Global Feasibility of Large-Scale Biofuel Production

Mark S. Laser & Lee R. Lynd

Thayer School of Engineering, Dartmouth College
Mascoma Corp.

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The Sustainable Resource Transition

Our circumstances are changing radically

Past: Few resource constraints, low prices, resource capital

Future: Multiple resource constraints, high prices, resource income

Big, systemic challenges require big, systemic solutions

Viable paths to a sustainable world (all sectors, resources)

Almost never feature

- Single, isolated changes
- New supply without increased resource utilization efficiency

Almost always feature

Multiple, large, complementary changes

Confronting the improbable

Currently probable trends are not sustainable

We must thus look beyond such trends to find sustainable futures

Business as usual is a fantasy rather than a baseline

The first step in realizing currently improbable futures is to show that they are possible

Land use issues & biofuels

Will have a dominant impact on the biofuels industry going forward

- Now: *Perceived merit* → policy support, investment
- Future: Scale, sustainability benefits attained

Many divergent opinions, no consensus on feasibility & desirability of biofuel production on a scale large enough to meaningfully impact sustainability & security challenges — say, 25% of global mobility

Biofuels Resource Sufficiency: Positive Studies

United States

Biomass will eventually provide over 90% of U.S. chemical and over 50% of U.S. fuel production (NRC, 1999, *Biobased Industrial Products*,).

20% of petroleum demand in 2025 (Lovins et al., 2004, *Winning the Oil End Game*).

50 % current transportation sector energy use, and potentially nearly all gasoline, by 2050 (Greene et al., 2004, *Growing Energy*)

1.3 billion tons of biomass could be available in the mid 21st century - 1/3 of current transport fuel demand (Perlack et al., 2005, *"Billion Tons Study"*).

Goal of 100 billion gallons of ethanol by 2025 (Ewing & Woolsey, 2006, *A High Growth Strategy for Ethanol)*

This year: 90 billion gallon of biofuel could be produced by 2030 (GM & Sandia)

Worldwide

Biomass becomes the largest energy source supporting humankind by a factor of 2 (Johanssen et al., 1993, *Renewables-Intensive Global Energy Scenario*).

Biomass potential comparable to total worldwide energy demand (Woods & Hall, 1994; Yamamoto, 1999; Fischer & Schrattenholzer, 2001; Hoogwijk et al., 2005)

Biofuels Resource Sufficiency: Negative Studies

David Pimentel's group (at least 11 papers, 1979 to 2008)

"Use of biomass energy as a primary fuel in the United States would be impossible while maintaining a high standard of living"

"Large-scale biofuel production is not an alternative to the current use of oil and is not even an advisable option to cover a significant fraction of it."

Others

Power density of photosynthesis is too low for biofuels to have an impact on greenhouse gas reduction (Hoffert et al., 2002)

Impractically large land requirements for biomass energy production on a scale comparable to energy/petroleum use (Trainer, 1995; Kheshgi, 2000; Avery, 2006)

