

Food, Feed, and Fuel From One Planet: Challenges and Opportunities

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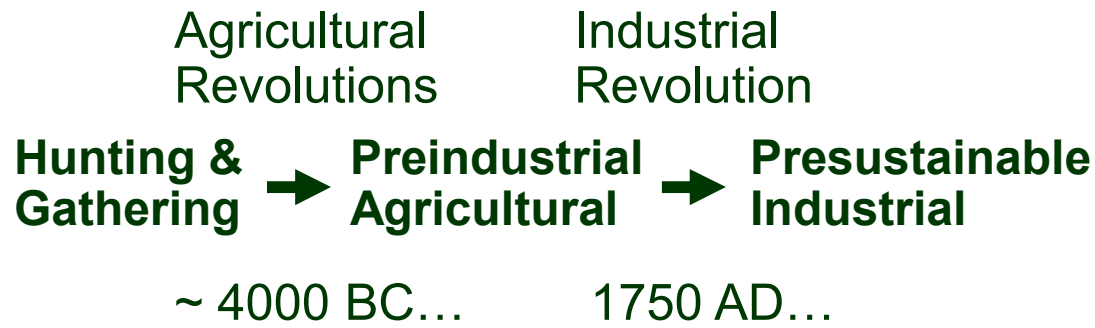
Global Sustainable Bioenergy Project
Bioenergy Science Center

ABIC 2010

**Saskatoon, Canada
September 13, 2010**

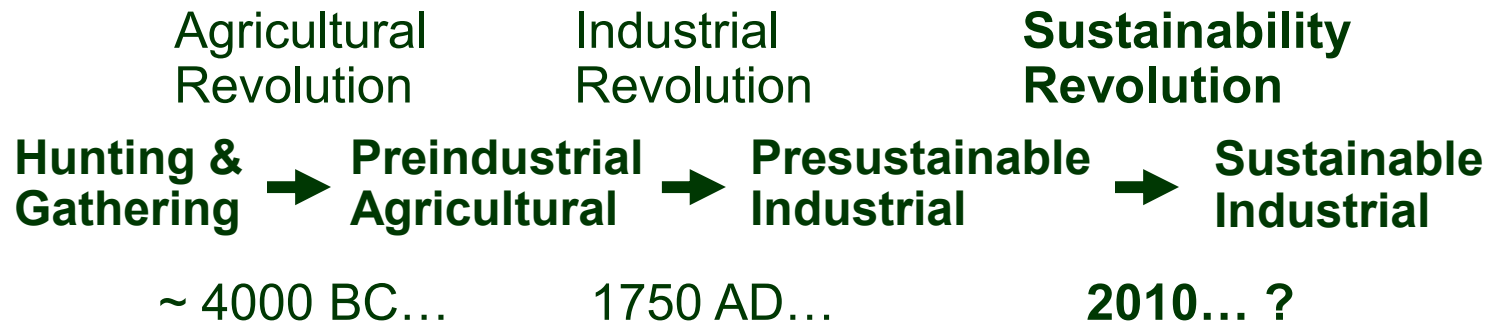


Twice in history, major changes in the resources used by humanity have resulted in transformative changes in day-to-day life and societal organization, appropriately called revolutions



Population:	50 million	750 million	
Duration:	Millennia	Several centuries	
Scale of societal integration/ collapse:	Small groups	Farms/ villages	Cities/countries

Today: There are abundant indications that a third revolution is required



Population:	50 million	750 million	~7 billion	
Duration:	Millennia	Several centuries	< a century	
Scale of societal integration/collapse:	Small groups	Farms/villages	Cities/countries	Global
	<i>The sustainability revolution: More people, less time, higher risk</i>			
	<i>The defining challenge of our time</i>			

The Sustainability Revolution

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 and currently improbable changes

