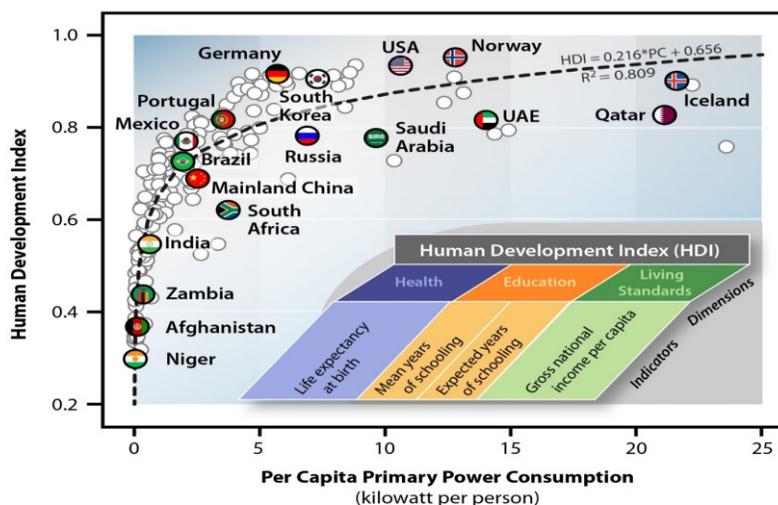
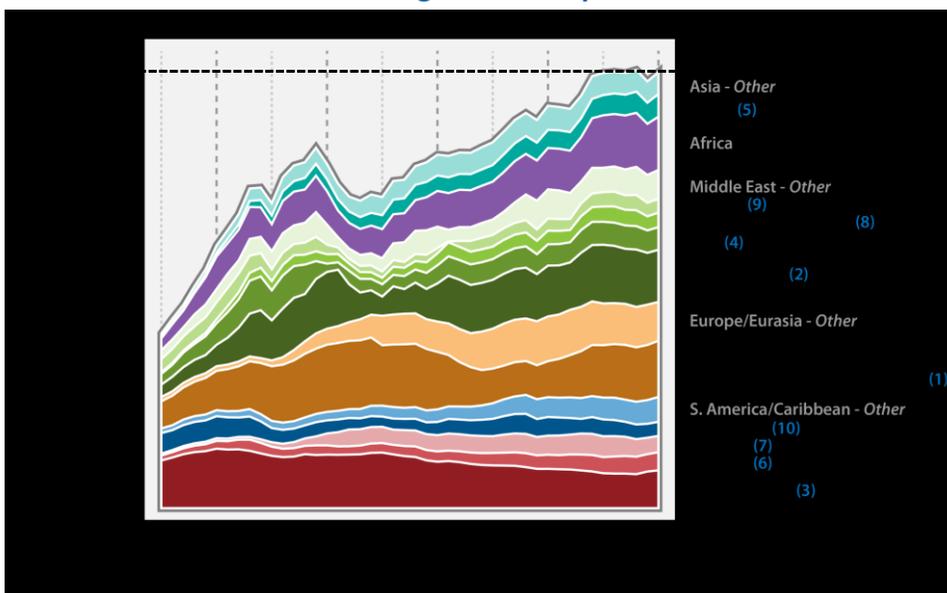


Figure 1. Human Development by Country versus Per Capita Power Consumption in 2010

(Renewable) Energy is Critical for Human Well Being

- Rate of energy use (rate of work done or power) largely determines national wealth and opportunities for human development
- Many people seem ignorant of (or indifferent to) this fact:
- **Energy use makes us prosperous (thus lack of energy will make us poor!!)**
- Current prosperity is based largely (~85%) on non-renewable fossil fuels—thus our prosperity is not renewable, it has an “expiration date”- it will end!
- Lack of energy access currently condemns billions of human beings to poverty—and will also impoverish future generations of those who are currently wealthy unless....
- We implement terawatt scale renewable energy systems—in the next few decades
- Bioenergy is an essential part (~25% at least) of a renewable energy future
- Farmers—those who own and manage land--must benefit from bioenergy production—**otherwise there will not be much bioenergy produced**
- **So the question is: “How can we produce many terawatts of sustainable bioenergy—and do it pretty ding-dang soon?”**

Worldwide Crude Oil Production – Subdivided into World Regions and Top 10 Producers in 2010



Audience Survey Question

ANSWER THE QUESTION ON BLUE SCREEN IN ONE MOMENT



Worldwide, what percentage of land that is managed by humans is used to grow food for direct human consumption?

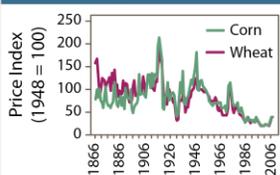
- Less than fifteen percent
- About twenty percent
- About twenty-five percent
- About thirty percent

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Sustainable Intensification of Agriculture via Biogasoneright™

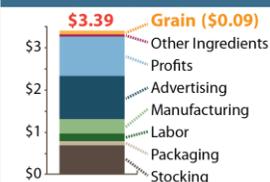
The Reality of Global Agriculture -- Economic Decline

Farm commodity prices are in long-term decline



Reproduced from: Sumner DA. Recent commodity price movements in historical perspective. *Amer. J. Agr. Econ.* 2009, 91(5):1250-6.

