Planning Bioenergy Options: Climate Feedbacks and Information Needs

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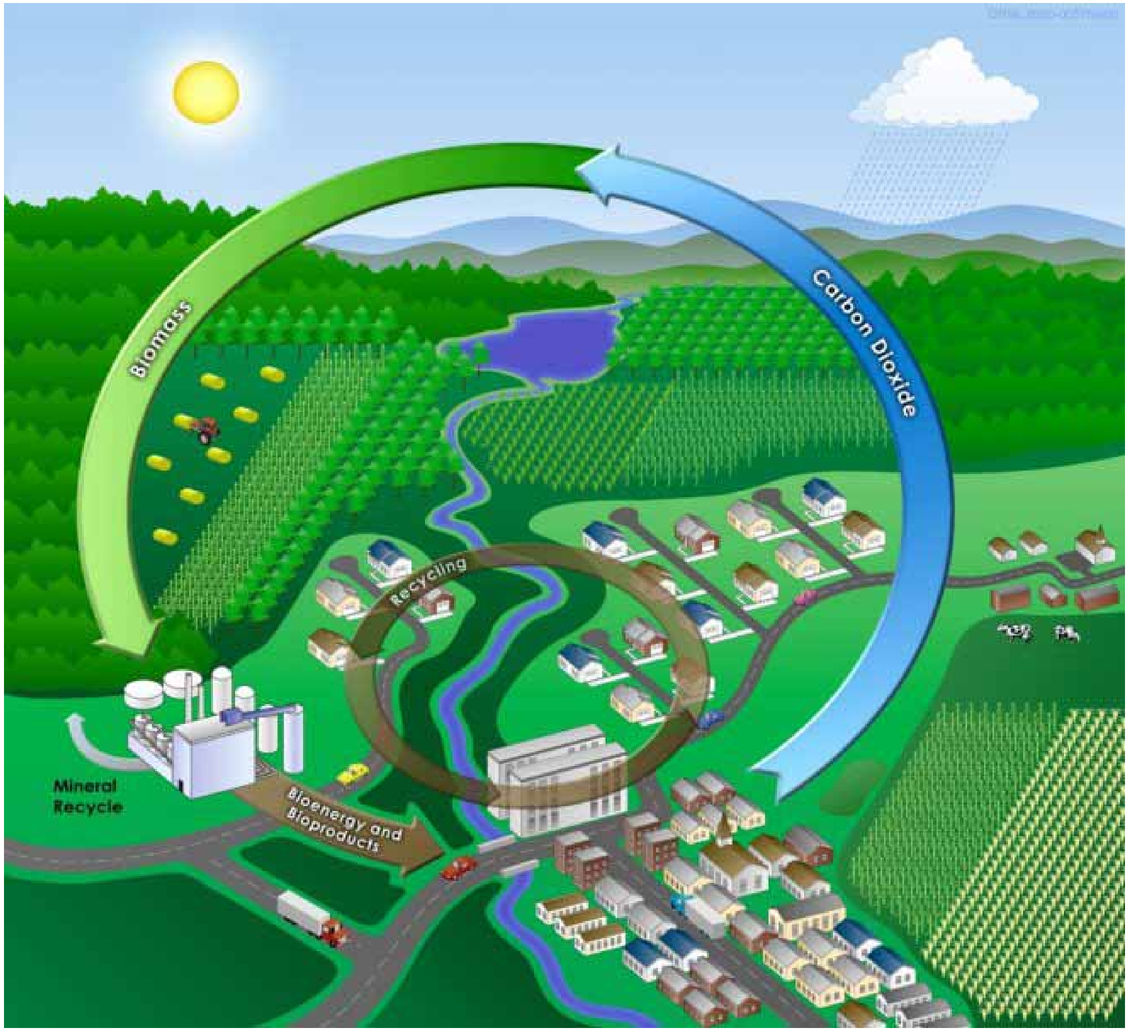
Climate Science in Support of Decision Making

Session 4 Breakout:
Energy Management and Planning: Application of Climate Science

