How Feasible Are Dreams of Biofuels?

Opinions and analysis with a view toward GHGs

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Sources of Support

USDA DOE
USEPA
CSiTE

Aspects of the question

- Will the dream persist -- market forces
- Will the dream persist – GHG forces
- Will the dream persist – modeling & analysis
- Will the dream persist – some results

An Aside

From a GHG perspective

Biofuels ≠ Ethanol

Particularly corn or sugar ethanol

GHG offset = a1 * crop ethanol
+ a2 * cell ethanol
+ a3 * biodiesel
+ a4 * bio fueled electricity

Will the dream persist ?

Market Forces

We have seen the dream before

Biofuels were a major dream in late 70’s and early 80’s

Biofuels have been known to society throughout history

Biofuels were reality pre 1900

Their usage has diminished over the long run (we used a lot of wood in early 1900’s) and has not greatly increased in the last few years particularly in unsubsidized forms

This is largely due to the availability of cheap fossil fuels.

For biofuels to serve significant role as GHG offset or energy security enhancement or cost reduction then forces will have to arise that will make them competitive.

What will make Biofuels economic

Rising energy prices due to

- **Scarcity and demand growth**
- **Increased cost of fossil fuel production**
- **Energy Security**
- **Trade disruption**

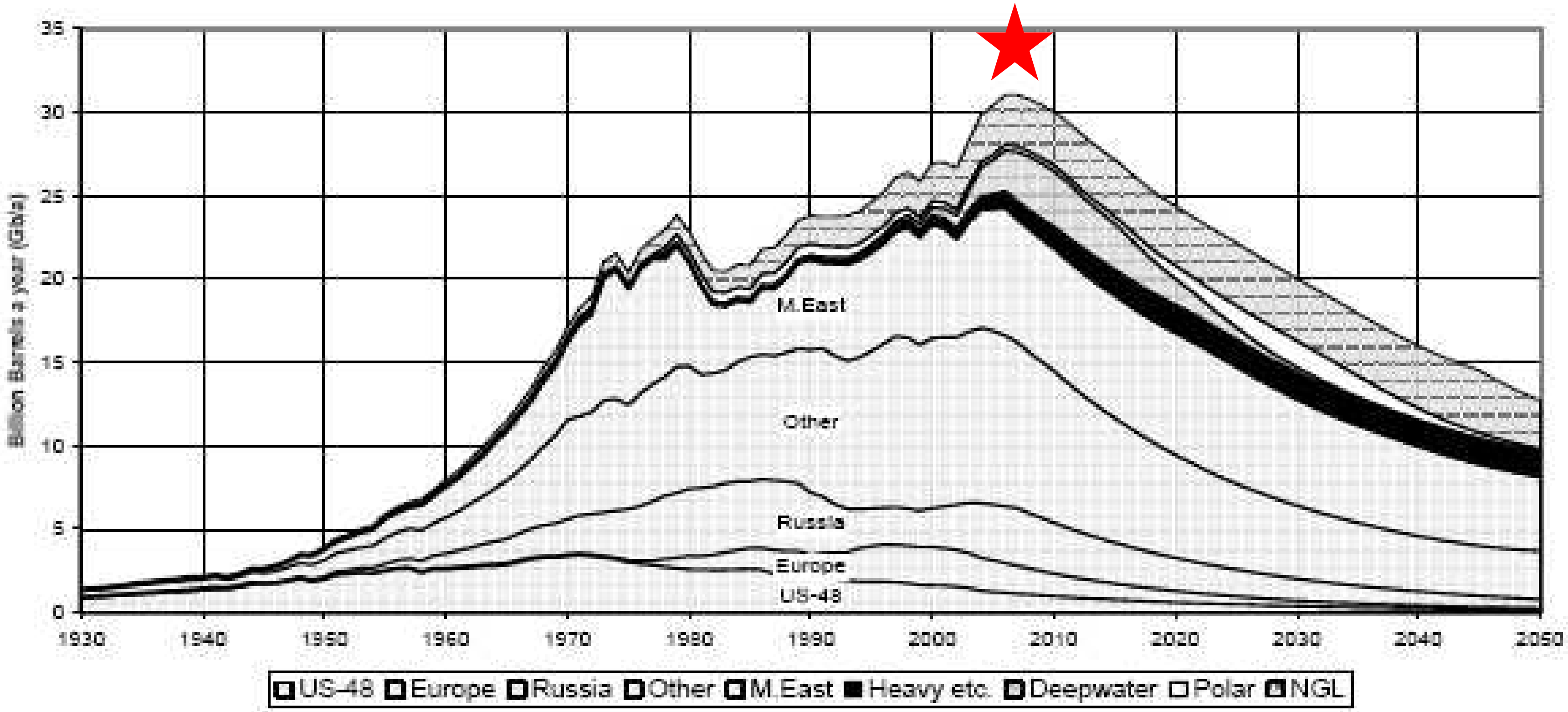
Privately realized value placed on GHG offset

Lower costs of delivered feedstock - higher crop yields, better prod. practices, cheaper hauling