Grain prices are small portion of food prices paid by consumers

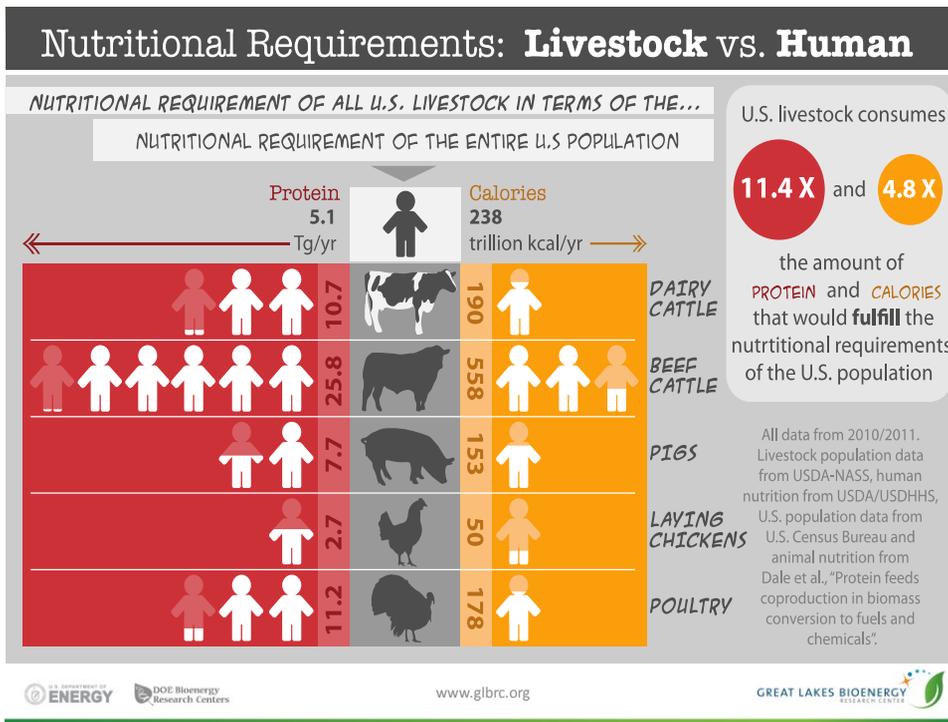


Data from: Whalen PJ et al. Ready-to-eat breakfast cereals. In: *Handbook of Cereal Science and Technology*, 2nd ed. Kulp K and Ponte, Jr. JG (ed), pp. 616.

Biogasoneright™ Can Benefit Farmers and the World



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Agriculture and biofuels/bioproducts: *we must ask the right questions*

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- ✘ The current approach to biofuel production is to impose a large new demand for biofuels on an existing agricultural system that otherwise does not change
- ✘ Current agriculture is designed to grow animal feeds: >80% of land
- ✘ We should be asking: Can we redesign US (and world) agriculture to produce biofuels, food/feed & large environmental benefits?
- ✘ Agriculture has changed greatly before; *it can, should (must) change again—and farmers are the essential key to that change*
- ✘ Therefore, how can we sustainably:
 - *integrate biofuel production with animal feed production?*
 - *motivate farmers to participate in biofuel production?*
- ✘ We need economically viable, sustainable, industrial food and fuel models....



Biofuels for GHG reductions *and much, much more*



Three Biofuel/Bioenergy Systems: Some Scale and Growth Characteristics

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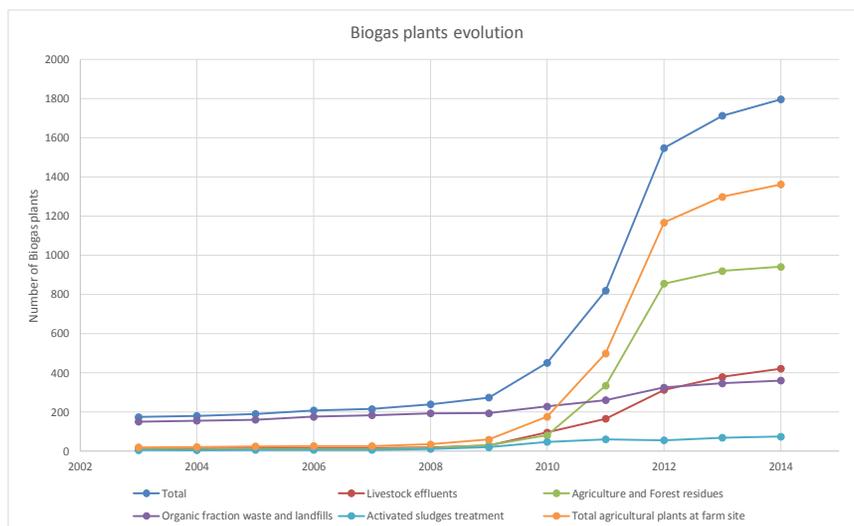
- ✘ **Brazilian Sugar Cane to Ethanol System**
 - Big (~30 billion liters/yr), large scale system model, not growing much.
 - Why not? *Big but mostly saturated markets for sugar*
 - Needs a new growth model... perhaps by pasture intensification?
- ✘ **Italian Biogas (to Electricity) Consortium**
 - **Existing, growing, large scale (~1 GW) based on individual farms, developing Biogasdoneright™ model**
 - **Not food versus fuel—it is “food and fuel” and environmental services**
 - **Market access is the key**
- ✘ **Emerging Cellulosic Biofuels System**
 - Existing, very slow growth. Why is it not growing?
 - *In part, because it currently is based on custom-built supply chains of a non-scalable feedstock—**we need viable large scale models!!***