Bioenergy background



Feedstocks

- Forest residue
- Black liquor
- Ag residues
- Grains
  - corn/soybeans/rapeseed
- Urban wastes
  - MSW, wood, cooking grease
- Energy crops
  - grasses
  - trees

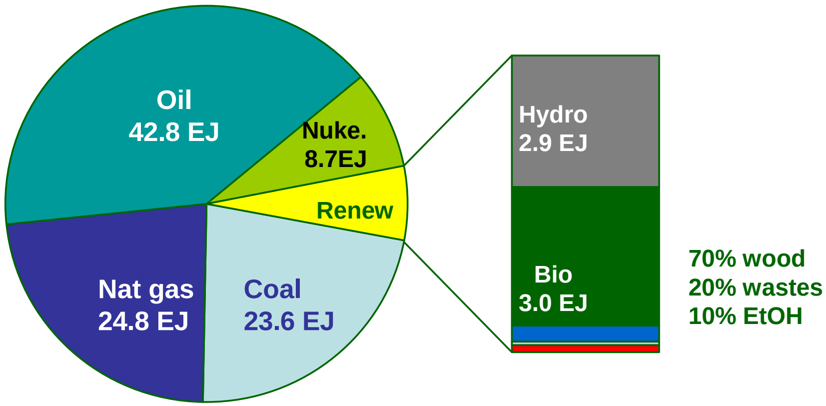
Energy forms

- Heat
- Power
- Fuels
  - ethanol
  - biodiesel
  - hydrogen

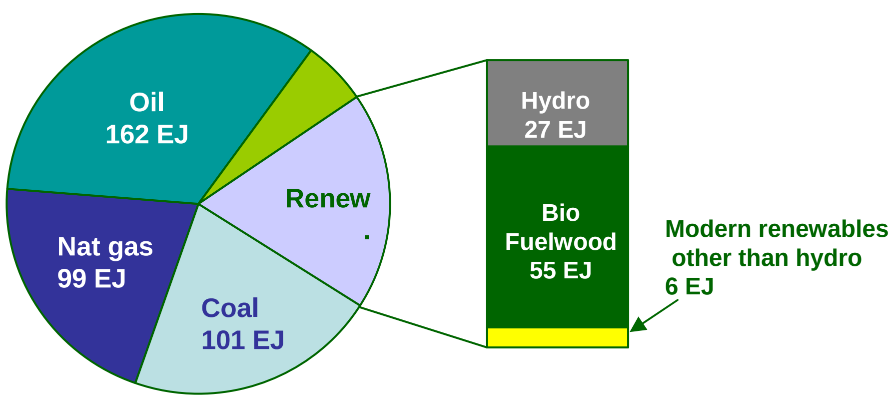
Bioenergy use

Current

2004 US Energy Consumption 105 EJ



2003 World Energy Consumption 470 EJ



Future??

2030 Goal – US Biomass R&D Act of 2000

- 4 EJ power & heat
- 8 EJ fuels
- 28 Tg of bio-based chemicals

World estimates of technical bioenergy potential based on IPCC land–use scenarios *(M. Hoojwijk et al. 2005)*

	2000 all	2050 Biobased	2100 biobased
Electricity (PWh/yr)	**15**	**63-132**	**98-225**
Liquid Fuels (EJ/yr)	**142**	**171-361**	**217-613**

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Bioenergy $\longrightarrow$ Climate

- Reducing GHG emissions by displacing fossil fuels
- Sequestering CO_2 in soils
- Changing land surface albedo ?

Quantifying greenhouse gas benefits from displacing Fossil Fuels

Net bioenergy emissions- net fossil fuel emissions = Benefit

Bioenergy GHG benefit depends on

- Energy type – transport fuel, electricity, heat
- Fossil fuel – coal, natural gas, oil
- Technologies used to create both the fossil and bio-based energy.

Challenging because a single feedstock e.g. maize will be merchandized into many products - EtOH, protein, oil, starch, etc.

Need to take a life cycle approach – e.g., from well to tailpipe or bare field to transmission line.