Improved energy recovery efficiency

Subsidies

Scarcity and Fossil Fuel Cost

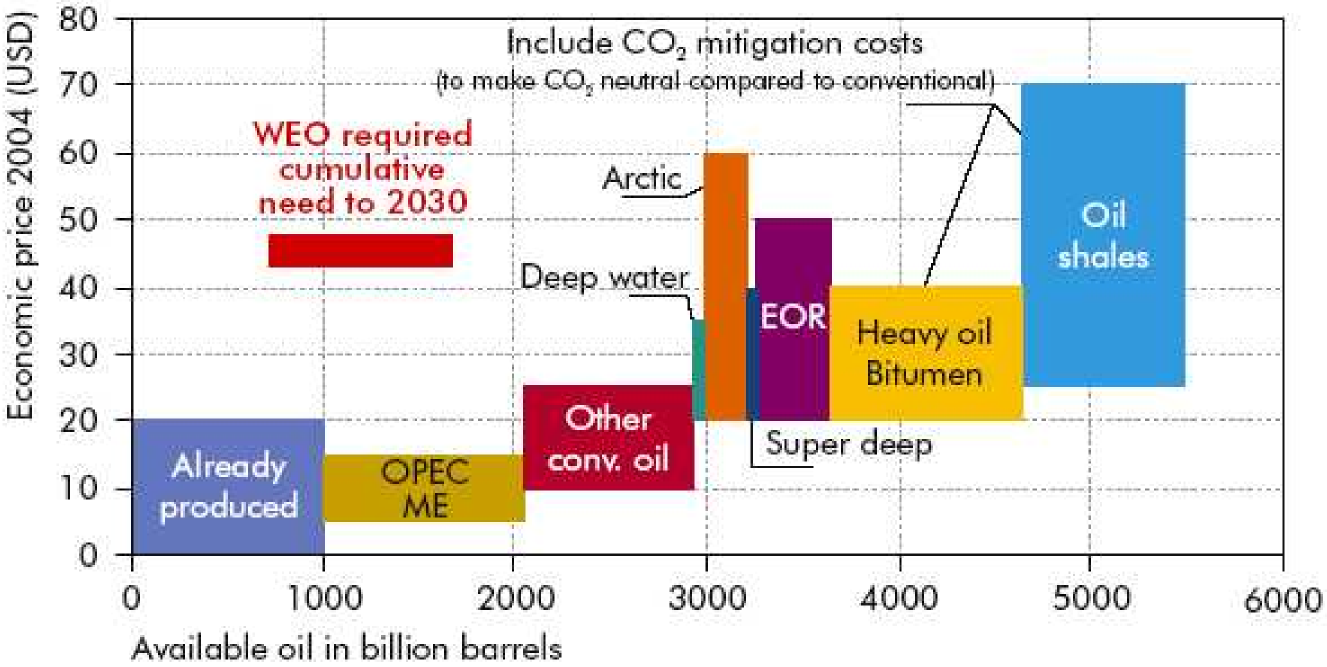


Graph of Oil Production
Source: Colin Campbell of the Association for the Study of Peak Oil and Gas (ASPO) Newsletter as in Wikapedia http://en.wikipedia.org/wiki/Peak_oil

Global Conventional Oil Production May Peak Soon
US has as has Texas

Scarcity and Fossil Fuel Cost

Figure ES.1 • *Oil cost curve, including technological progress: availability of oil resources as a function of economic price*



The x axis represents cumulative accessible oil. The y axis represents the price at which each type of resource becomes economical.

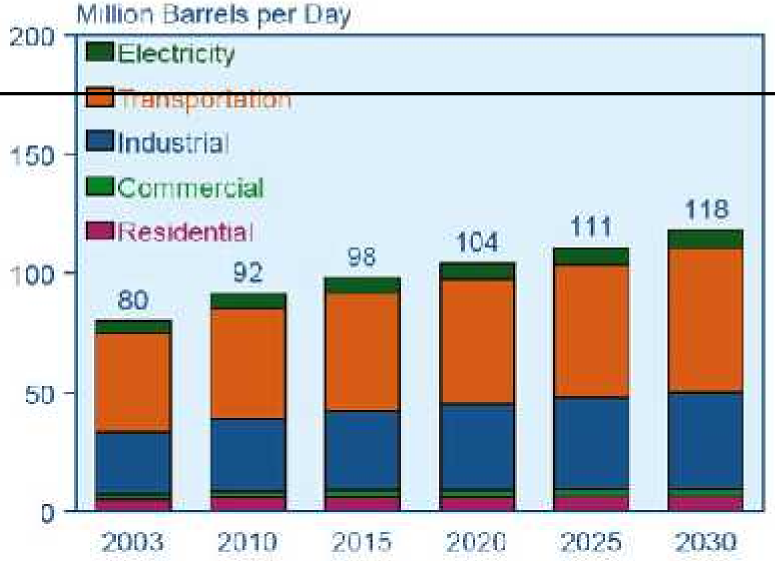
Source: IEA.

Lots of Oil But recovery cost will increase

Source: International Energy Agency Resources to Reserves Report
http://www.iea.org/Textbase/npsum/oil_gasSUM.pdf

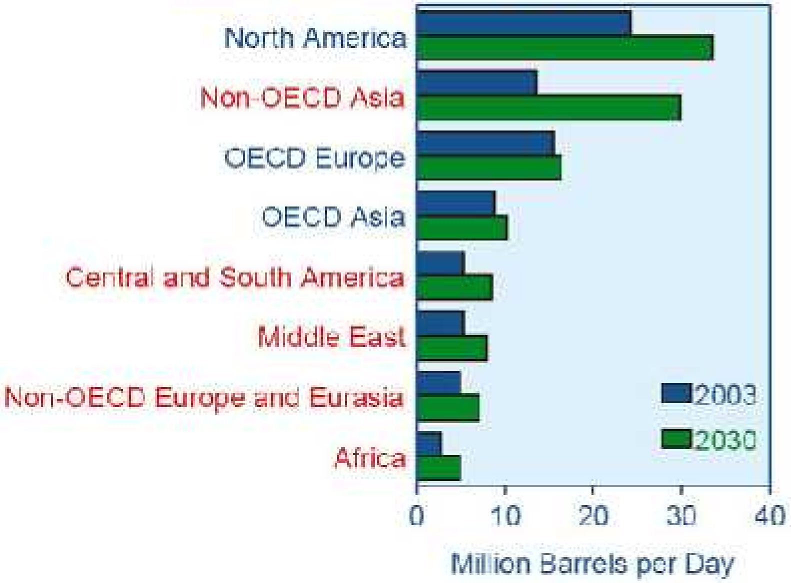
Consumption - Global

Figure 26. World Oil Consumption by Sector, 2003-2030



Sources: **2003:** Derived from Energy Information Administration (EIA), *International Energy Annual 2003* (May-July 2005), web site www.eia.doe.gov/iea/. **Projections:** EIA, System for the Analysis of Global Energy Markets (2006).