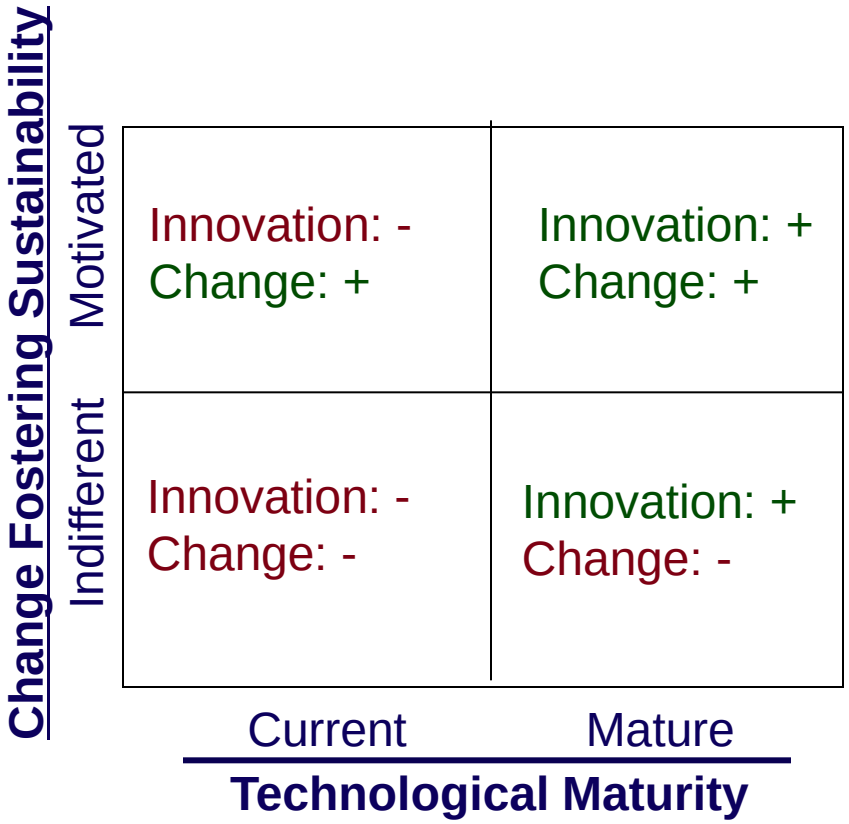
"The Clean Energy Scam" (Grunwald; May 2008; *Time*)

"National governments should cease to create new mandates for biofuels and investigate ways to phase them out." (Organization for Economic Cooperation and Development, August 2008)

This year: "Mandating the use and production of these fuels without fully understanding their effect on food production and the environment - as current US biofuel policy does - is irresponsible and dangerous." (Statement by 5 environmental groups calling for biofuel policy revamp).

How can presumably reasonable people with access to the same information reach such different conclusions about biofuel resource sufficiency?

Ultimately, questions related to the availability of land for biomass energy production and the feasibility of large-scale provision of energy services are determined as much by world view as by hard physical constraints… To a substantial degree, the starkly different conclusions reached by different analysts on the biomass supply issue reflect different expectations with respect to the world's willingness or capacity to innovate and change. *Lynd et al., "Thirteen Energy Myths, 2007"*