Comparison done based on appropriate fuel unit- Net emissions/mile driven or kWh or MBtu heat or ha in production.

Controversy over GHG benefits of bioenergy comes from how the system boundaries were drawn to do the analysis

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GHG benefits=f(Source of feedstock)

Table 7

Cradle-to-grave global warming impact associated with the different cropping systems for a 40-year cultivation period (based on 100-year global warming potentials, Unit: Mg CO_2 equivalent ha^{-1})

Includes carbon sequestration

	CS	CC	CC50	CwC70
Agricultural process	23.0	28.1	55.4	[illegible]
Wet milling	79.5	160	158	167
Avoided coproduct systems	1.3	−137	−136	−143
Soybean milling	13.7			
Biodiesel production	6.2			
B20 driving	127			
Avoided B20 driving system	−157			
Corn stover conversion			4.2	6.2
Avoided electricity			−38.1	−56.1
E10 driving	1794	3618	5067	5967
Avoided E10 driving system	−1923	−3877	−5431	−6395
Total	−35.4	−209	−320	−442

Life cycle analysis of GHG using a hectare of land for

-No till corn grain & soybeans production to produce starch-based EtOH * biodiesel

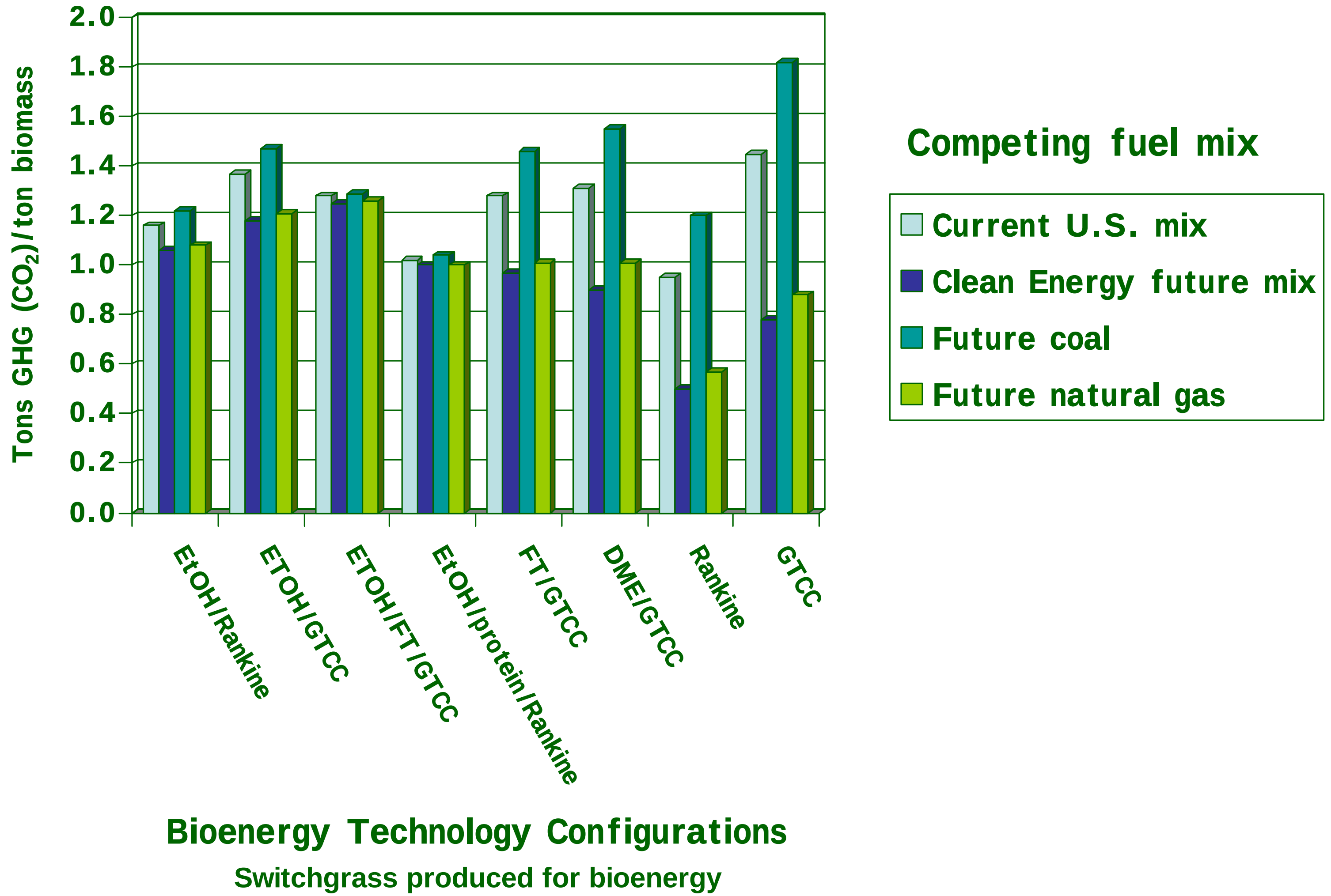
-Continuous no till corn grain production to produce starch-based EtOH

