Biofuels Potential and Sustainability

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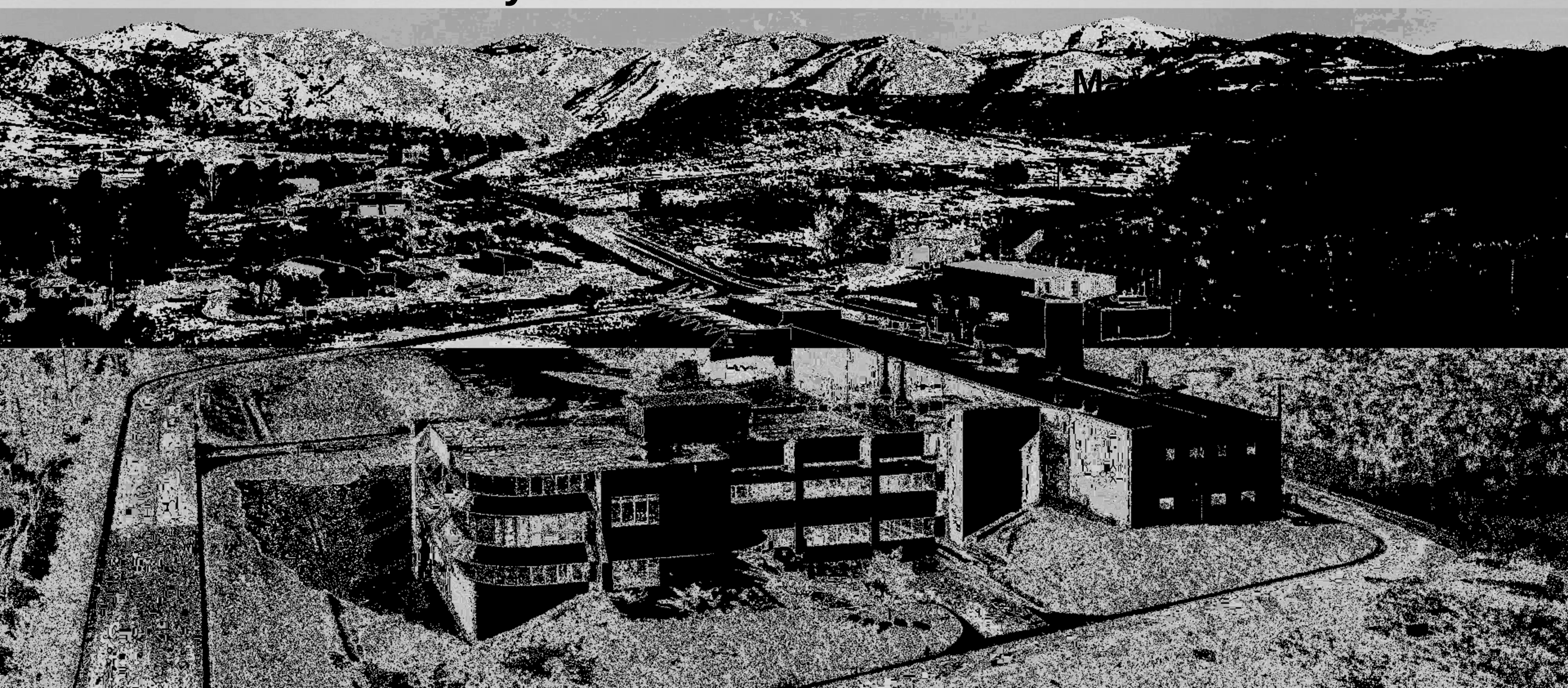
National Renewable Energy Laboratory (NREL)

2008 Rocky Mountain Land Use Institute Conference

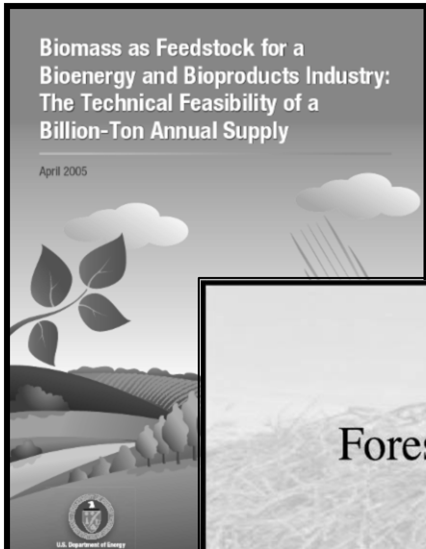


Outline

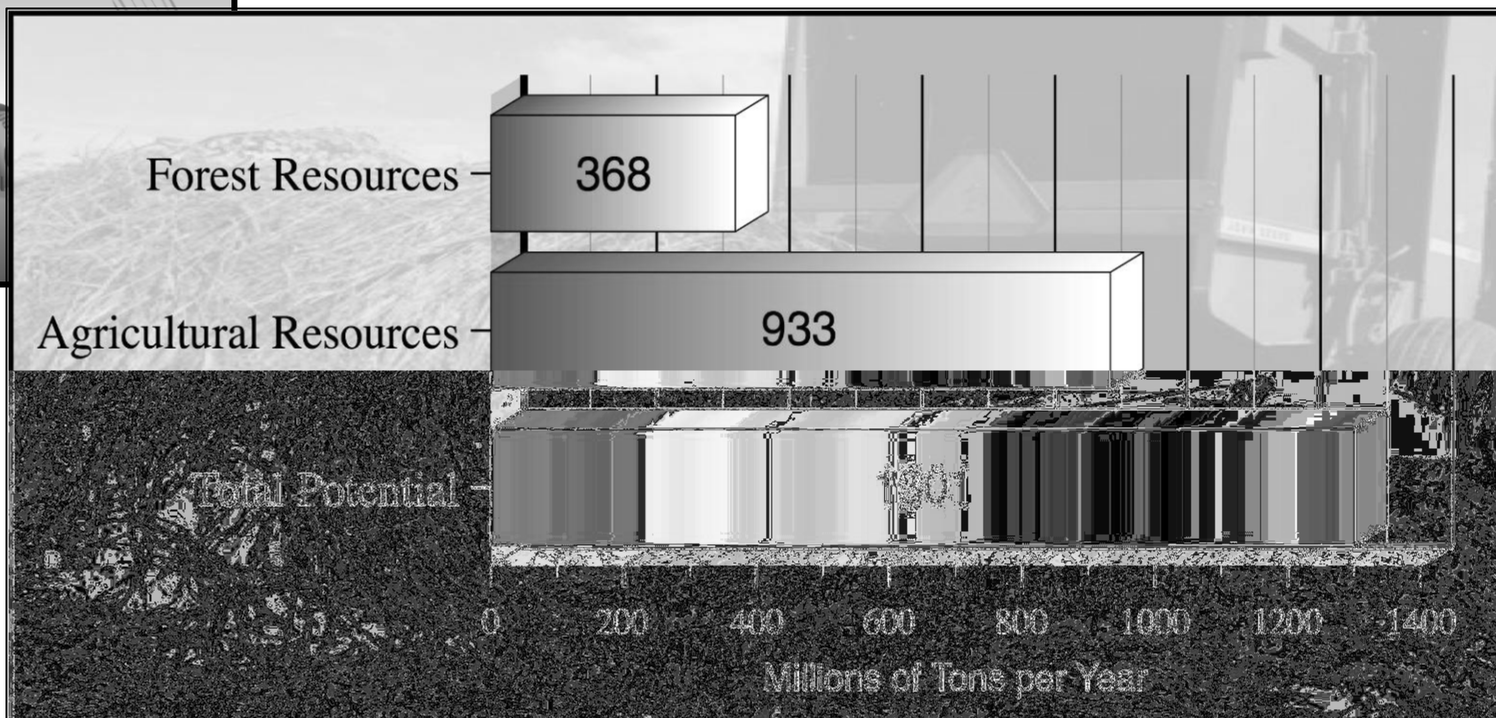
- Biofuels potential
- Current state of cellulosic technology
- Sustainability challenges for one biofuel -- ethanol
- Land use and soil quality
- Water demand and quality
- GHG emissions & air quality
- Conclusions