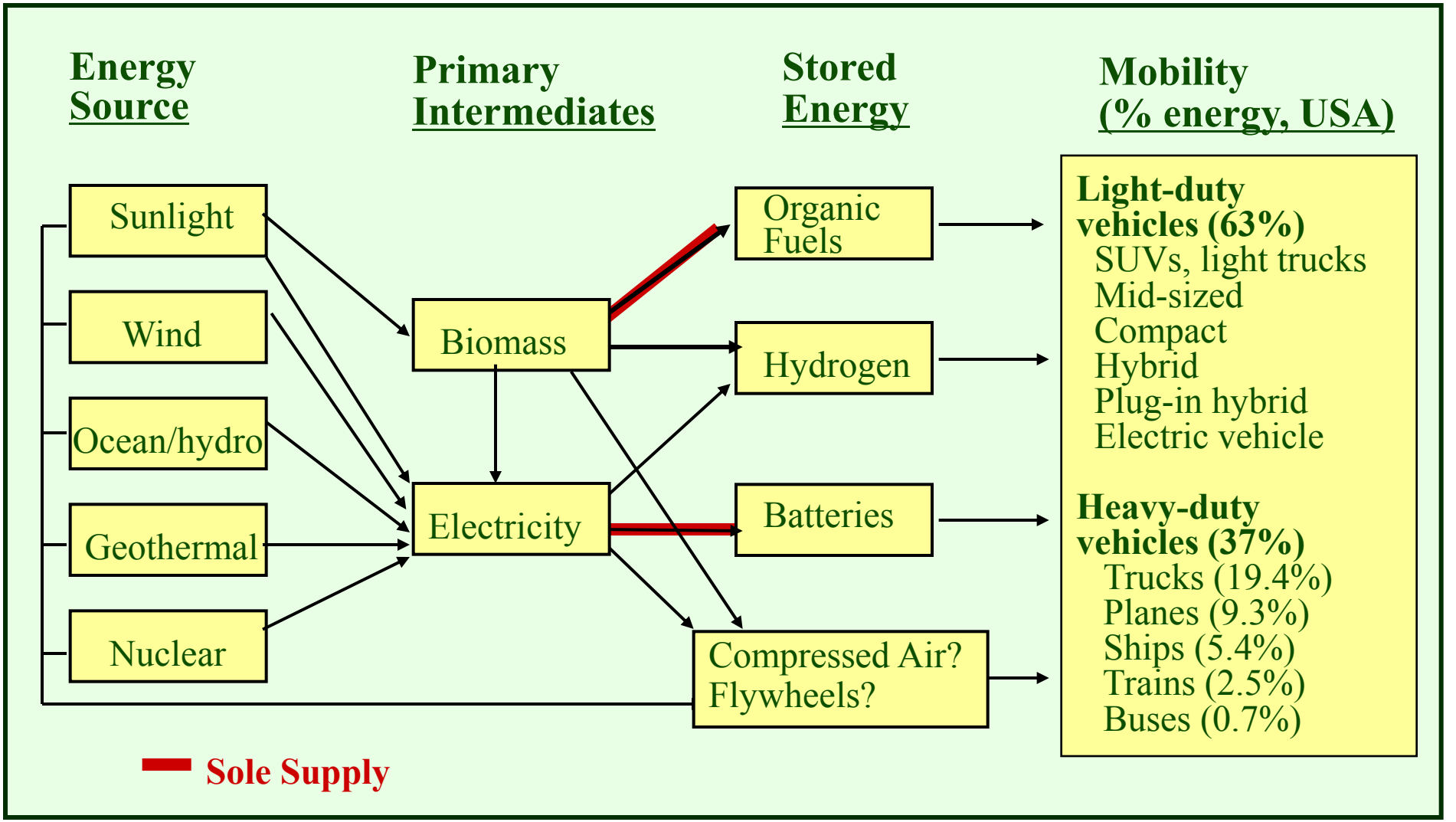
Advanced technology and motivation to solve energy challenges may seem optimistic, or improbable

…but it is entirely unrealistic to expect to meet these challenges without both

It has been suggested that we should forego the biofuel option because of land use challenges. A dispassionate response entails asking:

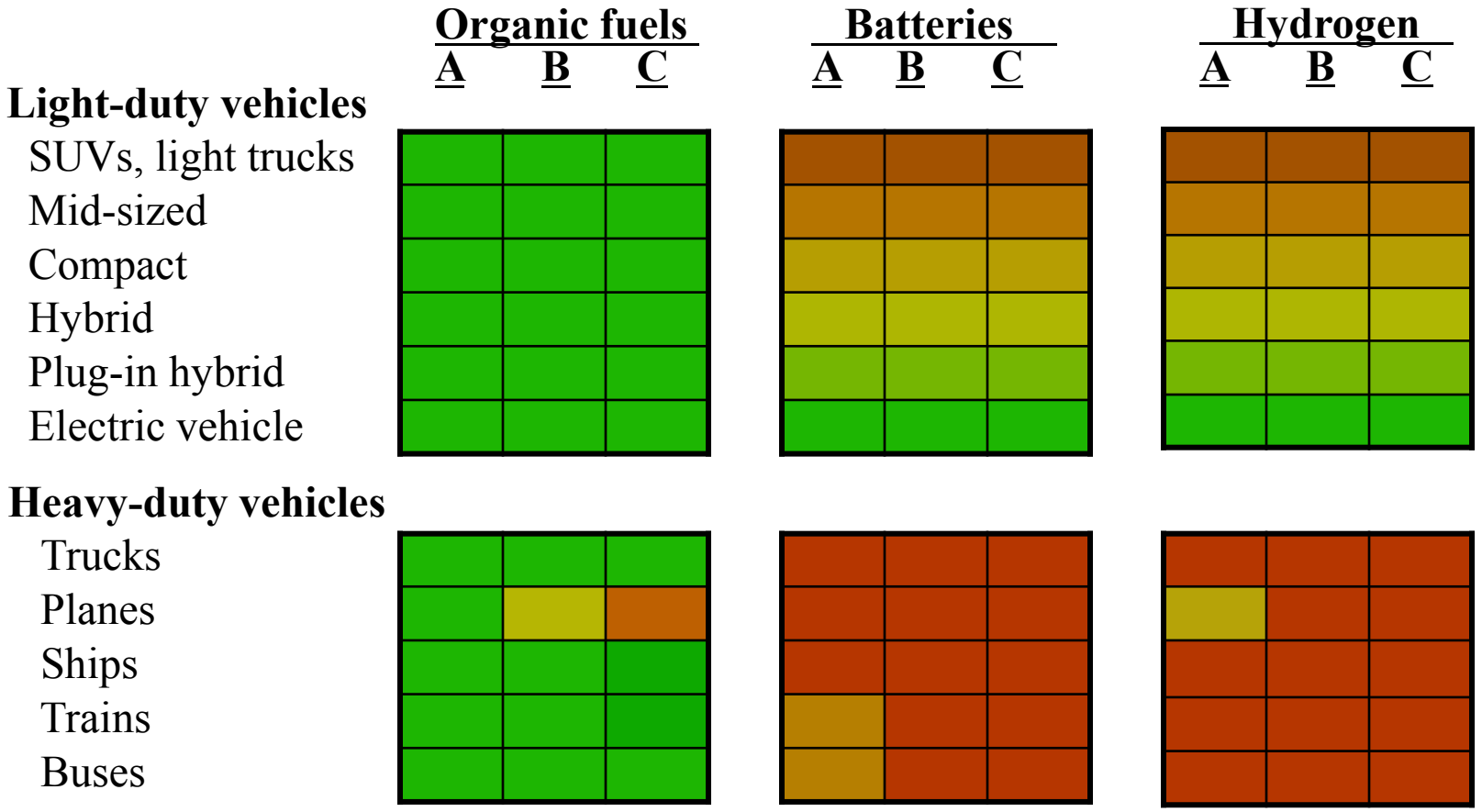
- What are our alternatives?
- What benefits would be missed?
- What are the prospects for gracefully resolving these challenges?

Sustainable Transportation Alternatives



Both innovation and change are required for all sustainable mobility options

Some vehicle-energy storage combinations are more feasible than others



- Electrification (batteries) impractical for most heavy duty applications
- Hydrogen faces many challenges, particularly if from low-C sources
- Even with extensive LDV electrification, organic fuels provide ≥ 50% mobility

Benefits missed if we forego the biofuel option

Energy security

Rural economic development

Environmental

- GHG emission reduction
- Reduced demand for unconventional petroleum (shale oil, tar sands)
- Increased use of low-carbon electricity to displace coal if less electricity needed for transport

Without biofuels, achieving a sustainable transportation sector is substantially more difficult and substantially less likely

Given these observations, it makes sense to approach with urgency the question:

Can biofuel land use challenges be resolved gracefully?