Figure 27. World Oil Consumption by Region and Country Group, 2003 and 2030

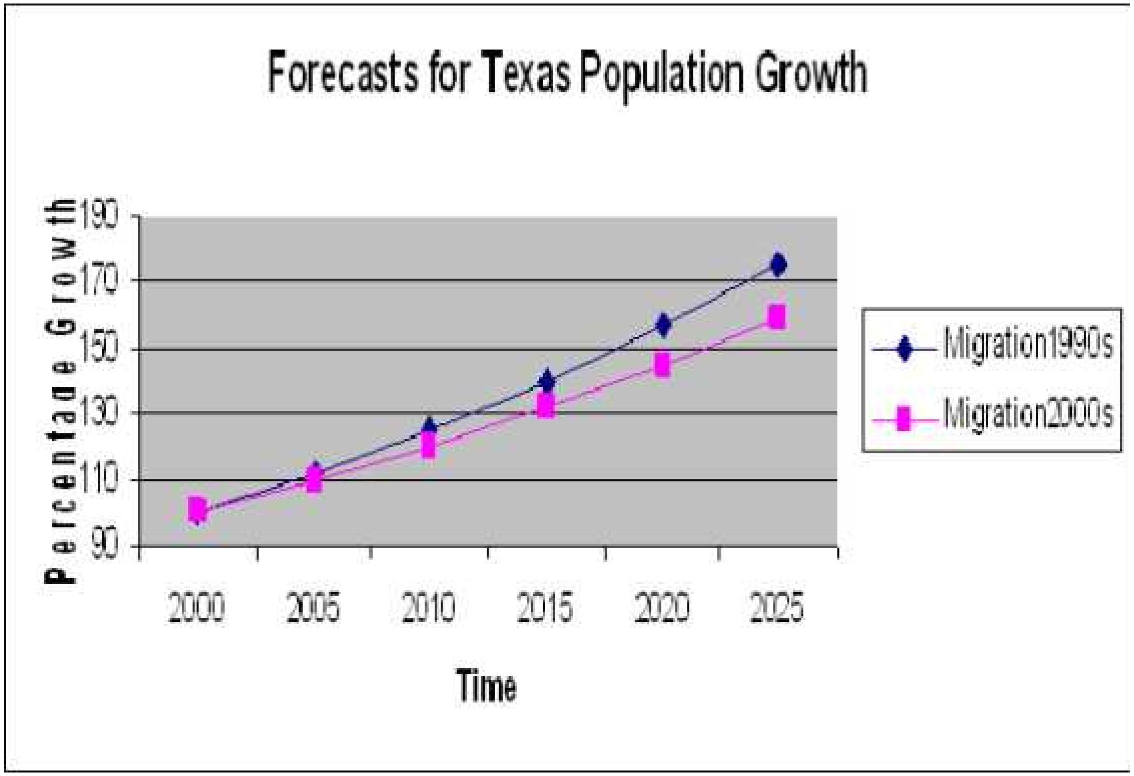


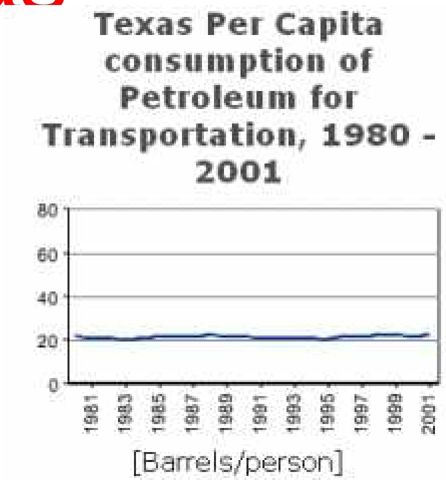
Sources: **2003:** Energy Information Administration (EIA), *International Energy Annual 2003* (May-July 2005), web site www.eia.doe.gov/iea/. **2030:** EIA, System for the Analysis of Global Energy Markets (2006).

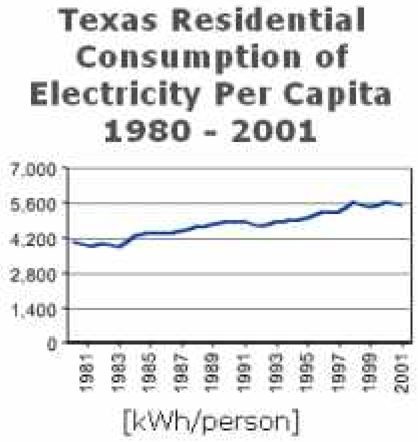
Source USDOE, Energy Information Agency, International Energy Outlook 2006 Report #:DOE/EIA-0484(2006)
Release Date: June 2006 , http://www.eia.doe.gov/oiaf/ieo/oil.html

Large oil demand growth especially in US and Asia – China and India

Consumption - Texas





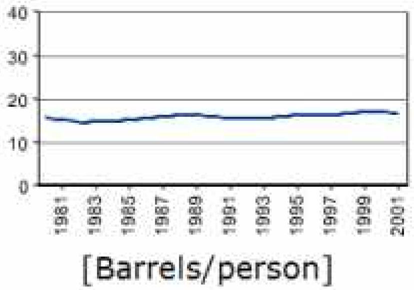


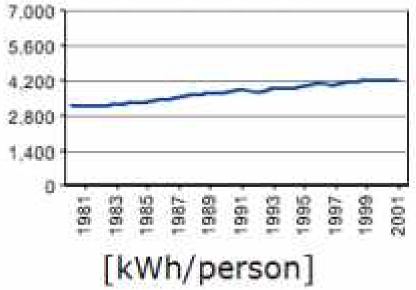
Source: Texas State Demographer
http://txsdc.utsa.edu/tpepp/2006projections/