Way-too-early adopters

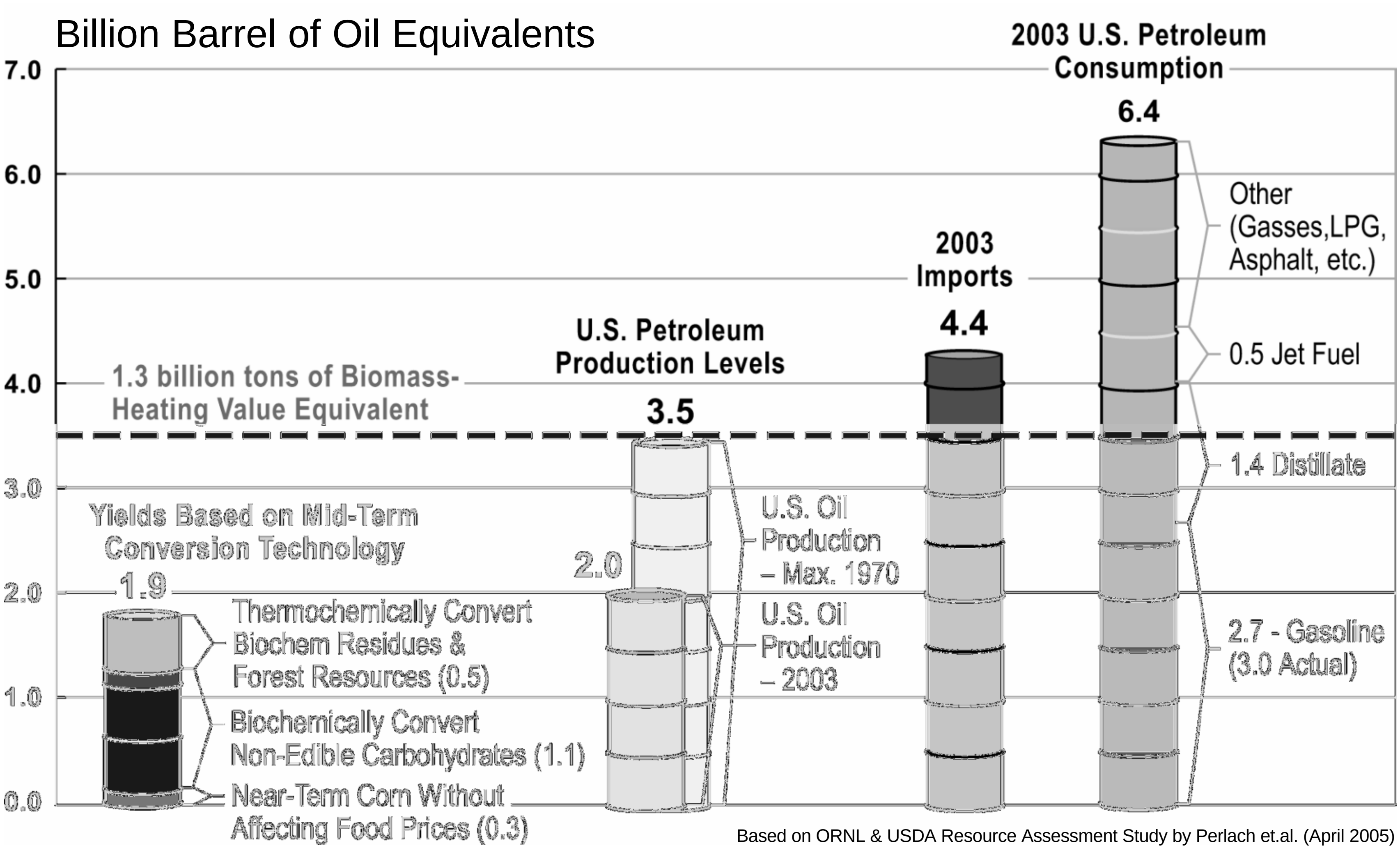
U.S. Biomass Resource Assessment



- Updated resource assessment - April 2005
- Jointly developed by U.S. DOE and USDA
- Referred to as the “Billion Ton Study”



The 1.3 Billion Ton Biomass Scenario



Based on ORNL & USDA Resource Assessment Study by Perlach et.al. (April 2005)
http://www.eere.energy.gov/biomass/pdfs/final_billionton_vision_report2.pdf

U.S. National Commitment to Biofuels Goals

"Cost-competitive cellulosic ethanol"