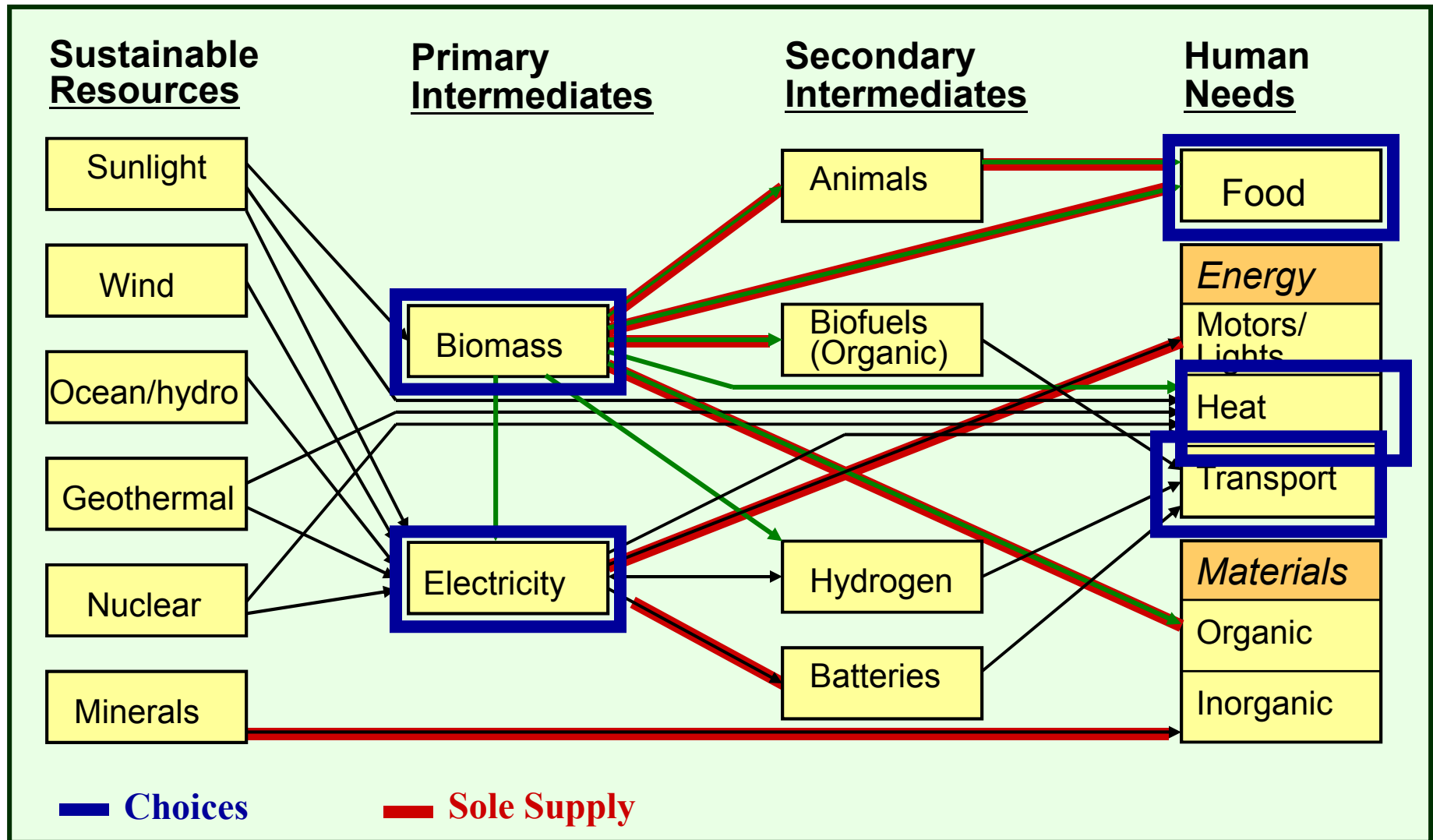
Embracing the improbable

Currently probable trends are not sustainable, we must look beyond them for 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

Imagining a Sustainable World



Biomass

Central and essential role in a sustainable world

The only foreseeable sustainable source of food, organic fuels, and organic materials

Bioenergy: Motivations & Observations

Energy Security: Capacity to produce biomass much more broadly distributed than fossil energy resources

Rural Economic Development: Bioenergy production could provide needed new markets for rural communities in both the developed and developing world

Potential for Near-zero GHG Emissions, Very Positive Energy Balance: Bioenergy production, utilization cycles begin with removal of atmospheric CO₂

- Renewable process energy (e.g. cellulosic, sugar cane)
- Avoid large carbon emissions from land clearing

Cellulosic Feedstocks

Low cost: @ \$60/dry ton = \$4/GJ = oil at \$23/barrel

Per acre environmental attributes generally positive

Potential to meet land-use challenges

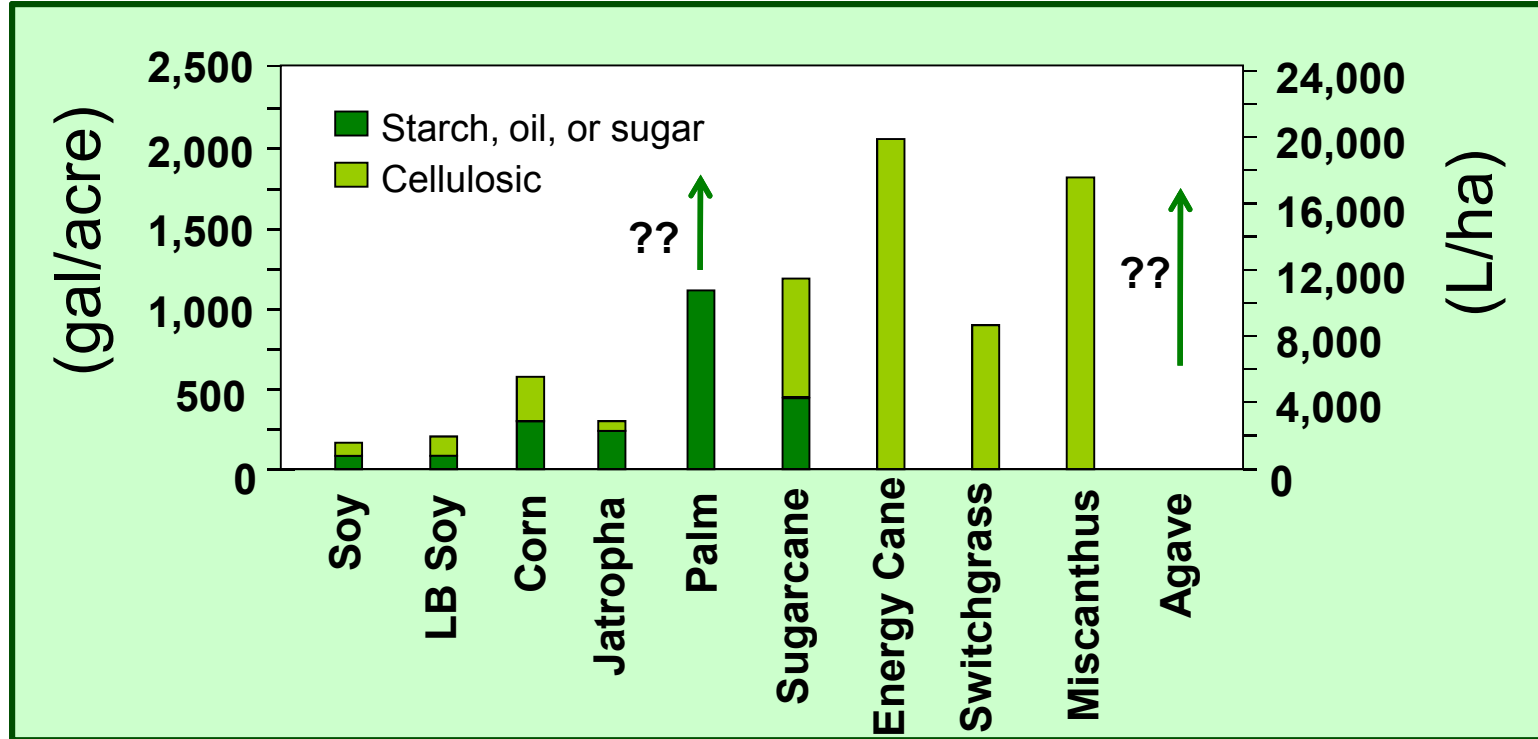
- Broad site range, including land with few other uses
- Graceful integration options (will present examples)
- High land productivity

Very large scale bioenergy production (e.g. \geq a quarter of global mobility) likely requires cellulosic feedstocks

Sugar cane. Most meritorious of current bioenergy feedstocks, substantial expansion potential. However, site range limited, 2/3 cellulosic biomass, per acre yield (ton/ha) would be higher with lower sugar content.