Dimensions of Innovation & Change Impacting Biofuel Land Requirements

Integrate feedstock production into managed lands

- Double crops
- Coproduce feed and feedstocks - e.g. early-cut grass in lieu of soy, perhaps other strategies
- Increase harvest from underutilized pasture, range, and/or CRP land
- Sustainably harvest agricultural residues, perhaps enhanced by new crop rotations
- Develop crop varieties with increased yields of non-nutritive cellulosic biomass (more residues)
- Sustainably harvest forest residues
- On abandoned, degraded, steep cropland

Produce food more land-efficiently

- Change animal feeding practices, e.g. pasture intensification, forage pretreatment
- Increase crop productivity, especially feed crops

Change diet

- Amount & kind of animal products

Decrease fuel demand

- Energy efficient cars
- Public transportation
- Smart growth

Mature feedstock technology

- High productivity
- Broad site range
- Low inputs
- High digestibility

Mature conversion technology

- Advanced pretreatment
- CBP
- Advanced process engineering

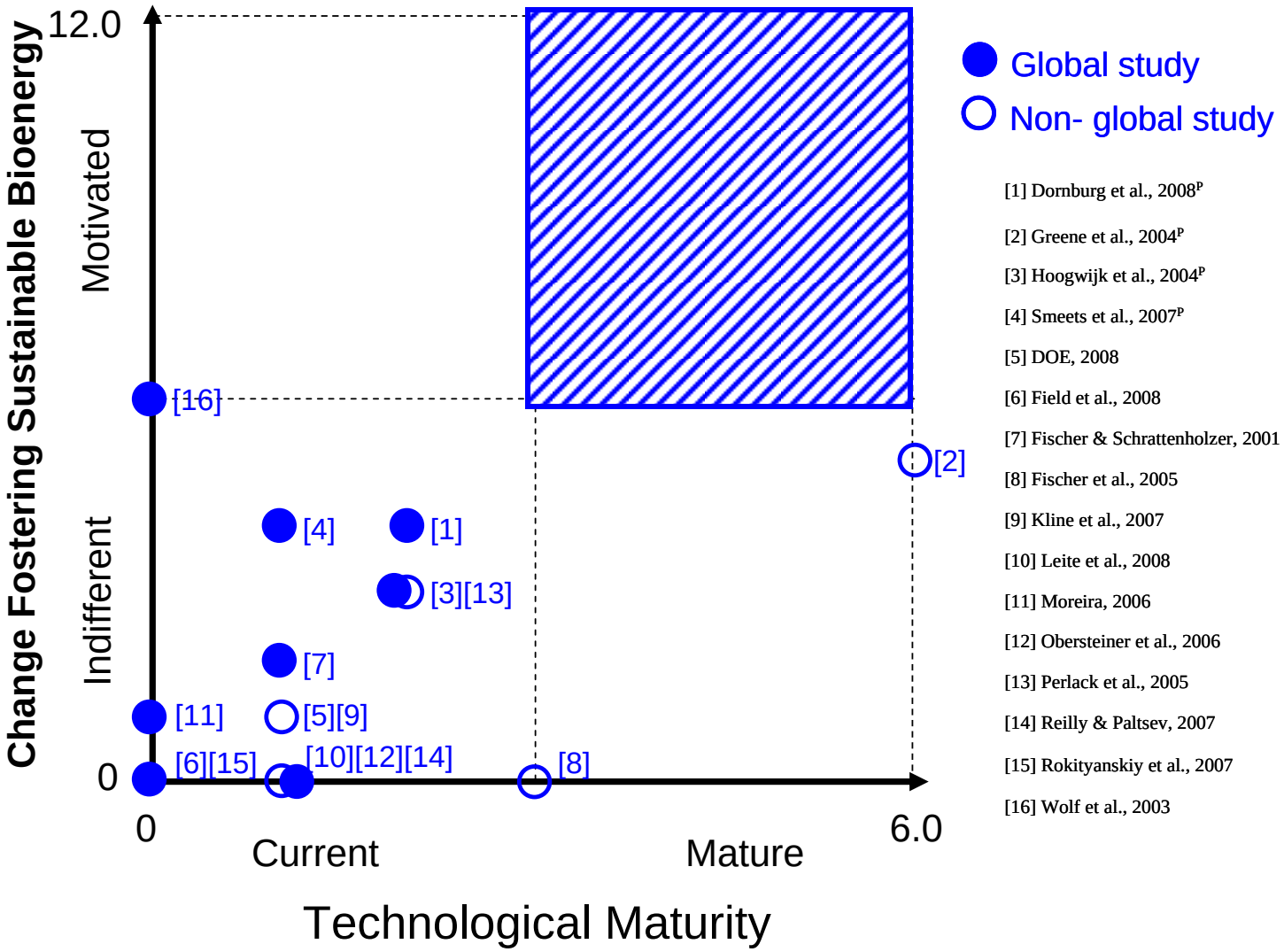
Consideration of Innovation & Change in Recent Studies Examining Biofuel Feasibility