- Cost-competitive in the blend market by 2012

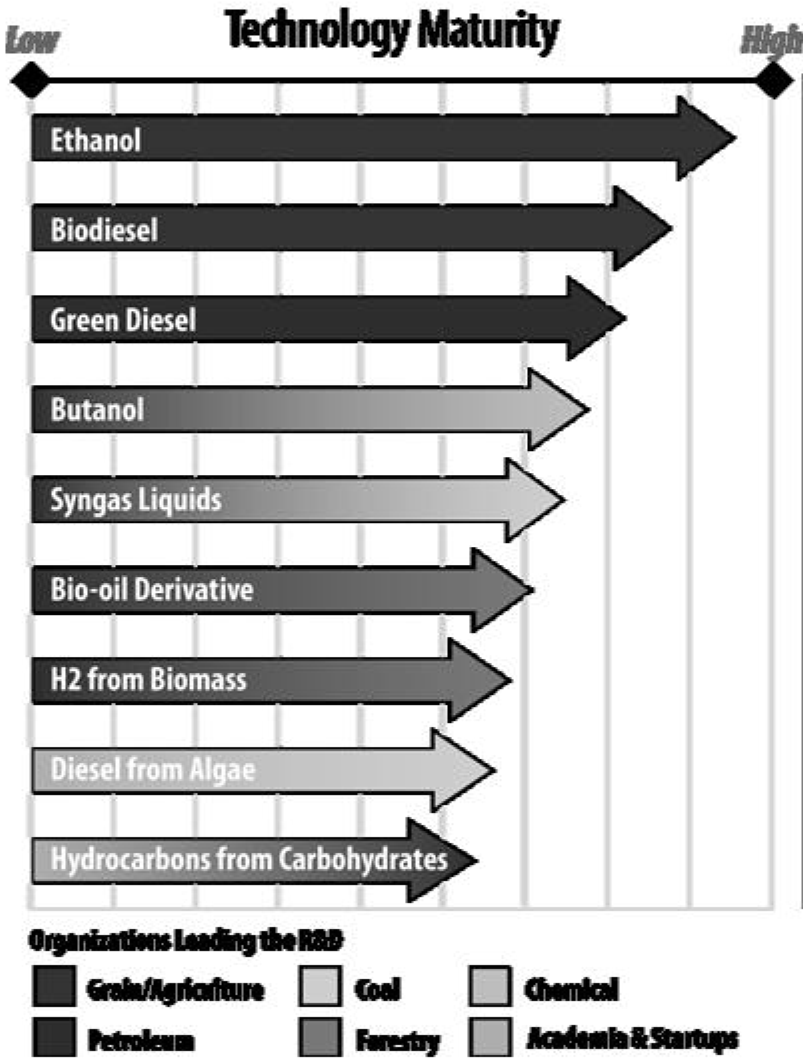
EISA (Energy Independence & Security Act)

- **36 billion** gallons renewable fuel by 2022
  - **21 billion** gallons advanced biofuels

30 x 30 (followed from the 2006 SOU)

- Longer-term biofuels goal
- Ramp up the production of biofuels to **60 billion** gallons
- Displace **30%** of U.S. gasoline consumption* (based on 2004 use) by 2030

Ethanol is the Most Mature Biofuel Technology



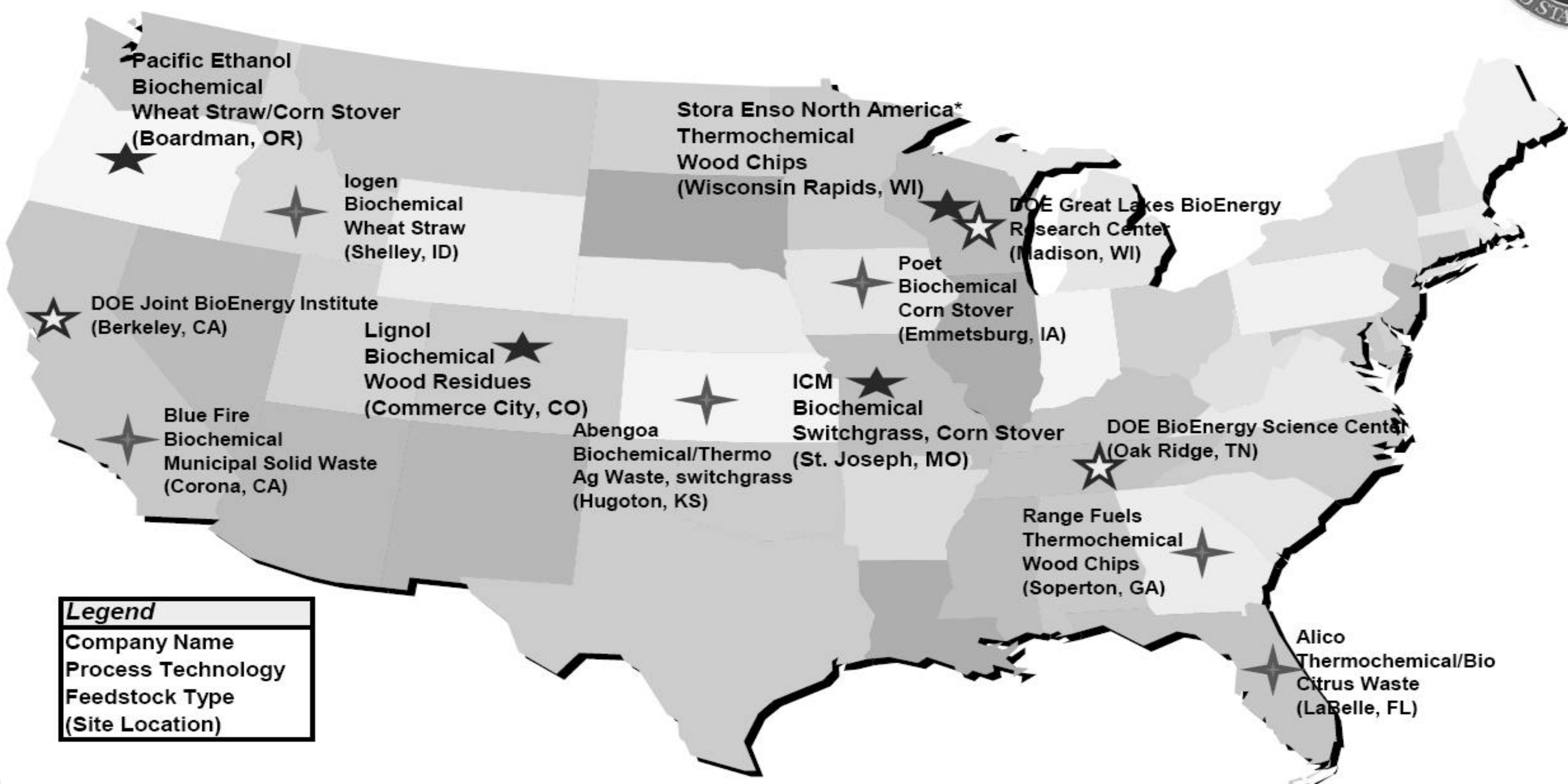
Key Drivers	Value Added
New market for grain and agriculture products. Large supply of lignocellulose.	High octane gasoline blend stock from carbohydrates.
New market for excess oils, fats, and greases.	Petroleum compatible and biodegradable.
Lower cost and higher product quality than FAME.	Utilize existing assets. High quality jet fuel or diesel.
New market for grain and agriculture products. Large supply of lignocellulose.	Better gasoline blending properties than ethanol.
Integration of biomass with Coal, Coke, Shale, or Heavy Oils.	High quality jet fuel or diesel. Reduced criteria for sequestration, and economy of scale (in combination with fossil).
Technical fit with woody biomass and liquid bio-crude.	Potential to integrate into existing large scale refinery and pipeline infrastructure.
Potential transportation fuel from any fuel/power source.	Ideal feed for fuel cells, and lowest tail pipe emissions.
Lg. source of biomass on non-arable land, and capture of CO^2.	High quality jet fuel or diesel yield per acre, with both off-shore and on-shore potential.
Better compatibility with petroleum products.	Potential for higher reaction rates than fermentation, and potential as H2 carrier.