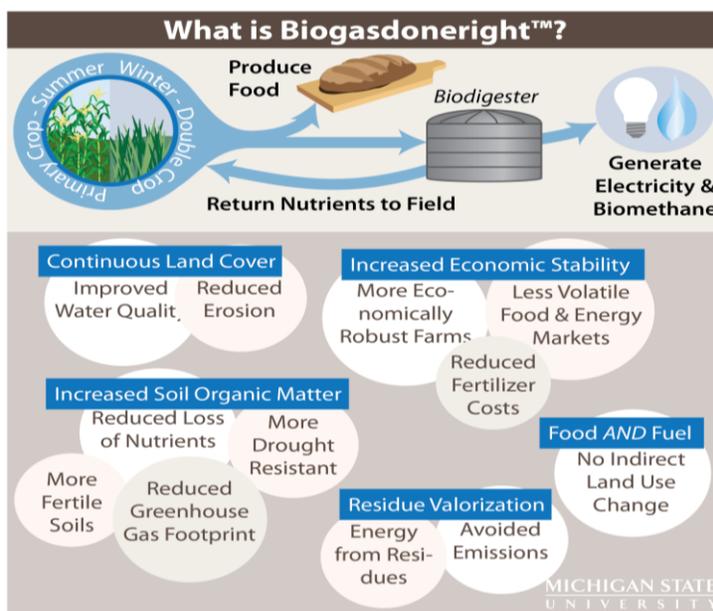
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Installed biogas plants in Italy



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Double Cropping

- Grow crops (grasses) over winter & spring on commodity crop land (eg, corn, soy, wheat) while still growing the commodity crops
 - Does **NOT** require new land- no expansion of agricultural “frontier”
 - Increases sustainable corn stover harvest rate
 - Biomass can be used for biofuels, animal feed, etc
 - Reframes the “food vs. fuel” debate—now “food AND fuel” (**and** environmental services!)



Anaerobic Digestion



Animal Wastes

Waste Treatment
Limited Scale



Biogasdoneright™

Produces Food and Low Carbon Energy
Large Scale
Increased Soil Organic Carbon
Improved Farm Economics
Widely Applicable
Nutrient Recycle



Energy Crops

Large Scale
“Food vs. Fuel”
Conflict

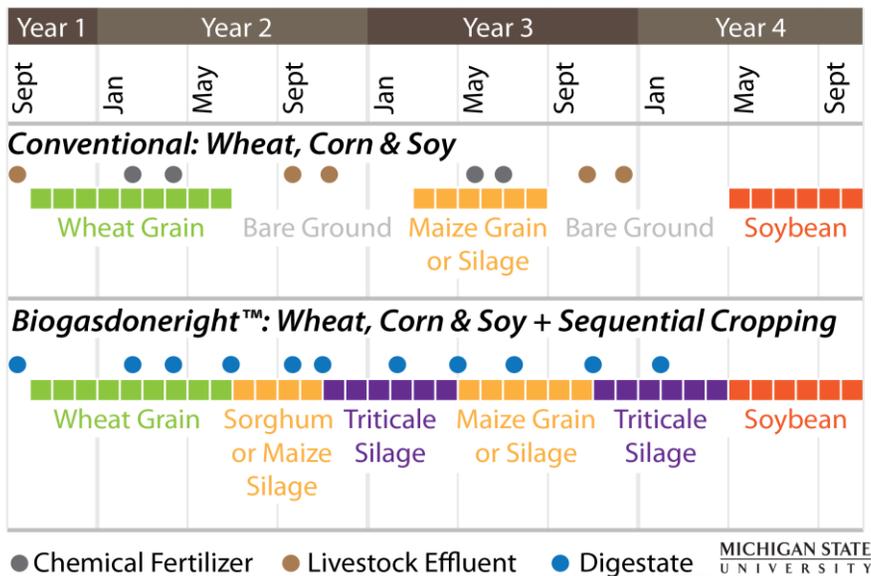
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Guiding Principles: “Biogasdoneight”