Algae. Some distinctive and attractive features, worthy of study. However, the case for production at a competitive cost/GJ has yet to be made.

Comparative Land Productivity of Bioenergy Feedstocks



Robust, fundamental rather than incidental conclusions about land-efficient biomass production can be drawn

Harvest the whole plant

Grow plants with composition optimized for photosynthesis rather than accumulation of sugar, starch, or oil

Perennials, C₄ plants

	Maximum Productivity (Mg/ha)
C ₄ perennials	70
C ₃ perennials	40
Most annual crops	< 20
	Nobel et al., 1992

Notwithstanding its potential, anticipation and realization of large-scale cellulosic bioenergy production are impeded by two key factors:

Recalcitrance of cellulosic biomass

Difficulty of converting cellulosic biomass to reactive intermediates such as sugars or synthesis gas, addressable by improved processing technology

Land use concerns

Competition with food supplies

Carbon emissions & habitat loss from clearing of wild lands

Could we produce enough biomass to meaningfully impact “mega challenges”?

Focus of this talk, Global Sustainable Bioenergy Project

Strong Negative Assessments (selected)

“Use of biomass energy as a primary fuel in the United States would be impossible while maintaining a high standard of living” (Giampetro & Pimentel, 1990)

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

“Any substantial increase in biomass harvesting for the purpose of energy production would deprive other species of their food sources and cause the collapse of ecosystems worldwide” (Huesemann, 2004)

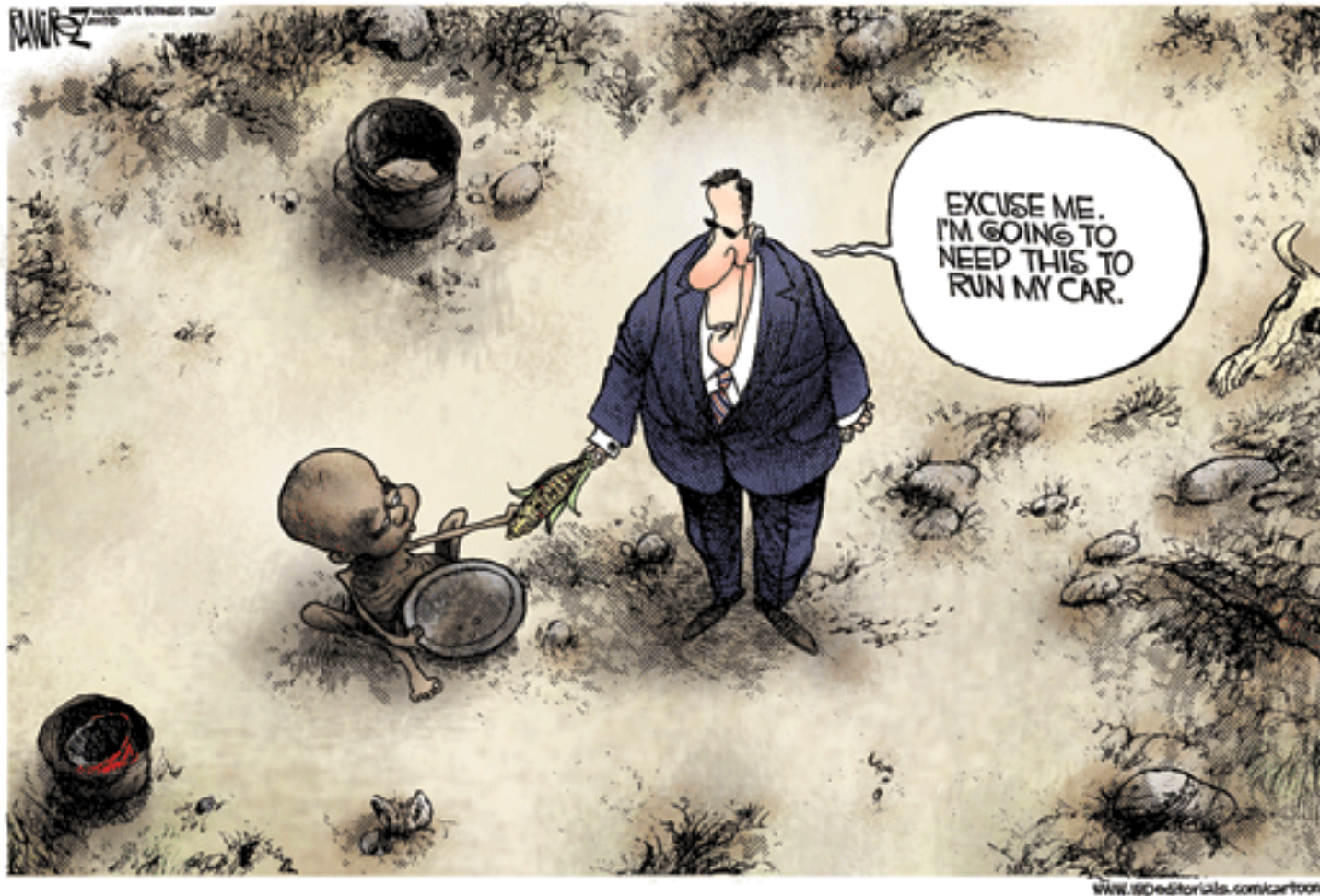
Impractically large land requirements for biomass energy production on a scale comparable to energy/petroleum use (Trainer, 1995; Kheshgi, 2000; Avery, 2006)

“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)

“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, 2009).