Renewable Fuels & Low GHG Emissions

Industry is Engaged!

Major DOE Biofuels Project Locations

Geographic, feedstock and technology diversity



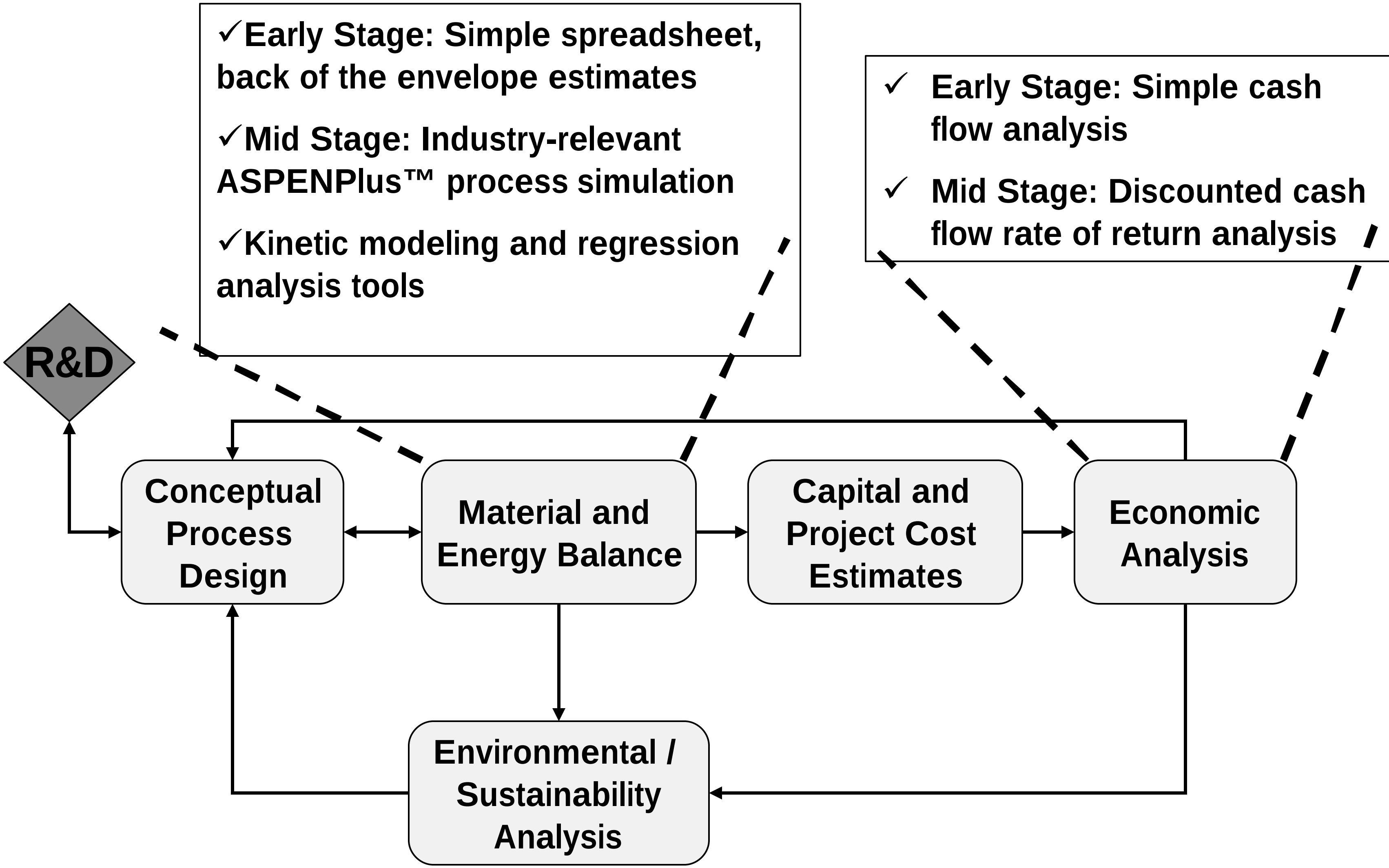
Six Commercial-Scale Biorefinery Projects; DOE will invest up to $385 million

Four Small-Scale Biorefinery Projects; DOE will invest up to $114 million (first round)