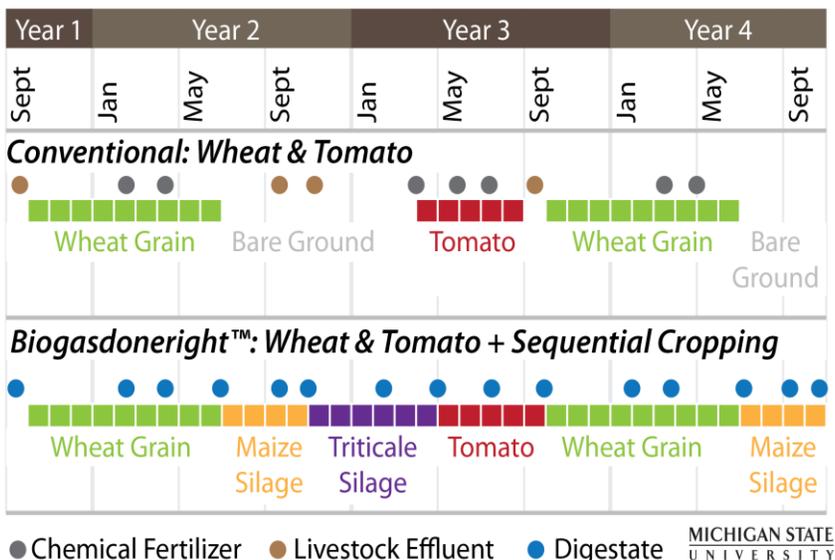
- Grow regular crop for feed/food market– no “food vs. fuel” conflict
- Grow and ensile a double crop for the anaerobic digesters (plus manure & other “wastes”– avoid GHGs caused by those wastes)
- Burn biogas (55% methane/45% CO₂) on farm to generate electricity for grid or upgrade and export biomethane via natural gas grid
- Fertilize fields with digestate liquid → reduce purchased fertilizers (and associated GHGs)→ have irrigation in drought times
- Land apply the residual digestate solids → rising soil carbon levels→ increased fertility and farm productivity→ low cost carbon capture & storage
- Improve farm profitability—increase income and resilience, reduce expenses





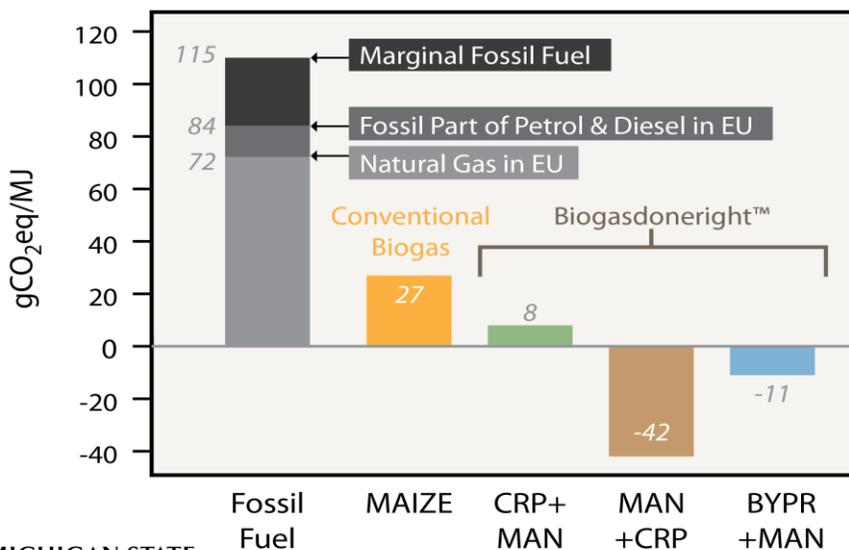
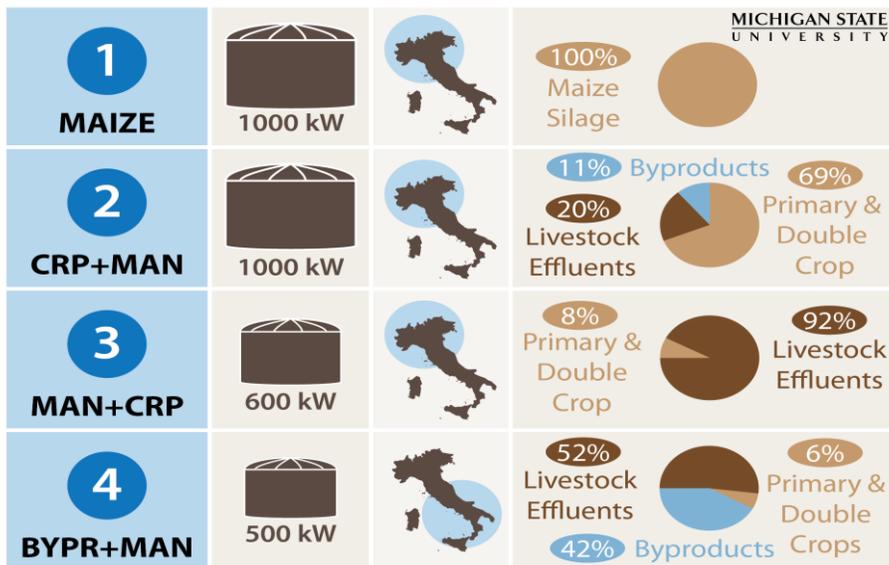