Source: USDOE Texas Energy Consumption
http://www.eere.energy.gov/states/state_specific_statistics.cfm/state=TX#consumption

60-80% growth in 20 years
Liquid fuel rises at rate of population, electricity faster
Large electricity and oil demand growth

Consumption - US


Per Capita consumption of Petroleum for Transportation, 1980 - 2001


Residential Consumption of Electricity Per Capita 1980 - 2001

Source
http://www.eere.energy.gov/states/us_energy_statistics.cfm

Population

2000 282,125,000 people

2030 362,584,000 people

Source: US Census projections
http://www.census.gov/ipc/www/usinterimproj/natprojtab01a.xls

22% growth in 30 years
Liquid fuel rises almost at rate of population, electricity faster
Large electricity and oil demand growth

Energy Economics Conclusion

Growing scarcity of conventional oil

Alternative sources possible at higher cost
= Higher cost future supply

Growing demand for Energy

(electricity and liquid fuels)

Global, US and Texas
= Higher future demand

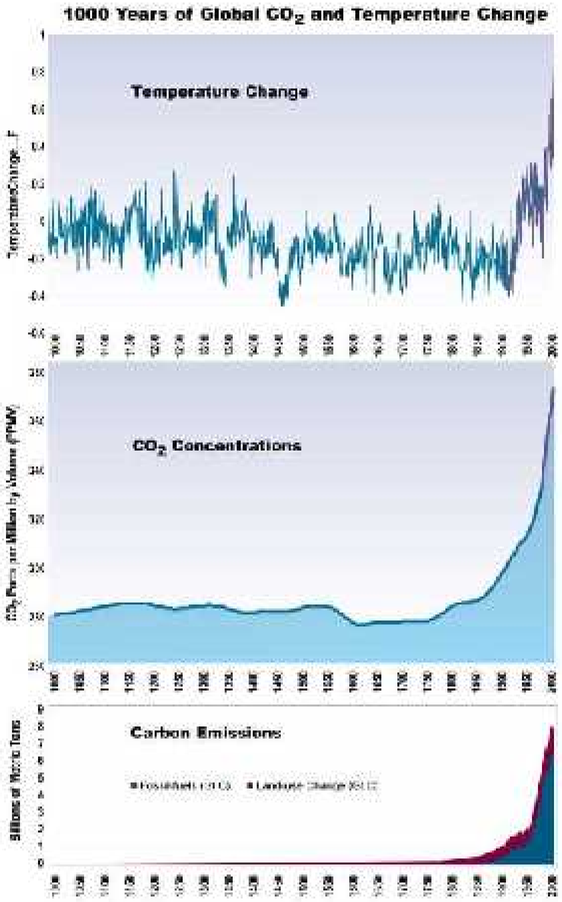
Collectively implies

Higher demand for alternative energy
Likely brighter future for Renewables and biofuels

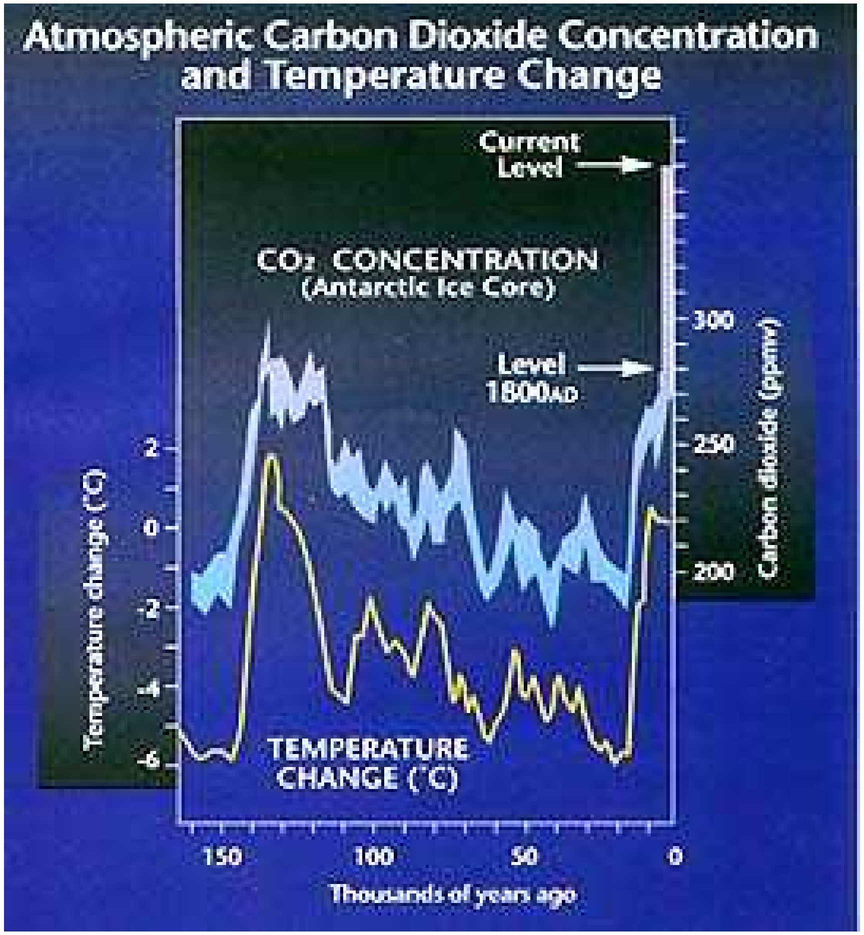
Will the dream persist ?