Strong Negative Assessments

“[I]t’s a crime against humanity to convert agricultural productive soil into soil... which will be burned for biofuel.” (Jean Ziegler, UN Special Rapporteur, 2007)



There are also more positive assessments, considered subsequently

Strong positive assessments (selected)

Biomass becomes the largest energy source supporting humankind by a factor of 2 by the middle of the 21st century (Johanssen et al., 1993)

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

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

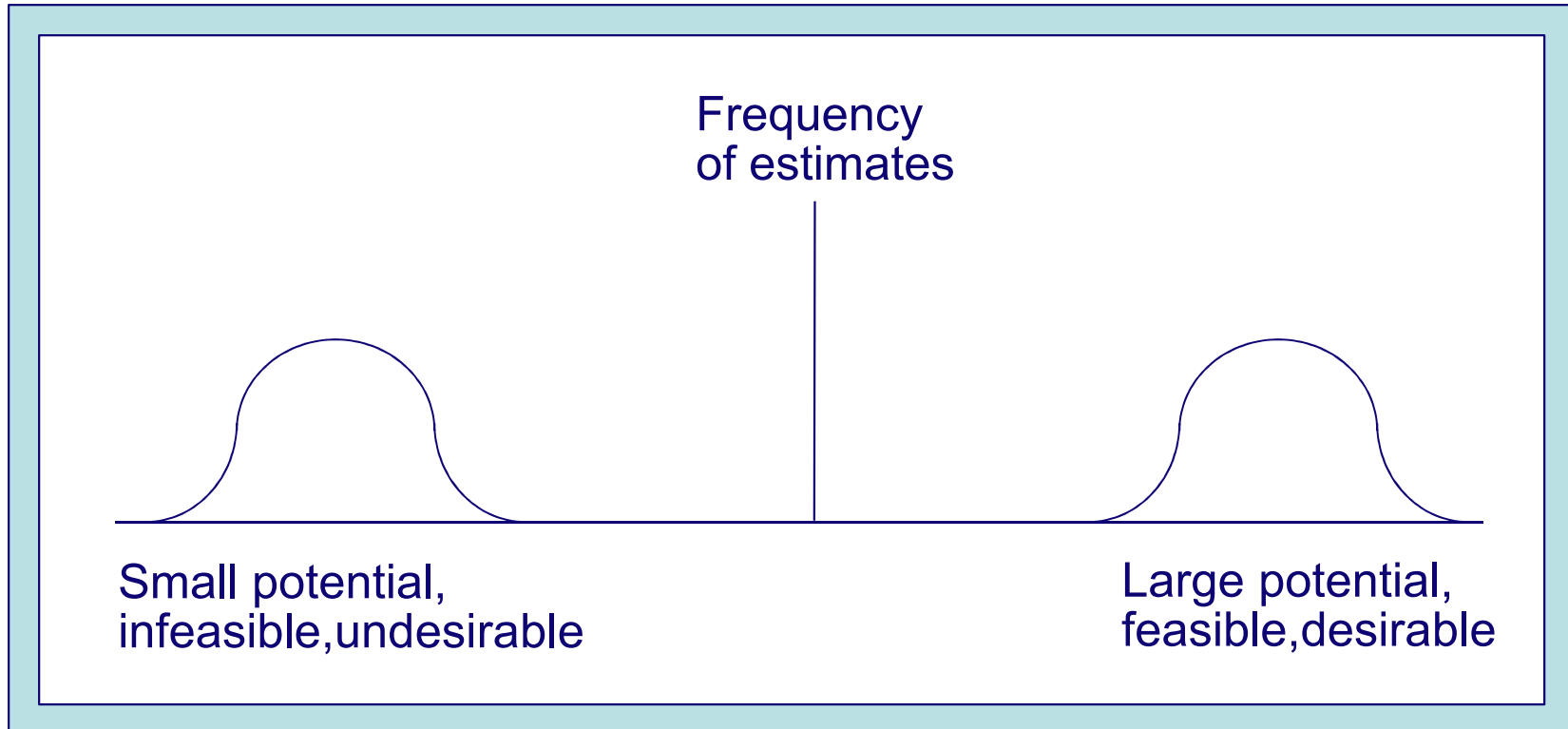
1.3 billion tons of biomass could be available in the mid 21st century - 1/3 of current US transport fuel demand (Perlack et al., 2005, *Billion Tons Study*).

30% EU primary energy demand by 2030 if 2nd generation lignocellulosic feedstocks grown on all areas available (REFUEL study, 2010)

Biomass the largest single energy source supporting humankind in 2050 (IEA, current "Blue Map" scenario, 50% reduction in CO₂ emissions)

Sharply-Divergent Assessments of Bioenergy

Rather than clustering about a mean, estimates for the potential energy contribution of biomass exhibit a bimodal distribution with most such estimates envisioning a very small or very large energy supply role for this resource¹



¹Lynd et al. in Sovacol and Brown (eds.) Energy and American Society. Thirteen Energy Myths. Springer. 2007.

Sharply-Divergent Assessments of Bioenergy: Consequences

Policy makers are understandably confused

Absence of clear understanding leads to uncertainty with respect to

- Feasibility and desirability of a sustainable bioenergy-intensive future
- What should such a future look like?
- What should be done to realize it?

Strong and coherent support is difficult to motivate

This is an unacceptable state of affairs in light of the urgency of the challenges inherent in the sustainability revolution

Sharply-Divergent Assessments of Bioenergy: Understanding

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

What is versus what could be. 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).

Change Fostering Sustainability

Motivated	Innovation: - Change: +	Innovation: + Change: +
Indifferent	Innovation: - Change: -	Innovation: + Change: -

Current

Mature

Technological Maturity

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

However, it is entirely unrealistic to expect to meet these challenges without both

Sharply-Divergent Assessments of Bioenergy: Understanding

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

What is versus what could be.

Low beam



High beam view



Sharply-Divergent Assessments of Bioenergy: Understanding

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

Many critics of bioenergy are responding to features of the substantial existing biofuels industry based on edible, 1st generation feedstocks.