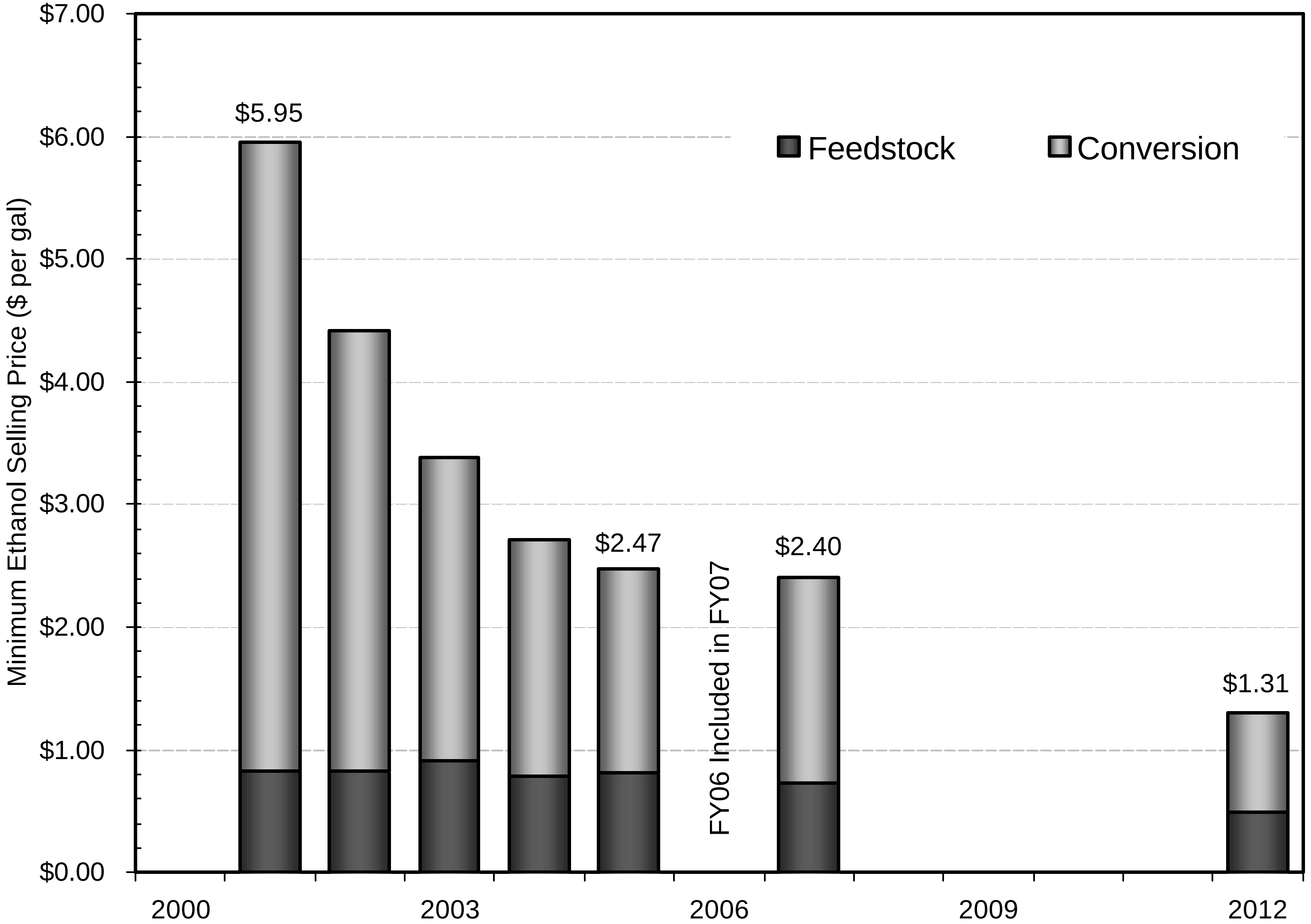
Three Bio-Energy Centers; DOE will invest up to $405 million

* Acquired by NewPage Corporation

Appropriate Stage Gate Level of Analysis for Project Stage of Development



Significant Research Progress Is Being Made



The Concept of Sustainability

"The common aim must be to expand resources and improve quality of life for as many people as heedless population growth forces upon Earth, and do it with minimal prosthetic dependence. That, in essence is the ethic of sustainable development."-

- \- E.O. Wilson, *Consilience: the Unity of Knowledge*

"[S]ustainable development meets the needs of the present without compromising the needs of the future generations"

- *Our Common Future*. United Nations' World Commission on Environment and Development (1987)

It's important to understand that systems are more or less sustainable. Nothing is absolutely sustainable.

Biofuels are a contributor to a complex food, feed, fiber, other bio-products and bio-energy … system embedded in the overall energy, materials, products, information, services, … worldwide

Sustainability Challenges
Biomass to Biofuels Systems

Greenhouse Gas Emissions

Economic Prosperity
- Rural and urban communities
- Industry

Social Well-being

Biofuels and Biomass
- Supply infrastructure
- Fuel production
- Distribution and use

Land
- Use and change
- Competition with food
- Soil

Biodiversity

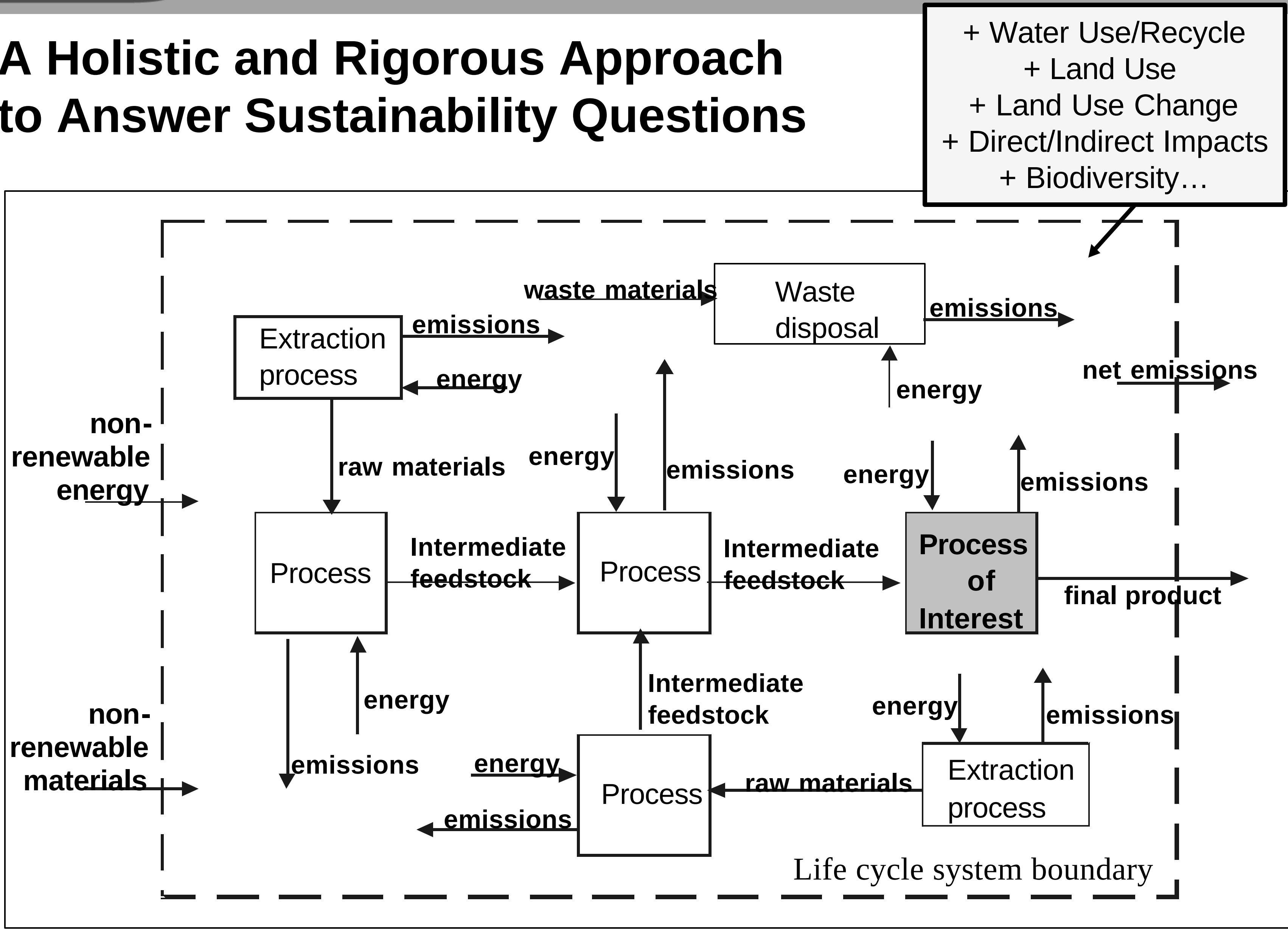
Water
- *Use*
- *Quality*
- *Efficiency of use*