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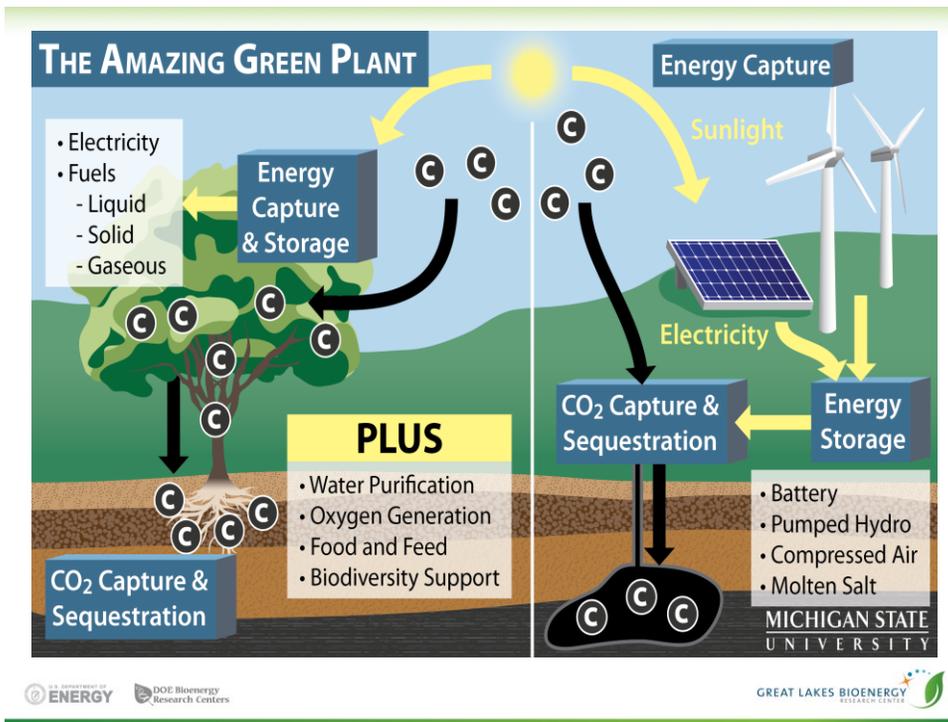
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Audience Survey Question

ANSWER THE QUESTION ON BLUE SCREEN IN ONE MOMENT



True or False: If we produce biofuels, we cannot have both sustainable food and fuel.

- True, Bruce hasn't convinced me. (If you select this answer, you get a homework assignment)
- False. I see that we can integrate sustainable production of food and fuel to their mutual benefit.
- I took a nap instead of listening to the webinar. Sorry about that.

Some Concluding Thoughts

- Energy use (power) is critical to human prosperity and well-being
- Without sustainable, large scale energy sources, we will not have sustainable, large scale prosperity— must act soon
- We need about 5 kW/capita— about 25% of which is bioenergy-to achieve good levels of wealth and well-being and simultaneously reduce GHGs
- Total bioenergy “ultimately” needed is roughly 8 terawatts—about half of current world energy use (17 terawatt)
- We cannot limit GHGs and we cannot produce significant biofuels without involving and benefitting farms and the farmers who manage land-to reduce emissions and sequester carbon
- Agriculture can provide energy, food, feed, and large sustainability services, *if redesigned to do so.*



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Some Features of Biogas and Biomethane

- ✘ Recall humankind’s needs for energy services: they include heat, electricity and mobility
- ✘ Biogas serves heat and electricity needs, but not mobility
- ✘ Biomethane serves heat, electricity, light duty mobility, heavy trucking, ocean transport and mobile work platforms (eg, tractors, plows, road construction, etc)
- ✘ Air transport and rail (?) are not served by biomethane
- ✘ Distribution and storage of biomethane is well-developed
- ✘ Biomethane is also a useful feedstock for bioproducts
- ✘ *Low (near zero) marginal cost electricity from nuclear, solar and wind may enable conversion of carbon dioxide in biogas to make “pure” biomethane*