	CHANGE TO ACHIEVE SUSTAINABILITY					TECHNOLOGY		
STUDY	Feedstock integration	Food production efficiency	Changing diet	Lower fuel demand	**Total**	Mature feedstock production	Mature cellulosic conversion	**Total**
Dornburg et al., 2008	1	2	0	1	**4**	2	0	**2**
Greene et al., 2004	2	0	0	3	**5**	3	3	**6**
Hoogwijk et al., 2004	1	0	1	1	**3**	2	0	**2**
Smeets et al., 2007	1	3	0	0	**4**	1	0	**1**
Leite et al., 2008	0	0	0	0	**0**	1	0	**1**
DOE, 2008	1	0	0	0	**1**	1	0	**1**
Field et al., 2008	0	0	0	0	**0**	0	0	**0**
Fischer et al., 2005	0	0	0	0	**0**	3	0	**3**
Fischer & Schrattenholzer, 2001	1	1	0	0	**2**	1	0	**1**
Kline et al., 2007	1	0	0	0	**1**	1	0	**1**
Moreira, 2006	1	0	0	0	**1**	0	0	**0**
Obersteiner et al., 2006	0	0	0	0	**0**	1	0	**1**
Perlack et al., 2005	1	2	0	0	**3**	2	0	**2**
Reilly & Paltsev, 2007	0	0	0	0	**0**	1	0	**1**
Rokityanskiy et al., 2007	0	0	0	0	**0**	0	0	**0**
Wolf et al., 2003	0	3	3	0	**6**	0	0	**0**

3 Extensive consideration
2 Moderate consideration
1 Minimal consideration
0 Not considered

Laser et al., in preparation

Consideration of Innovation & Change in Recent Studies Examining Biofuel Feasibility



Impact of Diet on Biofuel Production From Agricultural Land

Davis et al. (in preparation)