Environmental Impacts

Increase Food and Energy Security

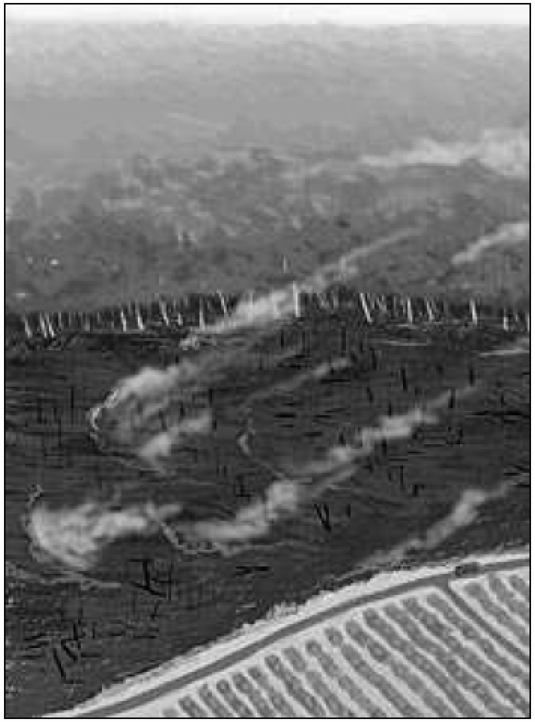
while safeguarding soil, water and biodiversity

A Holistic and Rigorous Approach to Answer Sustainability Questions



Direct and Indirect

Perhaps one of the least understood aspects of biofuels



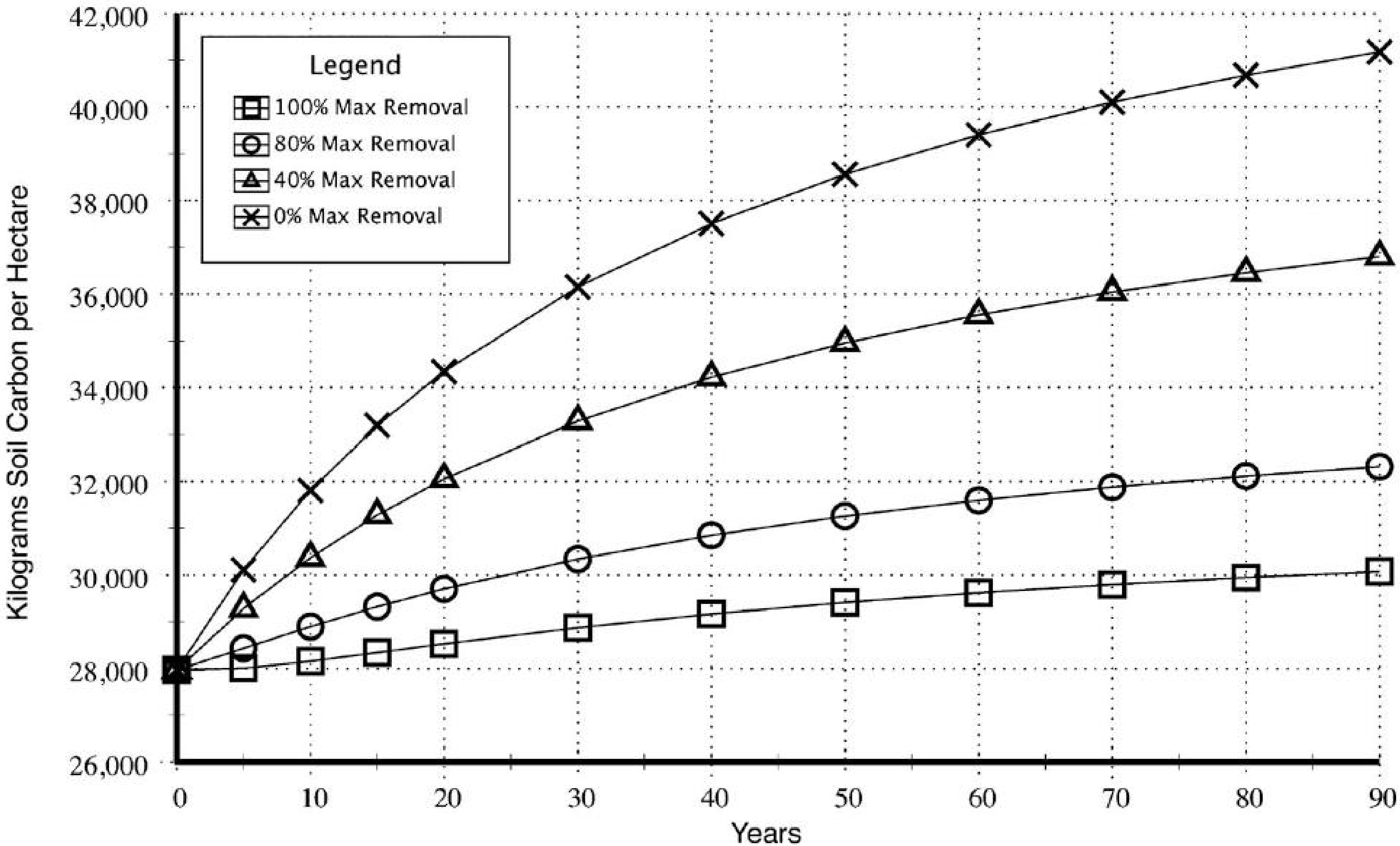
2004 Sheehan, et.al. life cycle assessment examined soil carbon effects of corn stover removal