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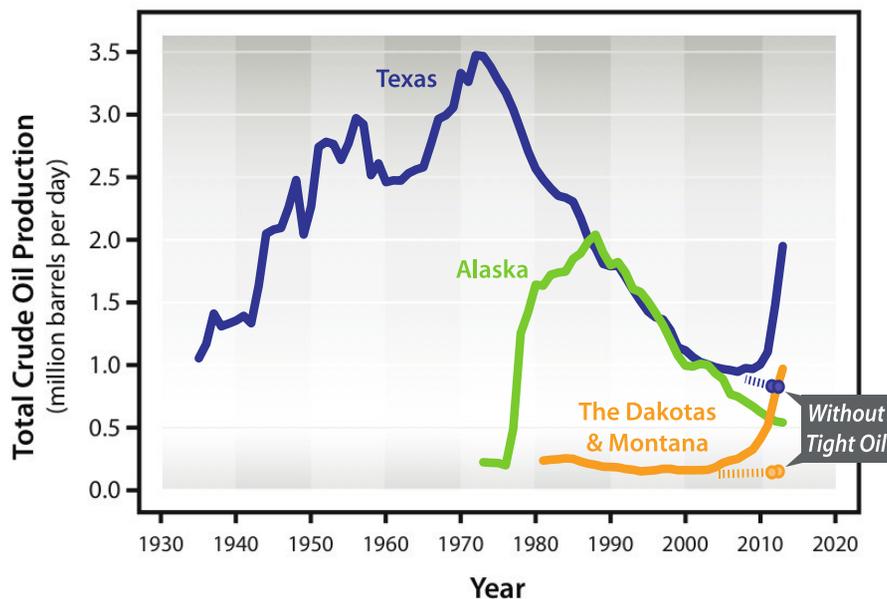
ANAEROBIC DIGESTION AND SOIL CARBON SEQUESTRATION
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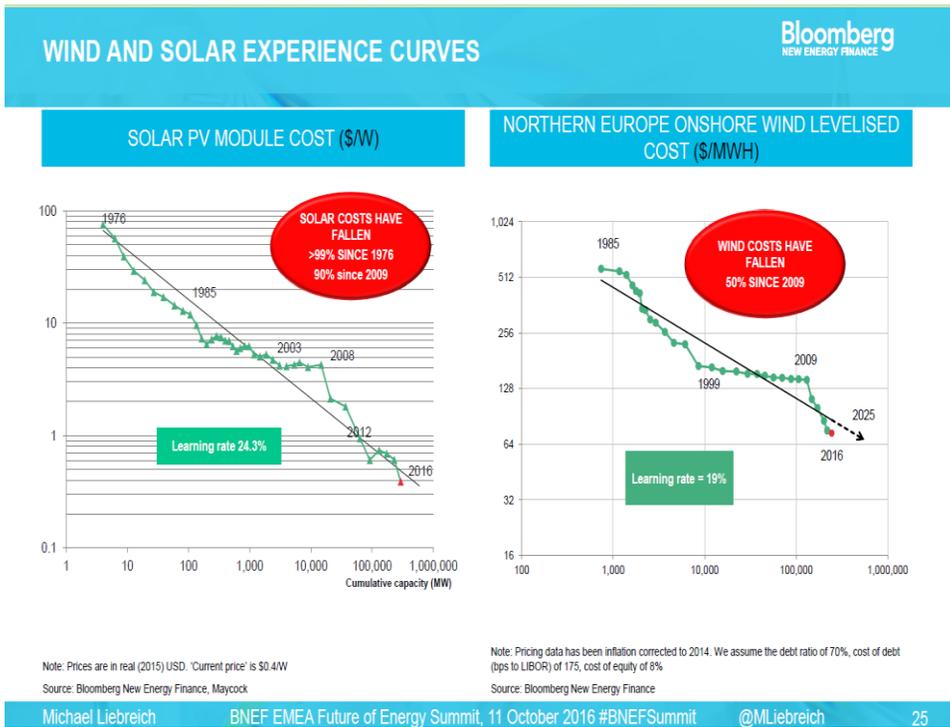
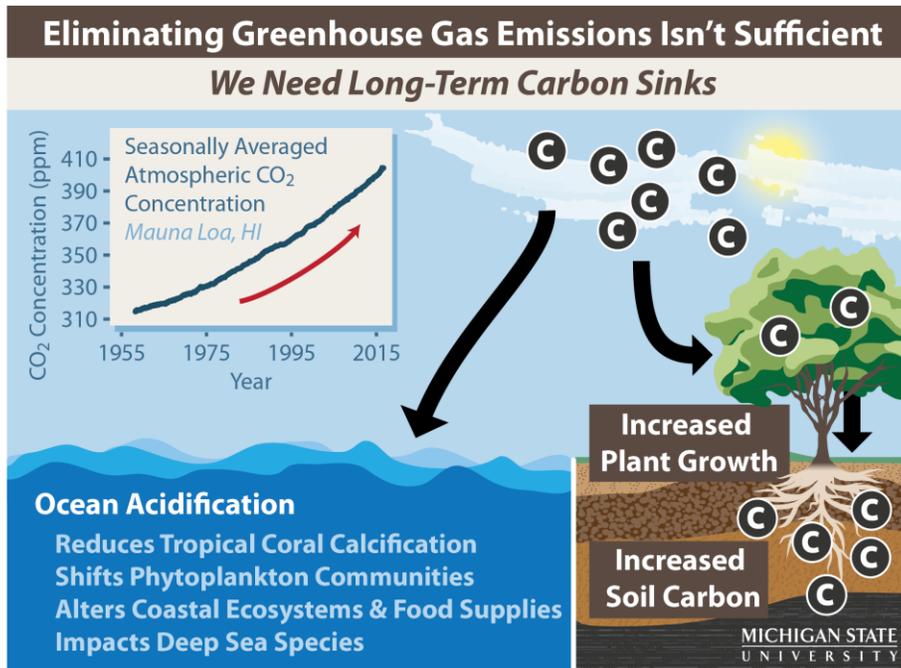