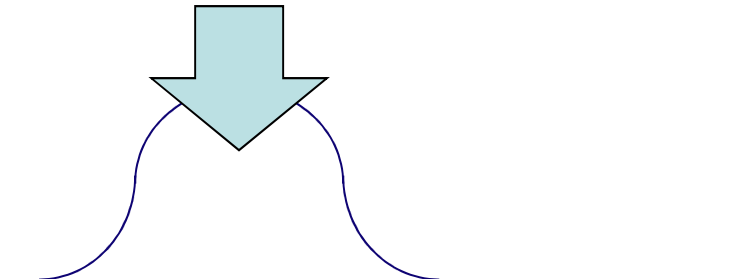
Existing biofuel industries are in turn a response to government incentives motivated by a variety of objectives

- Rural economic development
- Energy security
- Balance of payments
- Large-scale sustainable energy supply

...of which the latter has seldom been the most important

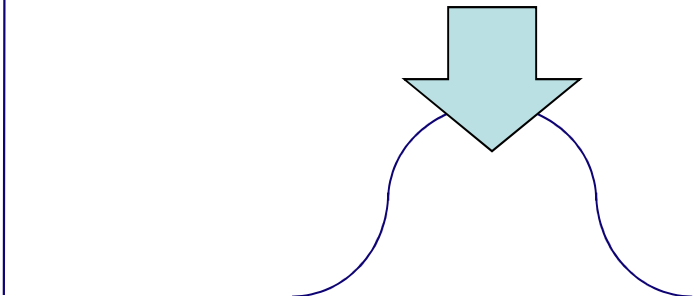
Sharply-Divergent Assessments: Reconciliation

What are the impacts of adding large-scale use of (usually today's) biofuels to a world based on extrapolating current practices?



Small potential,
infeasible, undesirable

What role could (usually advanced) biofuels play in a world reconfigured to meet energy challenges?



Large potential,
feasible, desirable

Value

What we shouldn't, or can't, do:
Achieve a sustainable and secure future
by extrapolating an unsustainable and
insecure present

What we could do

Biggest limitation

Does not illuminate solutions

Not consistent with current reality

It may be more productive, and also more correct, to view the sharply divergent assessments of bioenergy as informative answers to two different questions rather than irreconcilable answers to the same question.

We need to know

Could we – that is, is it physically possible to – gracefully reconcile large-scale bioenergy production with feeding humanity, meeting needs from managed lands, and preserving wildlife habitat and environmental quality?

Must we produce bioenergy at large scale in order to have a reasonable expectation of achieving a sustainable world?

Prevailing view (my informal impression)

Could we? Maybe at best. See strong negative assessments.

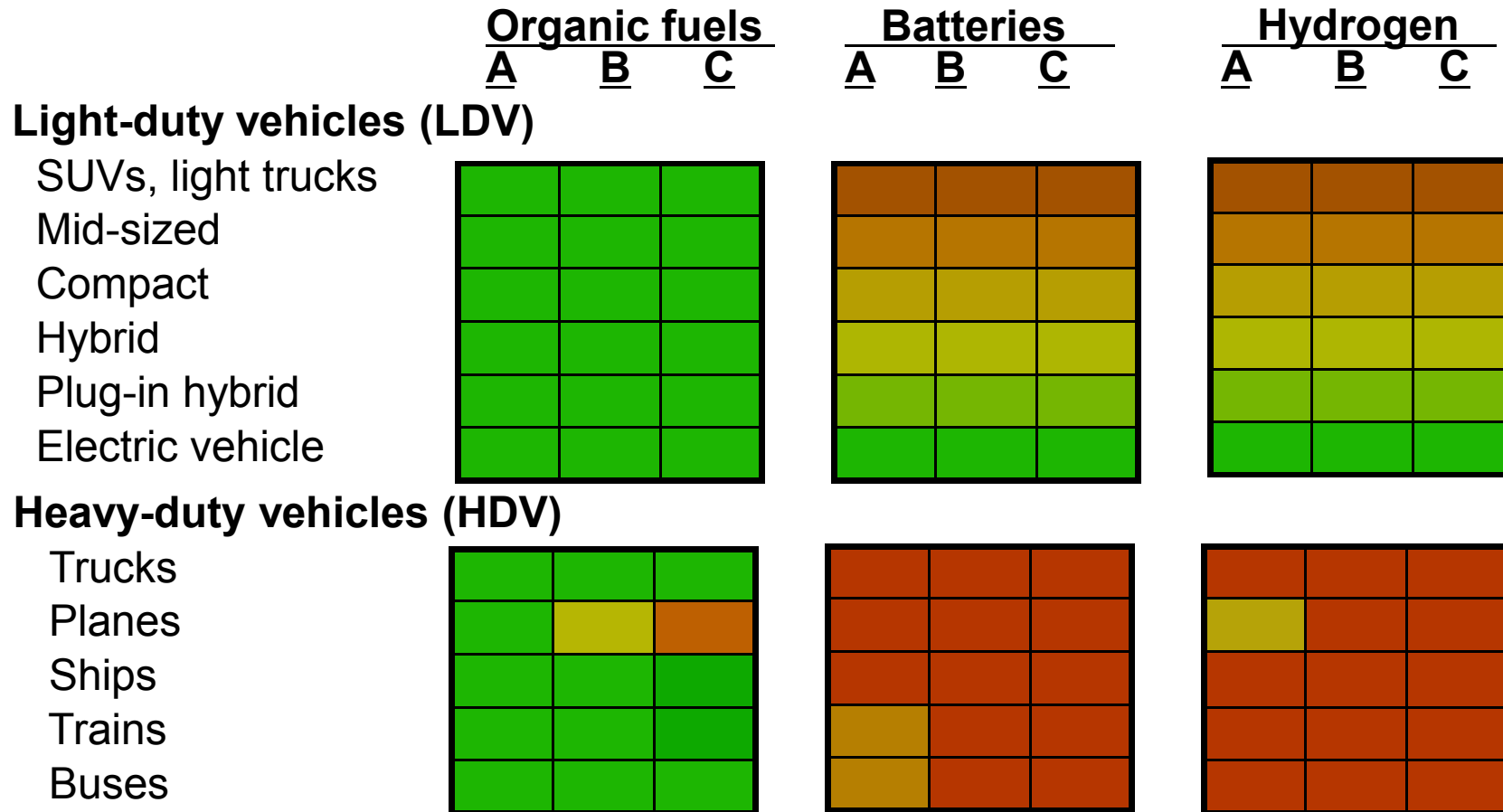
Do we have to? Probably not. Many see bioenergy as at most an interim solution.

My view

Could we? Yes; Further documentation to be provided by the GSB project

Do we have to? Yes

Must we produce bioenergy at large scale in order to have a reasonable expectation of achieving a sustainable world?



Electrification (batteries) impractical for planes, many heavy duty applications

With ultimate foreseeable electrification of LDVs, organic fuels still $\geq 50\%$ transport energy

Hydrogen faces many challenges, particularly for HDV, low-C

Without biofuels, achieving a sustainable transportation sector is unlikely

Could we – that is, is physically possible to – gracefully reconcile large-scale bioenergy production with feeding humanity, meeting needs from managed lands, and preserving wildlife habitat and environmental quality?