- Constrained to limit soil erosion
- Even at the maximum rate of stover removal, soil carbon levels show a modest increase over the 90-year period modeled

2008 Searchinger, et.al. and Fargione, et.al. published papers examining indirect land use change

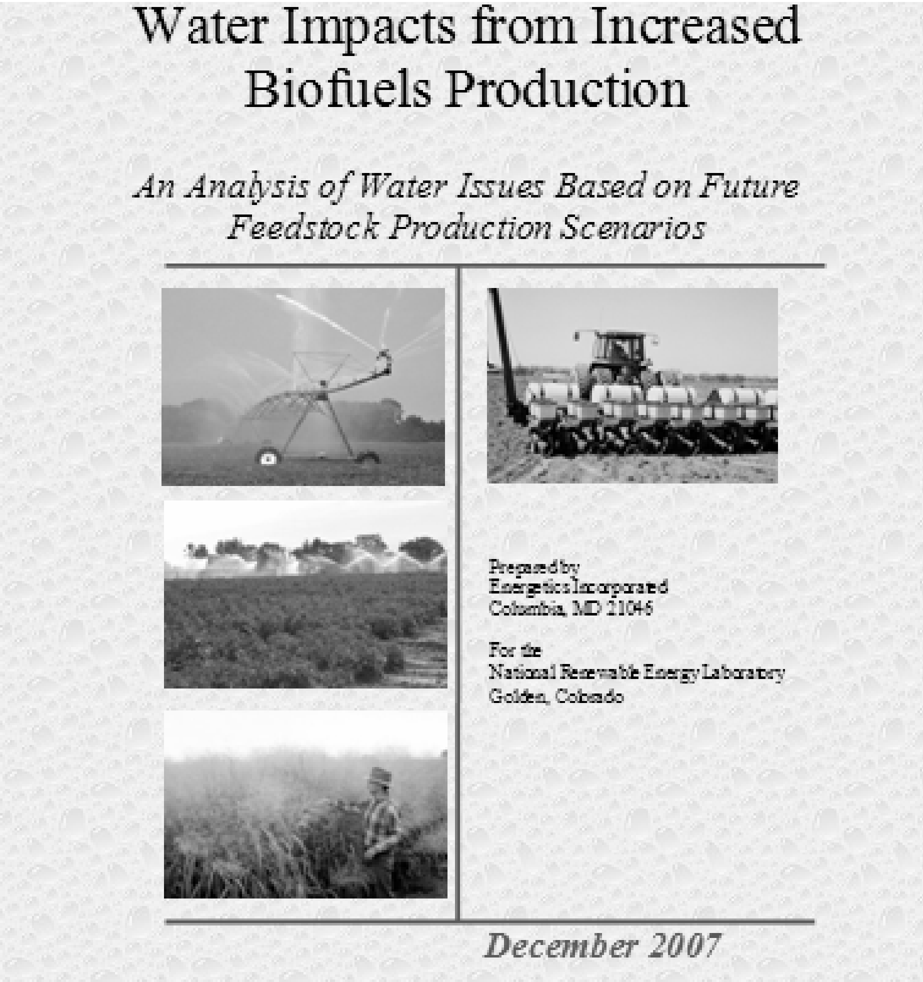
- Studies point to consequences of improper biofuels implementation

Effect of Residue Removal on Soil Carbon Flux
- Soil carbon can increase even with residue removal



Sheehan, et.al. *Journal of Industrial Ecology*, Volume 7, Number 3-4, 2004

Water Impacts


Water Impacts from Increased Biofuels Production

An Analysis of Water Issues Based on Future Feedstock Production Scenarios

Prepared by
Energetics Incorporated
Columbia, MD 21046

For the
National Renewable Energy Laboratory
Golden, Colorado

December 2007

Preliminary Study of 30 x 30 Scenarios -- Draft for Review

- There will be enough water to support the 30X30 scenario from a regional perspective (10 USDA regions) – given the preliminary scope and limitations of this study
    - Geographic variability within regions means areas with possible water shortages
- Agricultural practices and feedstock type will be a big factor
- Drought and its connections to water supply will require more study and analysis – conclusions are difficult
- Policies and regulations are all adjudicated at the State level – no real Federal or national controls
- Water rights are already an issue in many regions – mostly for competing uses with agriculture

Water Use

Fresh Water Demands	Corn Ethanol: Dry Grind	Cellulosic Ethanol: Biochemical	Cellulosic Ethanol: Thermochemical
Cooling tower makeup (percent)	68	71	71
Boiler and process makeup (percent)	32	29	29
Overall water demand (Gal H_2O / Gal EtOH)	3–4	6	1.9

Summary of ethanol production process water demands. Corn ethanol values are from commerically operating plants; cellulosic values are model-based.

The Numbers

96% of corn used for ethanol production is not irrigated
785 gallons water per gallon of ethanol (average crop irrigation)
3-4 gallons water per gallon ethanol (dry grind production)
1.9-6 gallons water per gallon ethanol (conceptual cellulosic production)
2-2.5 gallons water per gallon gasoline (petroleum refining)
0.6 gallons water per kilowatt-hour* (coal-fired power plant)

**15 gallons of water per gallon of ethanol equivalent energy*

A. Aden, 2007. Water Usage for Current and Future Ethanol Production, Southwest Hydrology, September/October Issue, p. 22-23

Ethanol – Water Quality and Availability

Water Demand & Utilization

- It takes between 3-4 gallons of water to produce one gallon of ethanol from corn grain (current best practice <3 gal/gal).
  - Almost all of this water is from utility consumption / losses (cooling tower, dryer)
  - Virtually all process water is recycled through a series of evaporators, centrifuges, and anaerobic digestors (called net zero discharge)

- How does this compare against other industrial sectors?
  - Gasoline / Crude Oil consumes between 0.75 and 1.6 gallons per gallon of crude (estimates vary), reforming and hydrogenation consume roughly 3.2 gallon/gallon.
  - Power industries (coal, nuclear) have substantially more cooling water requirements and therefore consume significantly more water

Ethanol – Water Quality and Availability

In areas where field corn used for ethanol is irrigated (Nebraska, Colorado), water consumption during crop production is the largest use

- USDA farm and ranch survey 2003 suggests average of 1.2 acre-ft of water per acre of land (equates to roughly 785 gallon water per gallon ethanol)
- However, irrigation is highly regional and much of the corn used for ethanol in the US is not irrigated

Water Availability in the mid-west will continue to be of concern as many demands are put on the aquifers

- Municipalities, Power plants, Agriculture, etc.