Diet Assumptions

↓ *DFL model*

Reduced Feed

↓ *DFL model*

Available Land

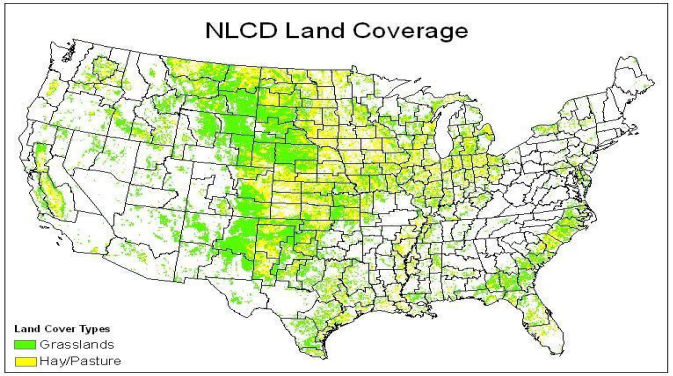
↓ *Biomass Productivity Model(s)*

Energy Crop Production

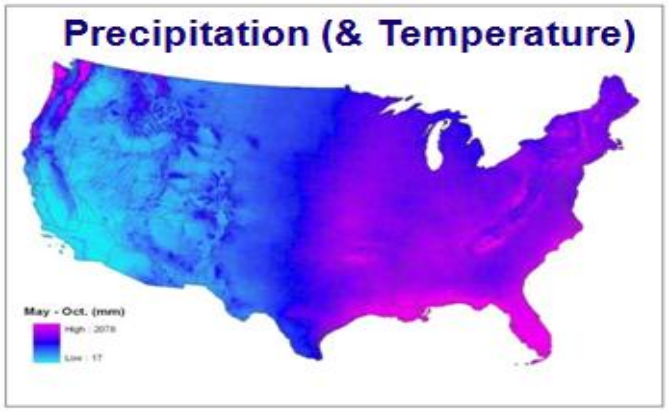
↓ *Process Yield*

Biofuel Production Potential

Portion of a given land-type



Climate Data for Liberated Land



In-progress analysis: Shifts in types of meat consumed could in some scenarios make available an amount of land with fuel production potential ***on the order of U.S. gasoline consumption****.*

Integrating Feedstock Production Into Currently-Managed Land

- **Food production is usually assumed to remain static**, or extrapolated, in analyses of biomass supply.
- Yet **new demand** for non-nutritive cellulosic biomass due to cost-competitive processing technology would likely bring **large changes**.
- Given a new value proposition, farmers would **rethink what and how they plant**.

Many options are possible.

Double cropping in Iowa
A. Heggenstaller, M. Liebman, R. Anex
US potential:
No protein displacement: 44 billion GGE*
With protein displacement: Larger

*Over the last century, the constant challenge in the world's functional breadbaskets has been supporting rural economies in the face of productive capacity exceeding demand - hence very **little policy or analytical effort has been devoted to feeding the world in a land efficient manner***

* GGE = Gallons gasoline equivalent; 240 mmacres*0.67*3 tons/acre*91 gal GGE/ton

Global Sustainable Bioenergy: Feasibility & Implementation Paths

Project initiated (June, 2009)

- International Organizing Committee formed
- Joint statement in *Issues in Science and Technology*
- Web site launched

Key Question: *Is it physically possible for bioenergy to meet a substantial fraction of future world mobility and/or electricity demand while our global society also meets other important needs.*

"High Beams" Approach

Staged structure

1. Meetings, assemble international team, scope project, get support
2. Address key question posed above
3. Policy, transition, equity, rural economic development issues

Global Feasibility of Large Scale Biofuel Production
Stage 1 Meetings & Organizing Committee

Representation	Host Institutions, Location	Meeting Chairs/ Organizing Committee Members	Dates
Asia, Oceana	PETRONAS Renewable Energy Laboratory, Kuala Lumpur, Malaysia	Reinhold Mann, Battelle Science and Technology, Malaysia	November 3-5, 2009
European Union	Kluyver Center for Genomics of Industrial Fermentations, Delft, The Netherlands	• Andre Faaij, Utrecht University • Patricia Osseweijer, Delft University of Technology	February 24-26, 2010
Africa	University of Sellenbosch, Stellenbosch, South Africa	• Emile van Zyl, University of Stellenbosch • August Temu, World Agroforestry Centre, Nairobi	March 17-19, 2010
South America	University of São Paulo, São Paulo, Brazil	▪José Goldemberg, University of São Paulo ▪Carlos Henrique de Brito Cruz, FAPESP, São Paulo	March 22-24, 2010
North America	University of Minnesota, Minneapolis/St. Paul, USA	• John Foley, University of Minnesota	May, 2010

http://engineering.dartmouth.edu/gsbproject

Parting Thought

Two key hypotheses

Biofuels are likely an obligatory part of a sustainable transportation sector

Very large scale biofuel production can be gracefully reconciled with food production, and preservation of habitat and environmental quality

Somehow, the world has gotten this far without widely accepted consensus and clear understanding with respect to these

It would be useful if this were to change

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