Favorable indications – land limitation is not a show-stopper

“Most studies assume that only a small fraction of additional land is needed to feed the world’s growing population – from 6.5 billion at present to 9 billion in 2050 – and that most of the increase in food requirements will be met by an increase in agricultural productivity”. Doornbosch & Steenblik, OECD, 2007

A billion acres of abandoned agricultural land globally (Campbell et al., Env. Sci. Technol., 2008)

Africa has 12 times the land area of India, similar land quality, 30% fewer people – yet India feeds itself and Africa does not. The green revolution bypassed Africa due to serious organizational and institutional weaknesses, not geographically-limited capacity (A. Temu, ICRAF)

Empirical evidence indicates that the majority – and by some credible evidence as much as three quarters - of earth's non-forest land area that is suited and available for rainfed agriculture without deforestation, lies fallow, abandoned or is underutilized due to primarily to political, socio-economic (market), and infrastructure constraints. (K. Kline, ORNL, manuscript in preparation)

Could we – that is, is physically possible to – gracefully reconcile large-scale bioenergy production with feeding humanity, meeting needs from managed lands, and preserving wildlife habitat and environmental quality?

Favorable indications – in progress analysis and sketches indicate great & underexplored potential in a reconfigured world (selected)

Crop residues burned in China would exceed current transportation energy demand if converted to fuel (Yan et al., 2006, 2009).

Double crops and changed animal feed rations based on leaf protein recovery
Potential exceeds 67 billion GGE (gal gasoline equivalent) in the U.S., ~50% current consumption (Bruce Dale & colleagues, Michigan State University)

Pasture intensification in individual countries (e.g. U.S., Brazil) could provide amounts of fuel commensurate with global gasoline demand

Dietary changes could have similar potential to pasture intensification (Davis & Lynd)

Water-efficient energy crops (e.g. Agave). Potential to access large amounts of land not suitable for row crops.

Achieving multiple benefits. Decreasing the time required to regenerate fertility is a potentially powerful strategy to minimize impacts of slash-and-burn agriculture and address land reclamation, particularly if coupled with revenues. (Peter Manang, Alternatives to Slash and Burn Agriculture Partnership)

Bioenergy as a means to enhance food security.

Could we – that is, is physically possible to – gracefully reconcile large-scale bioenergy production with feeding humanity, meeting needs from managed lands, and preserving wildlife habitat and environmental quality?

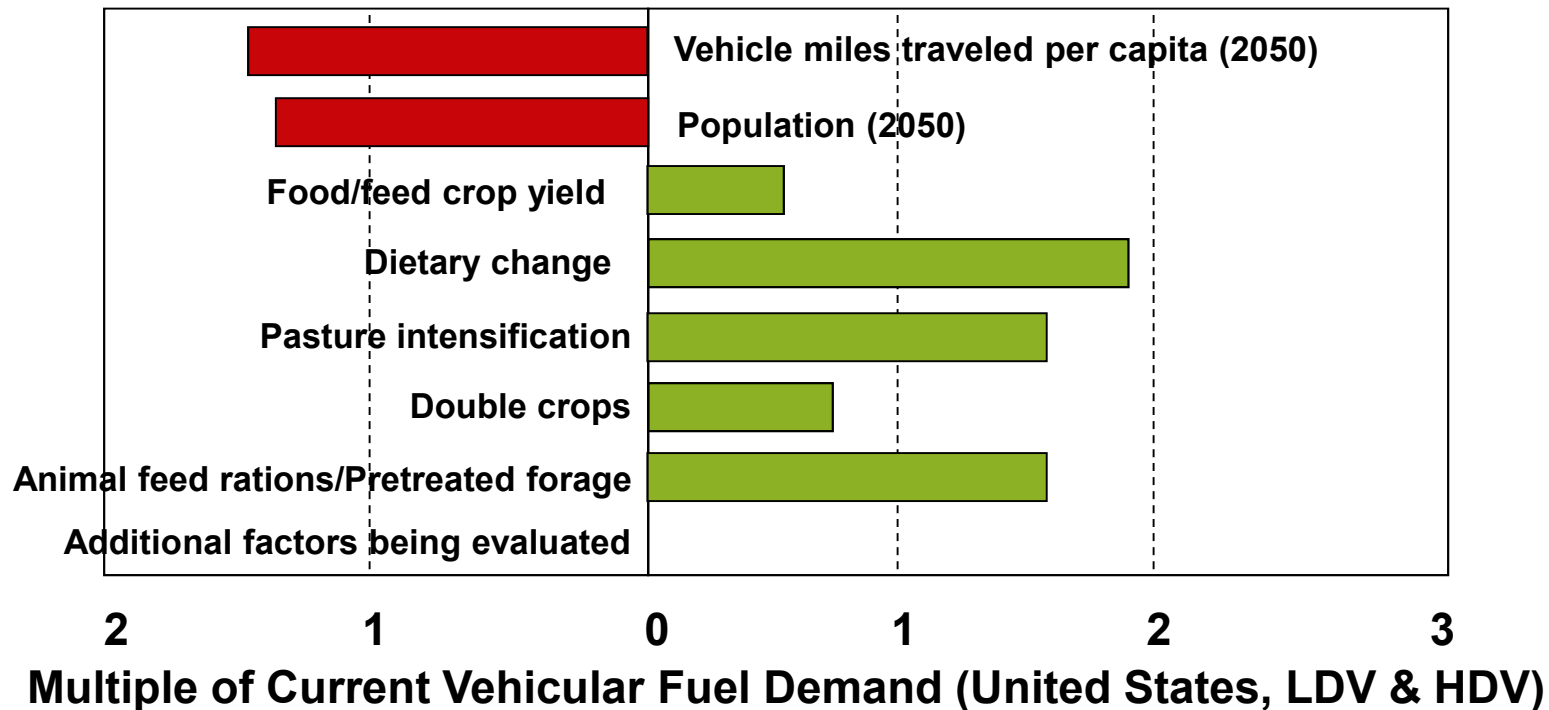
Favorable indications – in progress analysis and sketches

Factors that make satisfying mobility demand with bioenergy **more difficult**

Factors that make satisfying mobility demand with bioenergy **easier**

Current Vehicle Efficiency

Projected switchgrass productivity



Could we – that is, is physically possible to – gracefully reconcile large-scale bioenergy production with feeding humanity, meeting demands from managed lands, and preserving wildlife habitat and environmental quality?