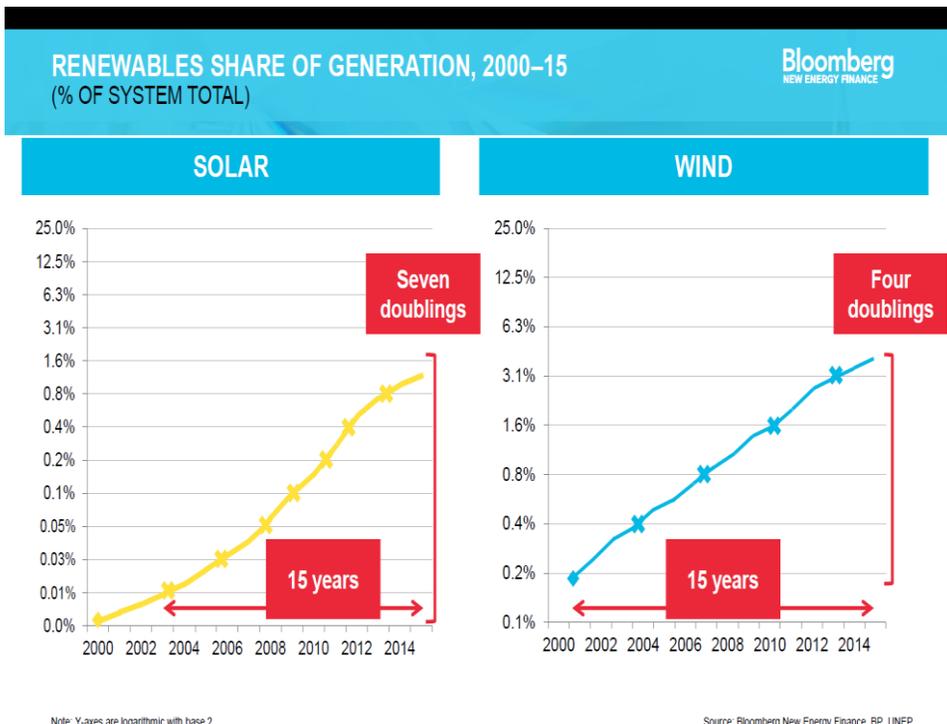
Available at <http://www.consorziobiogas.it/Content/public/attachments/527-Biogasdoneright%20No%20VEC%20-%20LowRes.pdf>



Won't "Tight Oil" Save Us?







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Why are solar and wind slowing down?

✘
✘
✘
✘
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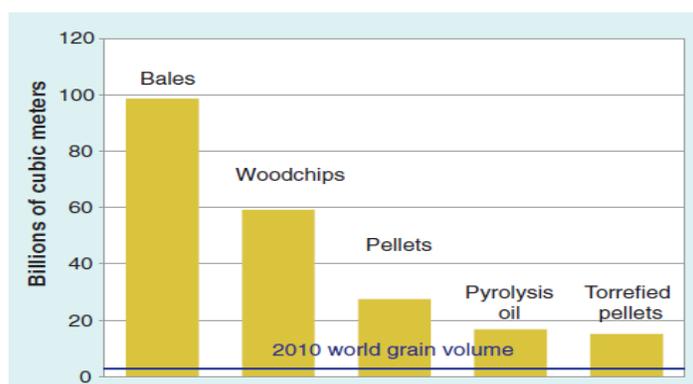
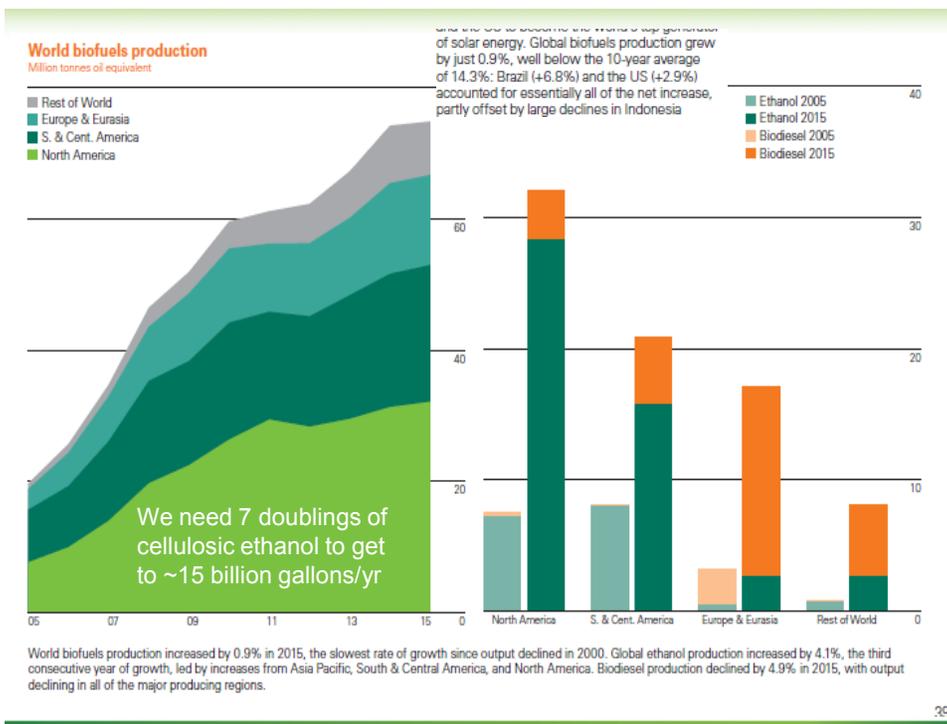


Fig. 1. Global biomass volumes required to achieve a 50% reduction in greenhouse gas emissions by 2050. A wide range of densification options are possible, but even the most effective will still require several times the biomass-handling capacity that the commodity grain system uses today.