GHG Forces

Greenhouse Gasses



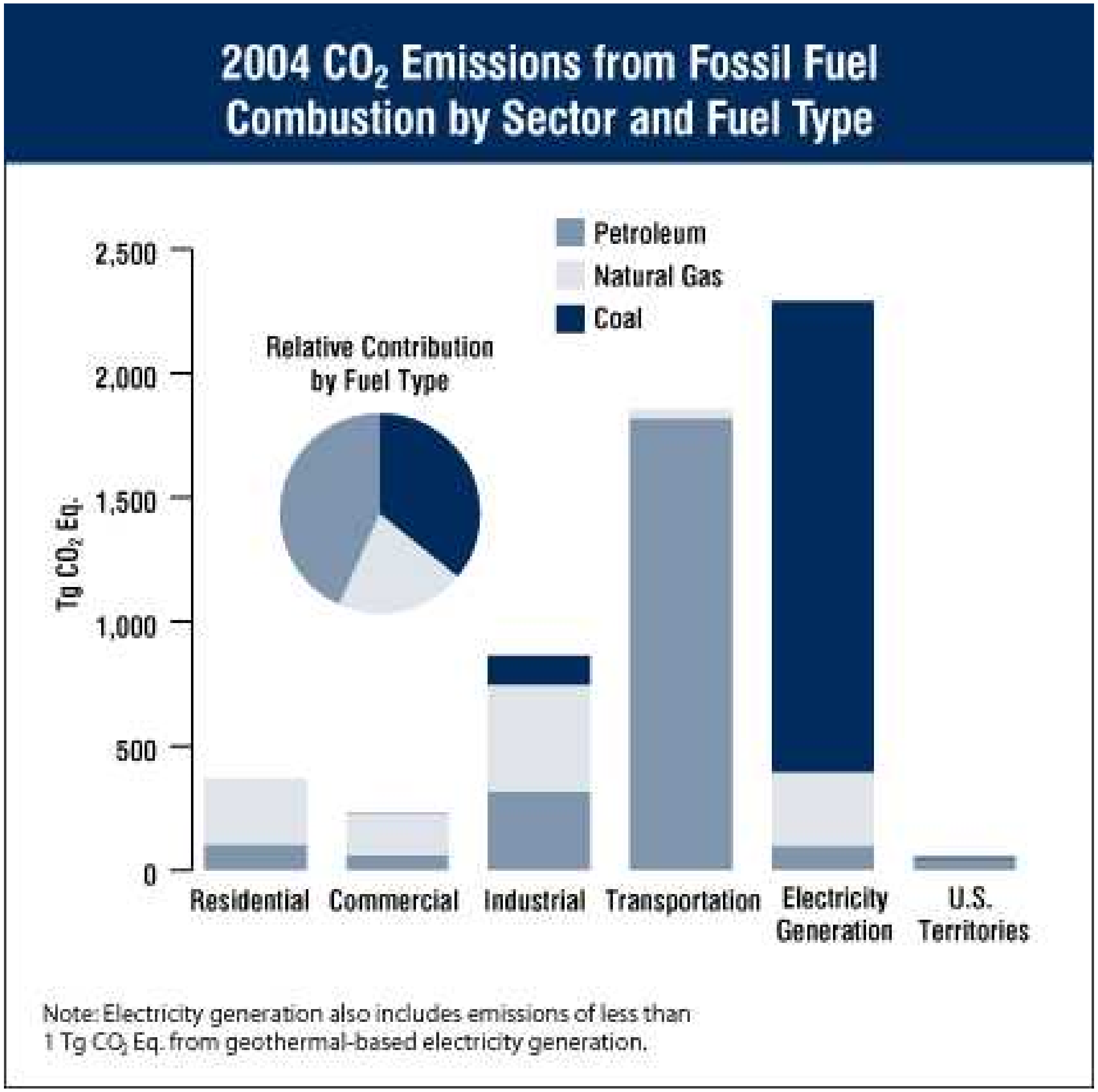
Source : U.S. National Assessment



Source http://ssca.usask.ca/2002conference/Bennett.htm

Carbon Dioxide highly associated with climate change
Policy around world working to limit emissions

Greenhouse Gasses



2004 CO_2 Emissions from Fossil Fuel Combustion by Sector and Fuel Type

Note: Electricity generation also includes emissions of less than 1 Tg CO_2 Eq. from geothermal-based electricity generation.