Favorable indications – in progress analysis and sketches

Factors that make satisfying mobility demand with bioenergy **more difficult**

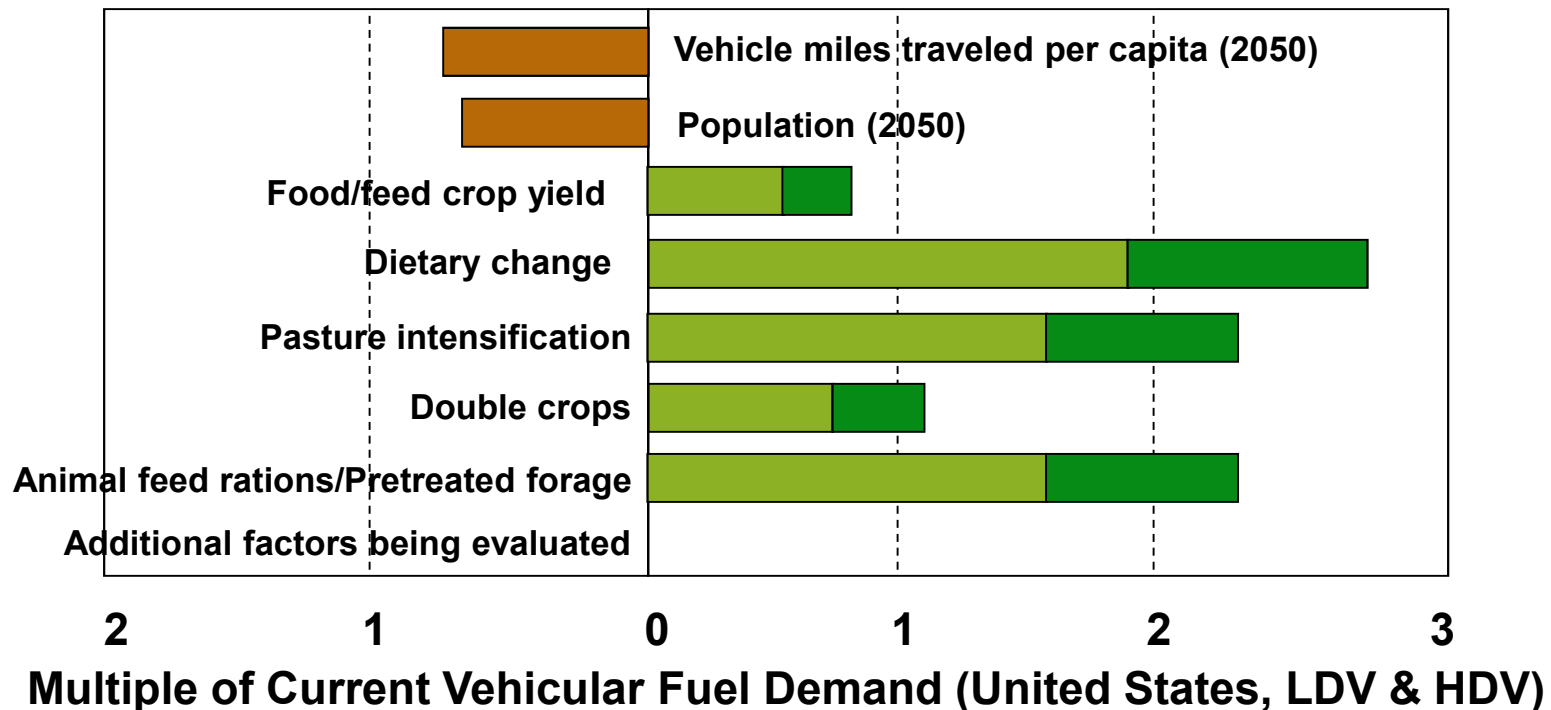
Factors that make satisfying mobility demand with bioenergy **easier**

Current Vehicle Efficiency

Projected switchgrass productivity

2 x Vehicle Efficiency

1.5 x projected switchgrass productivity



Bioenergy and Food Security

Could biofuel production be part of the solution to pressing food security and poverty alleviation challenges?