- Continuous no-till corn w/50% stover removal to produce cellulosic & starch-based EtOH

-Continuous no-till corn w/70% stover removal and a winter wheat cover crop to produce cellulosic & starch-based EtOH

Kim & Dale 2005. Life cycle assessment of various cropping systems utilized for producing biofuels:bioethanol & biodiesel. *Biomass and Bioenergy* (in press)

GHG benefits = f(bioenergy technology and competing fossil fuels)



Greene et al. 2004 Growing Energy: How Biofuels can help end America's Oil Dependence. Natural Resource Defense Council

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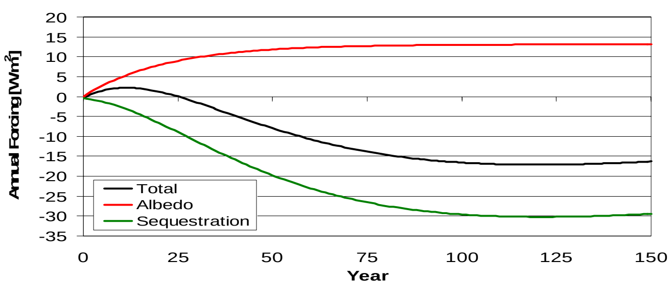
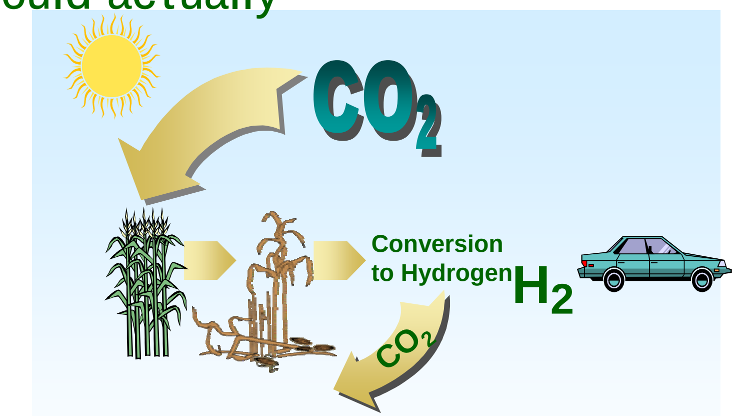
Bioenergy & C sequestration & albedo changes

- Production of biofeedstock can sequester or deplete soil carbon depending on land management (energy crops vs. ag residue removal)
- Bioenergy linked to geologic sequestration could actually reduce atmospheric CO_2 concentrations
  - Power/heat production
  - H_2 production
- Decrease in albedo if woody energy crop replaces herbaceous cover in a region with snow cover.



West & Marland 2005 personal communication



and sequester the CO_2

Climate ⟶ Bioenergy?

- EJ Bioenergy is function of
  - Plant productivity/yield (Mg/ha/yr)
    - Magnitude
    - Temporal variation
  - Land availability (ha)
    - Demand for food & feed
    - Demand for fiber
    - Demand for conservation/biodiversity
  - Demand for energy
  - ~~Conversion efficiency (EJ/Tg)~~

Obvious Climate impacts but not so easy to quantify

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What do we think we know about climate impacts?