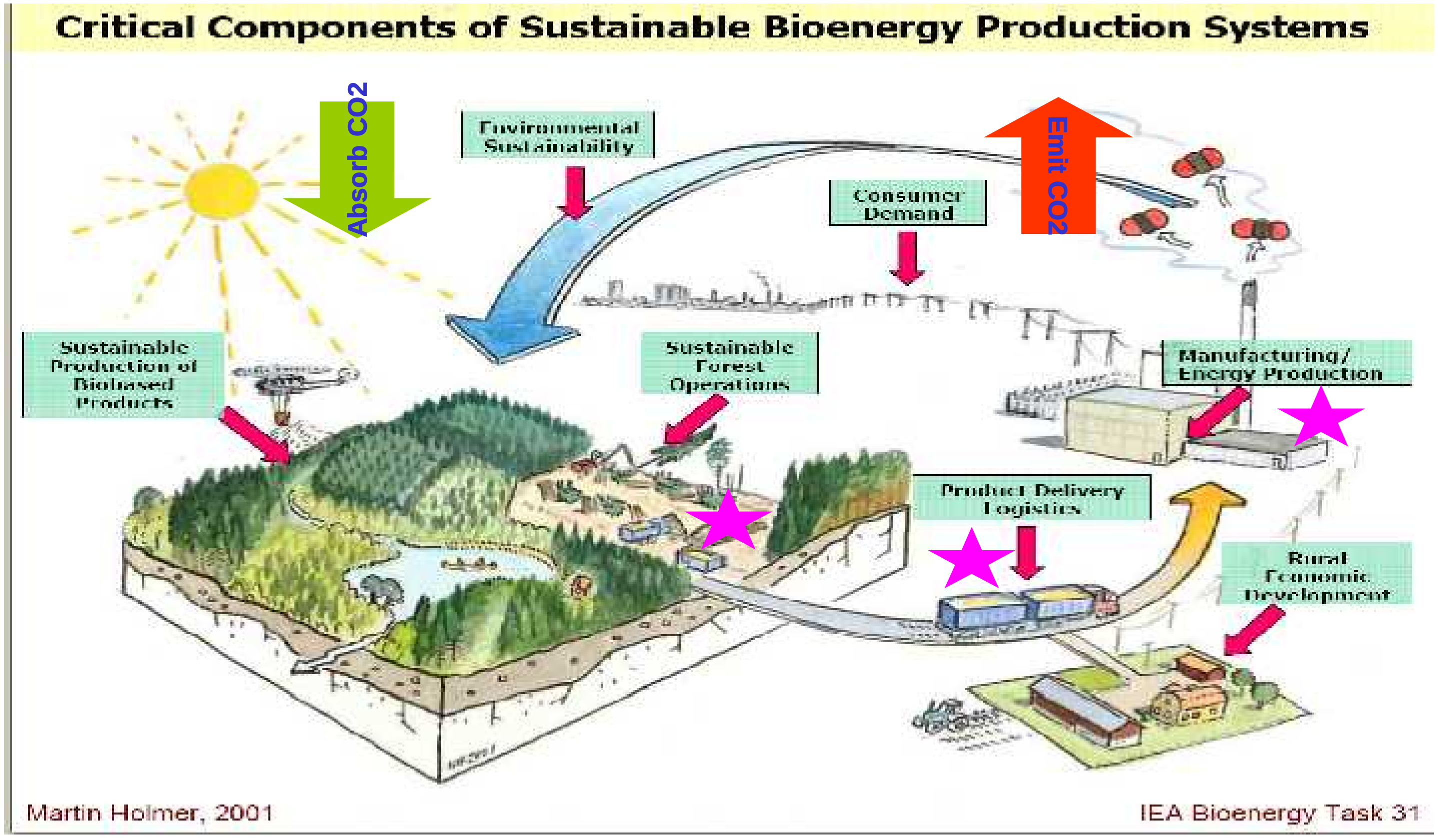
Source : EPA 2006 Inventory

More coal fire plants in progress of being built than there are on the planet – demand driven

How fast will emissions explode?

GHG emissions reduction could be major force and biofuels displace them

Greenhouse Gasses and Biofuels



Please Pretend the growing stuff includes crops

Feedstocks take up CO2 when they grow

CO2 emitted when feedstocks burned or when energy product derivatives burned

But Starred areas also emit

Source of underlying graphic: Smith, C.T. , L. Biles, D. Cassidy, C.D. Foster, J. Gan, W.G. Hubbard, B.D. Jackson, C. Mayfield and H.M. Rauscher, "Knowledge Products to Inform Rural Communities about Sustainable Forestry for Bioenergy and Biobased Products", IUFRO Conference on *Transfer of Forest Science Knowledge and Technology,* Troutdale, Oregon, 10-13 May 2005

Offset Rates - Lifecycle Analysis

Net Carbon Emission Reduction (%)

Bio feedstock	Ethanol	Electricity	Biodiesel
Corn	43		11
Soybeans			96
Sorghum	45		
Barley	43		
Oats	39		
Rice	12		
Soft White Wheat	42		
Hard Red Winter Wheat	41		
Durham Wheat	39		
Hard Red Spring Wheat	42		
Sugar	28		
Switchgrass	81	87	
Hybrid Poplar	72	89	
Willow	74	94	
Softwood Log Residue	68	91	
Hardwood Log Residue	69	91	
Bagasse	86	95	
Corn Residue	84	91	
Wheat Residue	79	88	
Sorghum Residue	73	76	
Barley Residue	56	64	
Rice Residue	55	62	
Softwood Mill Residue	76	95	
Hardwood Mill Residue	76	95	
Manure		91	

Electricity offsets higher when co-fired due to Efficiency and less hauling

Ethanol offsets are in comparison to gasoline

Power plants offsets are in comparison to coal.

Opportunities have different potentials

Will the dream persist ?