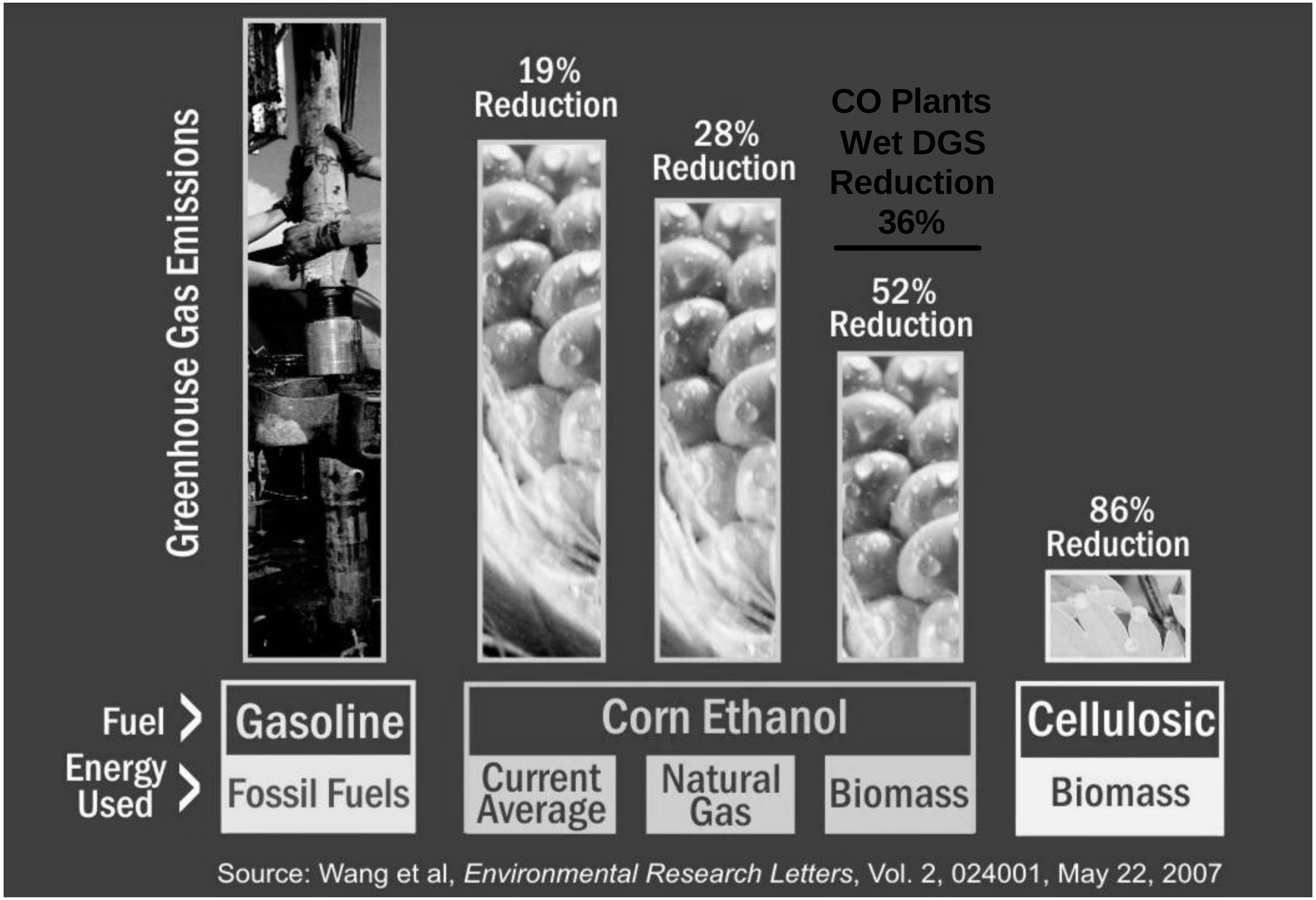
Water Quality

- Current agricultural practices are impacting water quality in the US
  - Example: growth of anoxic zone in Gulf of Mexico

- NREL report (Powers, 2005) has seen that continuous corn production with stover collection for ethanol increases the eutrophication potential by almost a factor of 3 over a corn-soybean rotation with conventional till.

- However that may be reduced by better management of fertilizers.

Relative Emissions Impacts



Greenhouse gas emissions of fuels vary by feedstock and by type of energy used for processing.

Conclusions

• Sustainability is a relative concept: more or less sustainable, nothing sustainable in the absolute sense.

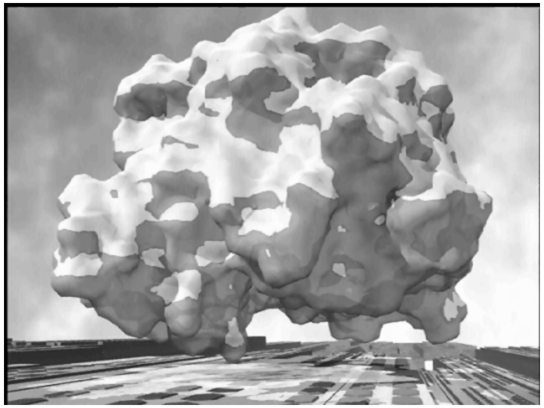
• Corn ethanol is an important step for the US but there are much more sustainable biofuels systems using lignocellulosic biomass

• There are always tradeoffs (ethanol has good air benefits, but water issues exist largely because of current agricultural practices

- Good news: many negative issues are fixable!
- Know where your ethanol comes from and what processes it uses!
- Future trend of sustainability practices (as in wood) possibly certification or good practices recognition

• Must maximize use of land (multiple uses for food, fuel, feed)

• We have the opportunity to do it right, let's do it right!



Information Resources

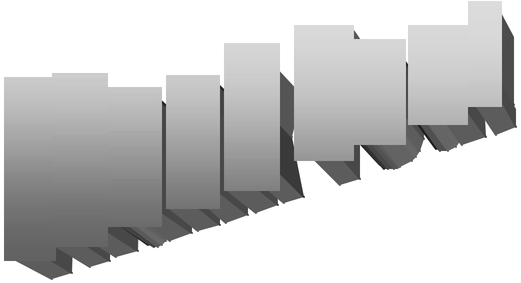
The National Renewable Energy Laboratory:
http://www.nrel.gov

DOE’s Biomass Program:

http://www.eere.energy.gov/biomass/

Alternative Fuels:

http://www.afdc.doe.gov



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