Potentially yes, more likely/extensively with 2nd generation feedstocks

Challenging, relatively underexplored, first step is to show it is possible

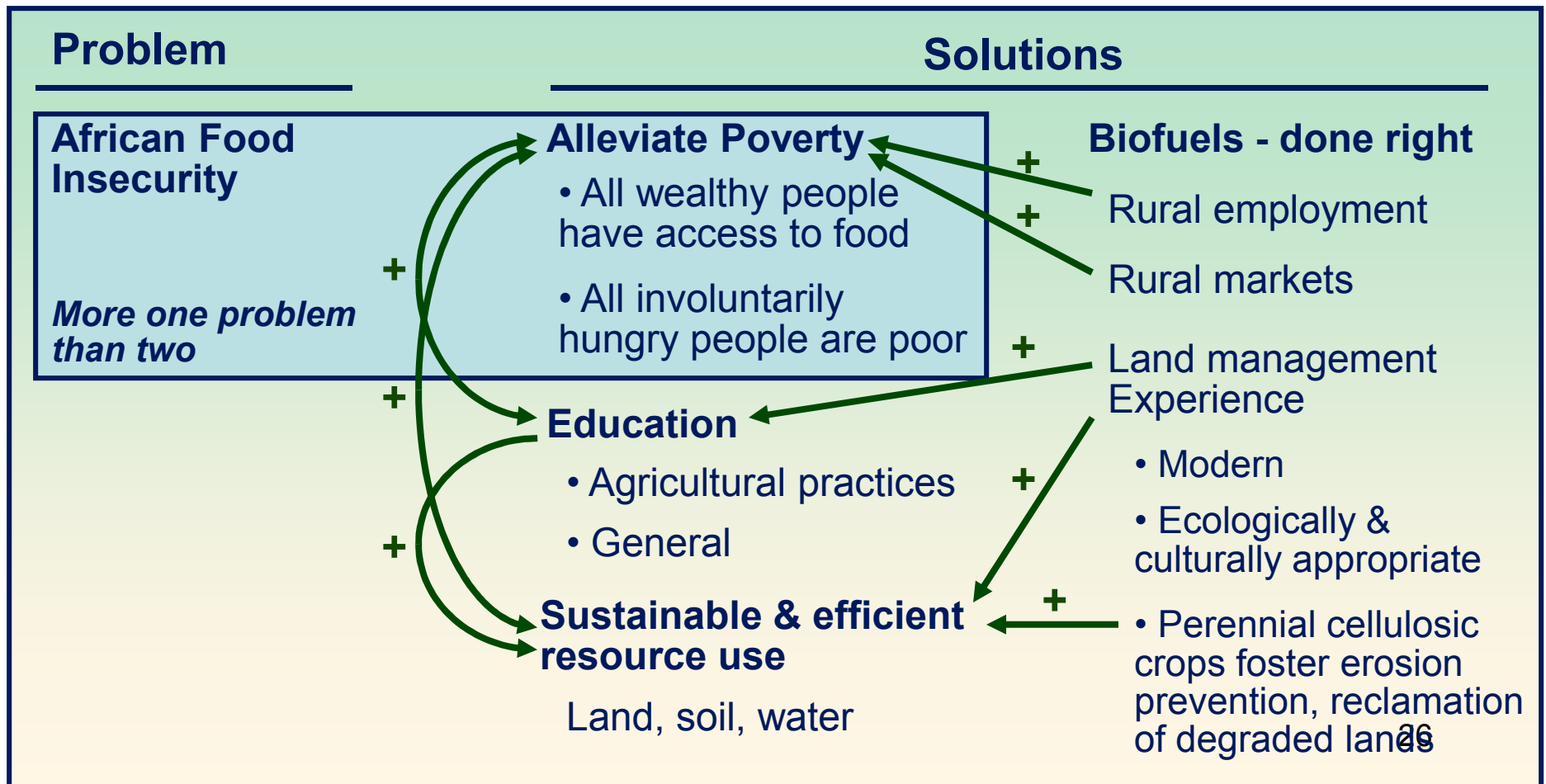
Problem	Solutions
African Food Insecurity	Alleviate Poverty <ul style="list-style-type: none">• All wealthy people have access to food• All hungry people are poor

Bioenergy and Food Security






















Could biofuel production be part of the solution to pressing food security and poverty alleviation challenges?

Potentially yes, more likely/extensively with 2nd generation feedstocks

Relatively underexplored



Bioenergy and Food Security

<u>Factors Contributing to Food Insecurity*</u>	<u>Food Security Impact of Biofuel Production</u>		
	<u>Food crops</u>	<u>Cellulosic Crops Cropland</u>	<u>Cellulosic Crops Non-cropland</u>
Poverty			
Rural unemployment			
Lack of marketable skills			
Low currency value			
High food prices			
Local production undermined by foreign subsidies			
Poorly developed ag. infrastructure (Physical, market, knowhow)			
Degraded land			

Bioenergy has clear potential to be developed in ways that are responsive to ... [African] ... challenges, including enhancing food security, but could also be developed in ways that exacerbate them. A vision for bioenergy in Africa that is responsive to African challenges is both an urgent need and an important opportunity.” **African GSB Convention**

* Thurow, R, S. Kilman. Enough: Why the World’s Poor Starve in an Age of Plenty. 2009. Public Affairs.

Global Sustainable Bioenergy: Feasibility & Implementation Paths “GSB Project”

Initiated June, 2009

Working hypothesis: It is physically possible to gracefully reconcile large-scale bioenergy production ($\geq 25\%$ of global mobility or equivalent) with feeding humanity, meeting other needs from managed lands, and preserving wildlife habitat and environmental quality.

Staged structure

Stage 1. Five Continental Conventions

- Gather input on framing stages 2 and 3
- Continental and common resolutions
- Recruit participants & funds

Stage 2. Address working hypothesis, unconstrained by current realities.

Stage 3. Analyze implementation paths, recommend policies



GSB Project: Stage 1 Continental Conventions

Representation	Host Institutions, Location	Meeting Chairs, also Members of the GSB Organizing Committee	Dates
Europe	Kluyver Center for Genomics of Industrial Fermentations, Delft, The Netherlands	<ul style="list-style-type: none"> • Andre Faaij, Utrecht University • Patricia Osseweijer, Delft University of Technology 	February, 24-26, 2010
Africa	University of Stellenbosch, Stellenbosch, South Africa	<ul style="list-style-type: none"> • Emile van Zyl, University of Stellenbosch • Miyuki Iiyama and August Temu, World Agroforestry Centre, Nairobi 	March, 17-19, 2010
Latin America	University of São Paulo, São Paulo, Brazil	<ul style="list-style-type: none"> • José Goldemberg, University of São Paulo • Carlos Henrique de Brito Cruz, FAPESP, São Paulo 	March, 23-25, 2010
Asia, Oceania	Universiti Teknologi Malaysia Kuala Lumpur, Malaysia	<ul style="list-style-type: none"> • Ramlan Abdul Aziz, Universiti Teknologi Malaysia • Reinhold Mann, Battelle Science and Technology, Malaysia 	June 14-16, 2010
North America	University of Minnesota, Minneapolis/St. Paul, USA	<ul style="list-style-type: none"> • Jon Foley and John Sheehan, University of Minnesota 	September, 14-16, 2010

Steering Committee (expansion anticipated): Lee Lynd (Chair), Dartmouth, Mascoma Corp.
 Nathanael Greene, Natural Resources Defense Council
 Tom Richard, Pennsylvania State University

GSB Project: Approach and Differentiation

	Most Bioenergy Projects & Analyses	GSB Project
Focus	Most probable	Most desirable
Expert opinion	Reflected, often sharply divided	Informed, seek new understanding & consensus
Point of reference	Current reality	Future vision
Value	✓	✓

While there is a natural reluctance to consider change, we must do so since humanity cannot expect to achieve a sustainable and secure future by continuing the practices that have resulted in the unsustainable and insecure present.

Statement made on behalf of the GSB Stage 1 Organizing Committee, Issues in Science and Technology, Summer, 2009