Modeling Approach

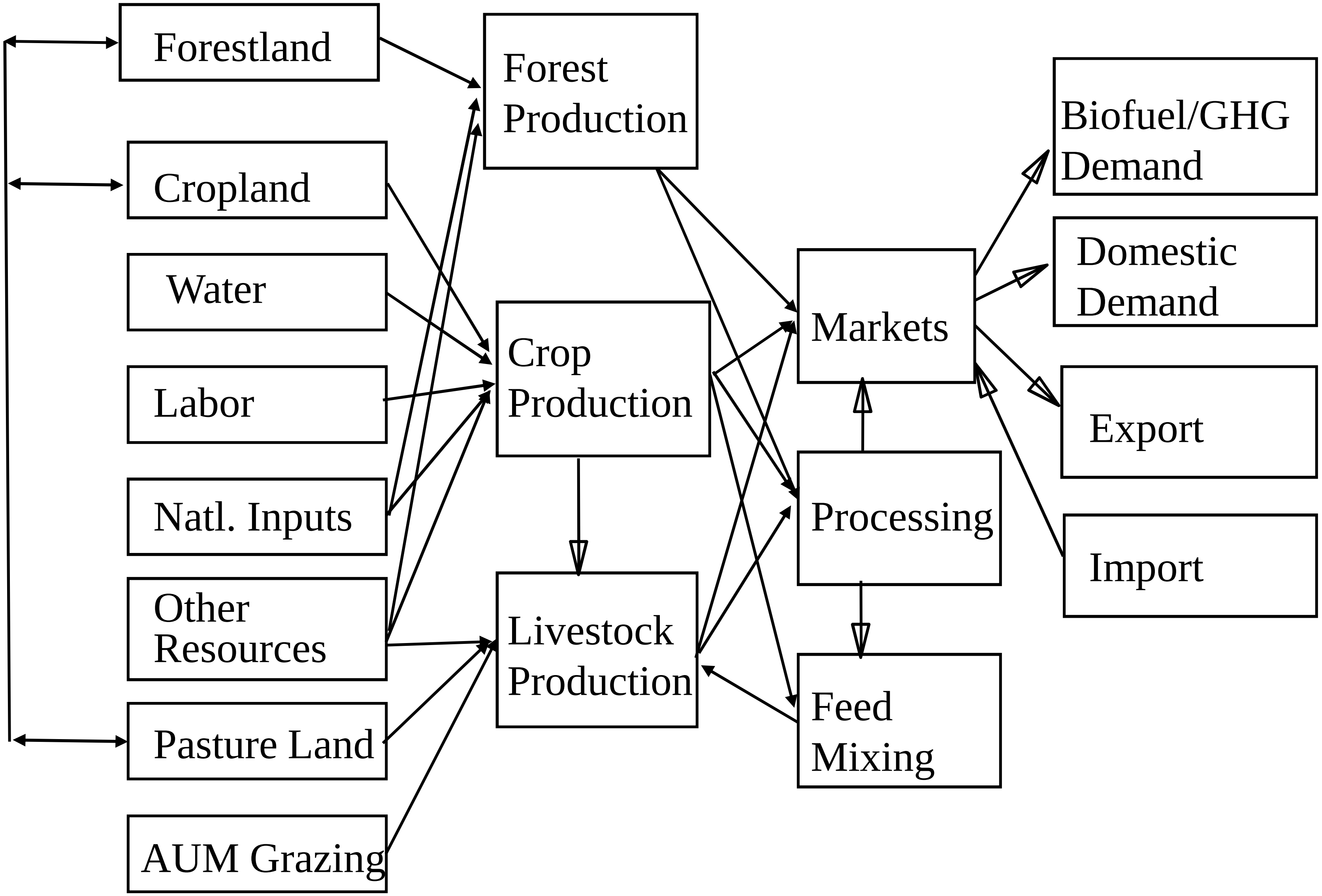
McCarl Project Goals

- **Examine the portfolio of land based biofuel possibilities**
- **Bring in a full cost and GHG accounting**
- **Look at motivations for their use in terms of energy prices, and GHG mitigation strategies**
- **Look comparatively across many possibilities including Afforestation, Forest mgt, Biofuels, Ag soil, Animals, Fertilization, Rice, Grassland expansion, Manure, Crop mix**
- **Look at market, energy price, time and technology conditions under which strategies dominate**
- **Look at market effects and co benefits/ costs**

Constrained Optimization Problem

- Objective Function: Maximize NPV of sum of producers’ and consumers’ surpluses
  - Across Ag and Forest sectors
  - Over time (70 yrs)
  - Including GHG payments
- Constraints
  - Total Production = Total Consumption
  - Tech Input/output relationships hold
  - Land use balances

Basic Modeling


Forestland

Cropland

Water

Labor

Natl. Inputs

Other Resources

Pasture Land

AUM Grazing

Forest Production

Crop Production

Livestock Production

Markets

Processing

Feed Mixing

Biofuel/GHG Demand

Domestic Demand

Export

Import

Condensed Tableau of MP Model

CARBON

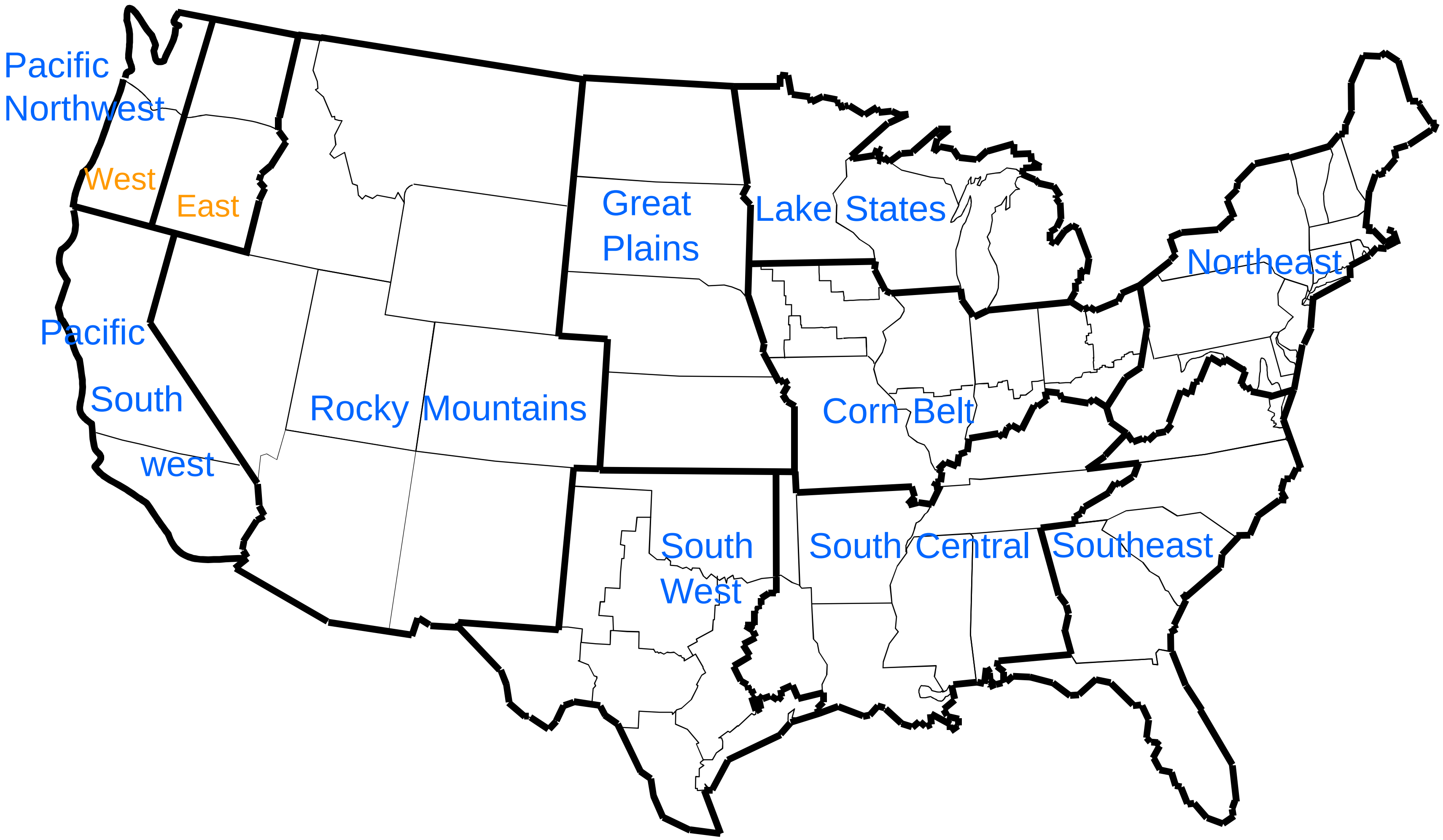
	FOREST CONSUMPTION	FOREST PRODUCTION	LAND FROM FOREST TO AG	LAND FROM AG TO FOREST	AG PRODUCTION	AG CONSUMPTION	AG INPUT SUPPLY	GHG INCENTIVE	
OBJECTIVE – NPV VALUE MAX	+INTEGRAL UNDER DEMAND	-COST	-TRANSFORM COST		- COST	+INTEGRAL UNDER DEMAND	- COST	+PRICE	
FOREST HARVEST	+1	- PRODUCTION							≤ 0
FOREST LAND BALANCE		+1	-1	+1					≤ FL
AG OUTPUT					+PRODUCTION	+1			≤ 0
AG LAND BALANCE			+1	-1	+1				≤ AL
AG INPUTS					+USE		-W		≤ AV
AG > FOR LAND MAX			+1	-1					≤ AFMAX
FOR > AG LAND MAX			-1	+1					≤ FAMAX
CARBON AND OTHER GHG		Δ GHG IN FOREST			Δ GHG IN AG			+1	≤ 0