- Yield- Applicable to energy crops and ag residues
  - Expected to go up in most of N. America due to CO_2 and technology
  - Yield will go down in some places largely due to drought (e.g. Subsaharan Africa)
  - Secondary impacts on productivity (disease & pests) are largely unknown but expected to be negative
  - Assume energy crop yields will increase like historic ag crop yields have increased (1-1.5%/yr) due to technology
  - C_4 plants will respond less to CO_2 increase
  - Yield variability may increase with increasing climate variability

- Land area available for energy crops
  - Most bioenergy potential studies don't factor in land-use competition (Hoogwijk et al. 2003)
  - Complex as it's a function of climate change, population, food crop yields, technology assumptions
  - Will increase in temperate latitudes; decrease in tropical

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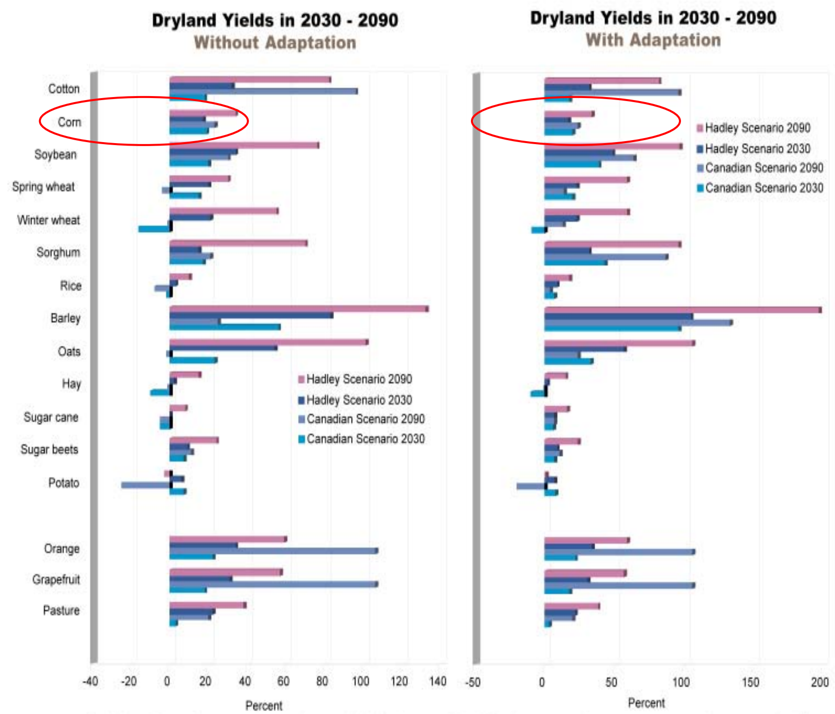
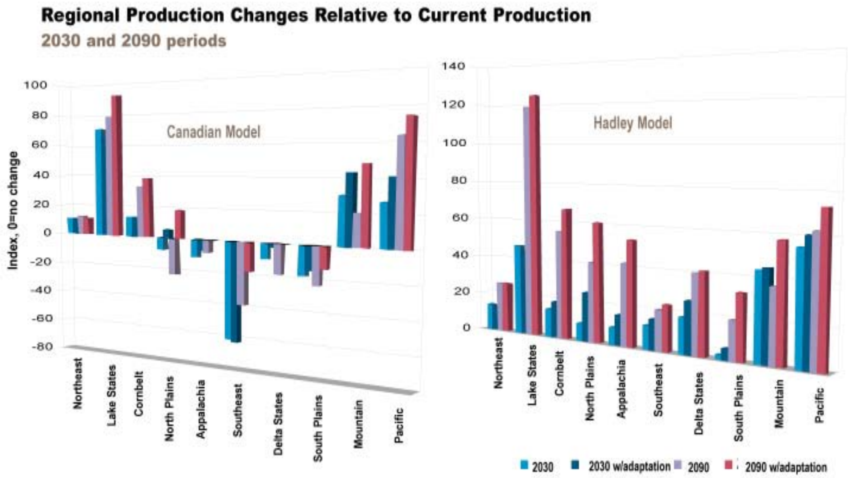
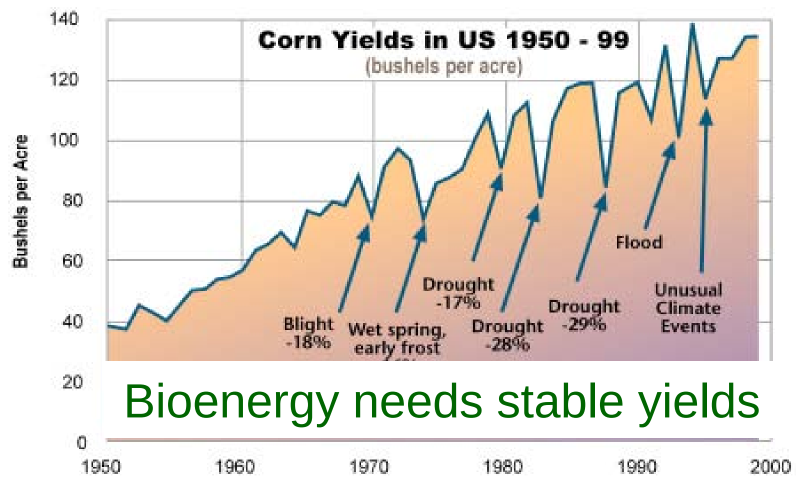
Direct Climate change effects on Ag Yield – U.S.