Challenges in Scaling Up Biofuels Infrastructure
 Tom L. Richard, *et al.*
Science 329, 793 (2010);
 DOI: 10.1126/science.1189139



Some Basic Energy Facts:

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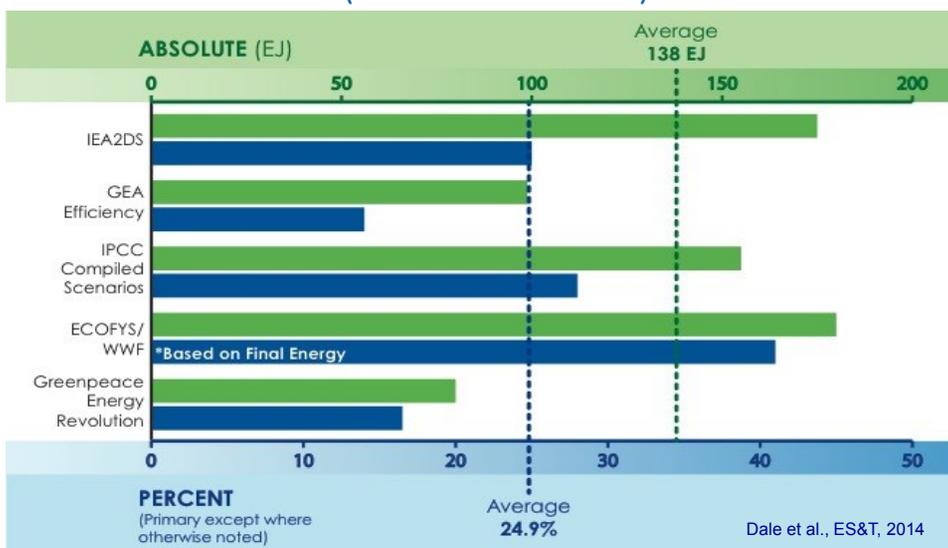
Why Mobility Fuels are So Important

- ✘ **Services** we need from energy (current primary sources of these services: fossil and **renewable**)
 - **Heat** (natural gas, coal— **solar, wind, geothermal, biomass**)
 - **Light/electricity** (coal, natural gas, hydro/nuclear— **solar, wind, geothermal, biomass**)
 - **Mobility** (liquid fuels from oil—96%, some **ethanol & biodiesel**, & CNG)- **most commerce**
- ✘ **All energy services (all BTU, ergs, GJ) are not created equal—we value mobility above all other energy services**
- ✘ Electricity/batteries can never provide more than about half of mobility needs—and they cannot support commerce at all
- ✘ Commerce moves by trucks, ocean shipping, rail & jet aircraft
- ✘ *Transportation fuels: not “energy” is the key economic security issue—and right now transportation fuels means refined oil products*
- ✘ *The only potentially sustainable, very large scale source of renewable transportation fuels is from sustainable plant matter— or “biofuels”*



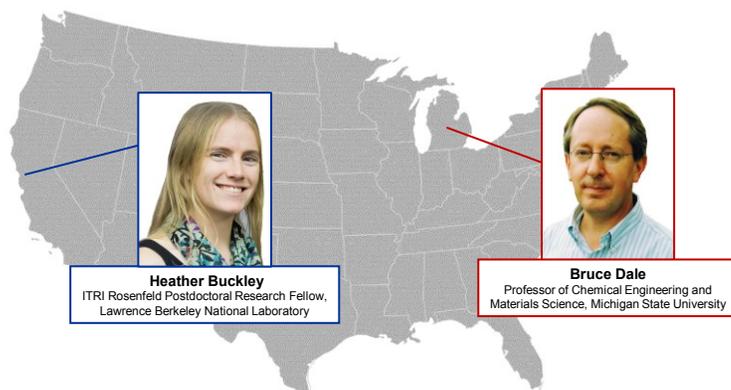
Large Scale Bioenergy & Biofuels are NOT Optional (for GHG Reduction)

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**“Sustainable Bioenergy Systems:
Unlocking the Power of Renewable Plant Biomass”**



Heather Buckley
ITRI Rosenfeld Postdoctoral Research Fellow,
Lawrence Berkeley National Laboratory

Bruce Dale
Professor of Chemical Engineering and
Materials Science, Michigan State University

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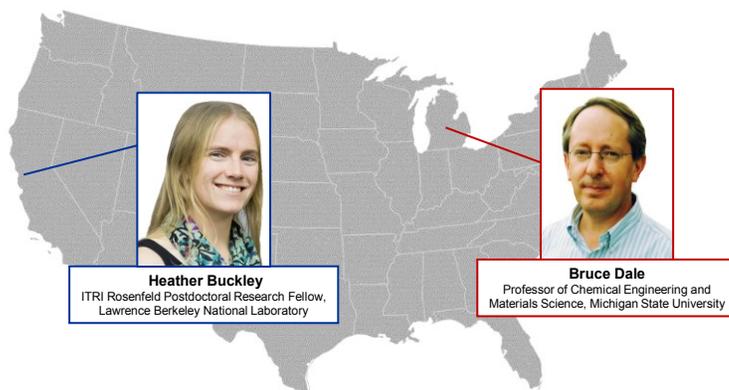
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