Model simulations of average changes in crop yields for 16 crops. The yield changes are given as percentages and represent the differences between current yields and those projected for two time periods, 2030 and 2090. Two scenarios of future climate, the Canadian and Hadley, were used. The results consider physiological responses of the crops to climate under either dryland or irrigated cultivation. They also consider either "no adaptation" or "adaptation" responses by producers to climate change. Adaptations included changes in planting dates and crop varieties. Only 11 of the 16 crops were actually modeled: cotton, wheat (winter and summer), corn, hay, potato, orange, soybean, sorghum, rice, pasture grass. Results for the other crops are based on extrapolations from the modeled crops.





Bioenergy needs stable yields

Climate Change Impacts in the United States *the Potential Consequences of climate Variability and Change*
By the National Assessment Synthesis Team, US Global Change Research Program
Published in 2000

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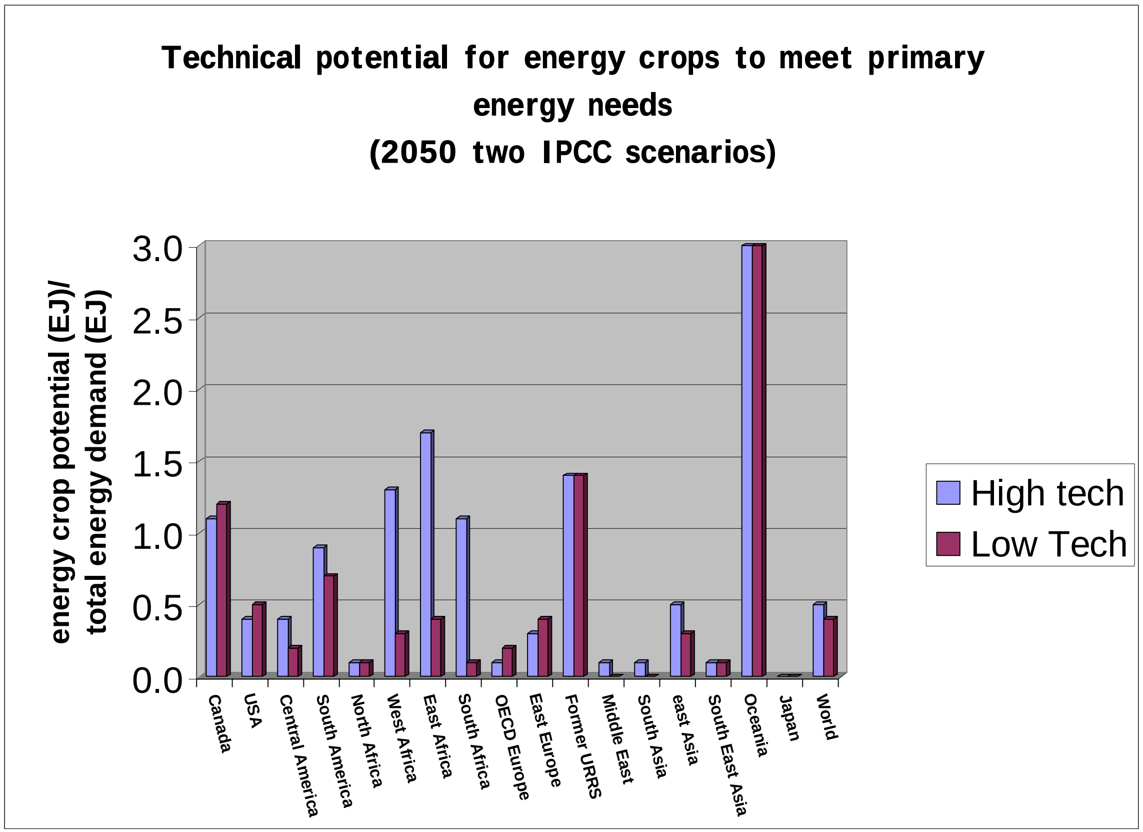
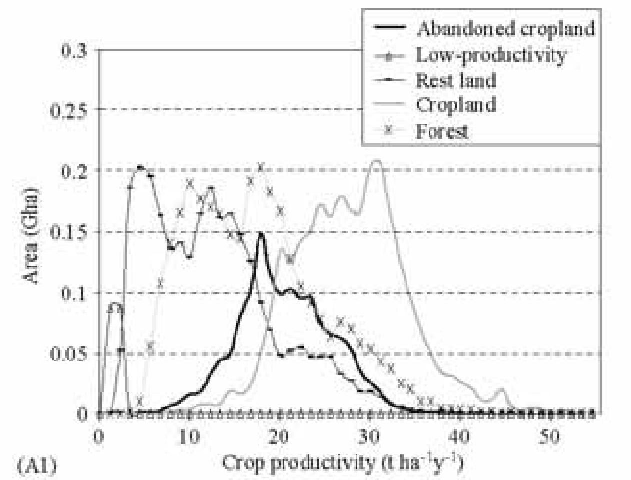
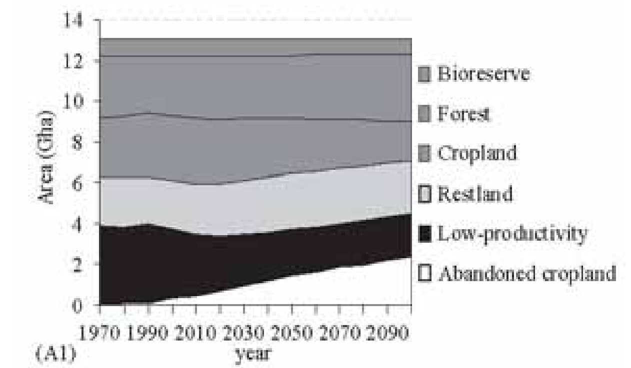
Planning Bio-energy Options-Information needs







Hoogwijk et al. 2005 Potential of biomass energy out to 2100, for four IPCC SRES land-use scenarios. Biomass and Bioenergy, 29:225-257

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Relevant CCSP research

- Ecosystems – (Yield)
  - Potential consequences of global change for ecological systems – productivity, disturbance
- Land use/Land-cover Change (Land availability)
  - Drivers of land-use and land-cover (LULC) change
  - Future patterns of LULC
- Human Contributions and Responses to Environmental change (Demand)
  - Changes in energy demand
  - Changes in diet and fiber demand
  - Changes in population and location of population
  - Technology adoption

And of course predicting climate

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