FOREST SECTOR

LAND TRANSFER

AGRICULTURE SECTOR

FASOM Agricultural Regions



FASOMGHG Temporal Dimensions

- 70-100 year horizon
- Five year time step
- Dynamically optimal: agents forward-looking
- Biophysical data from USDA RPA assessment:
- Captures non-linear, time-dependent processes of:
  - Soil carbon accumulation,
  - Forest growth
  - CO2 releases through forest product decay
  - Ag CO2 in soils
  - Bio fuel offsets and market penetration
  - Emission offsets

Forest products

SWSAWTLOGWOODS
HWSAWTLOGWOODS
SWSAWTLOGMILL
HWSAWTLOGMILL

SWPULPLOGWOODS
HWPULPLOGWOODS
SWPULPLOGMILL
HWPULPLOGMILL

SWFUELLOGWOODS
HWFUELLOGWOODS
SWFUELLOGMILL
HWFUELLOGMILL

SLUM
HLUM
OSB

SPLY
HPLY
SRESIDUES

SWMISC
HWMISC
HRESIDUES

SPWOOD
SWPULP
OLDNEWSPAPERS
PULPSUBSTITUTE
UNCFREESHEET
CGROUNDWOOD
KRAFTPKG
SBLBOARD
DISPULP
RECMPULP
SWLOGRES

HPWOOD
AGRIFIBERLONG
OLDCORRUGATED
HIGDEINKING
CFREESHEET
TISSUE
LINERBOARD
RECBOARD
SWKMPULP
CTMPMPULP
HWLOGRES

HWPULP
AGRIFIBERSHORT
WASTEPAPER
NEWSPRINT
UNCGROUNDWOOD
SPECIALTYPKG
CORRUGMED
CONSTPAPER
HWKMPULP

Ag Primary Commodities

Cotton
SOFT
Rice
Silage
Sugarbeet
Orangeproc
HybrPoplar
SorgRes
BarleyRes
Corn
HRWW
Oats
Hay
Tomatofrsh
Grpfrtfrsh
Willow
RiceRes
Soybeans
DURW
Barley
Alfalfa
Tomatoproc
Grpfrtproc
BioManure
WheatRes
Sorghum
HRSW
Potatoes
Sugarcane
Orangefrsh
SwitchGras
Cornres
OatsRes

Sheep
HogFarrow
StockSCav
VealCalf
Beefcows
CowCalf
FeedPig
StockHCav
Turkeys
BeefFeed
PigFinish
StockSYea
Broilers
Dairy
OthLvstk
StockHYea
Eggs

Ag Secondary Commodities

OrangeJuic	GrpfrtJuic	SoybeanMeal	SoybeanOil
HFCS	Beverages	Confection	Baking
Canning	RefSugar	GlutenMeal	GlutenFeed
DDG	CornStarch	CornOil	CornSyrup
Dextrose	FrozenPot	DriedPot	ChipPot
FedBeef	NonFedBeef	Pork	Chicken
Turkey	WoolClean	FluidMilkwhol	FluidMilkLowFat
SkimMilk	Cream	EvapCondM	NonFatDryM
Butter	AmCheese	OtCheese	CottageChe
IceCream	**Bagasse**	**Lignin**	LigninHardwood
LigninSoftwd	**EdTallow**	**NonEdTallow**	**YellowGrease**
CropEthanol	CellEthanol	Biodiesel	BiodieselWO
MktGasBlend	SubGasBlend	Tbtus	

Bio feedstocks into Energy

Bio feedstocks can be direct inputs into power plants to substitute for coal

They also can be used to produce liquid fuels such as ethanol and biodiesel

For Example

- **Energy crops, crop residues, manure and trees can fire or co-fire power plants**
- **Ethanol can be made from the cellulosic content of energy crops, residues and trees**
- **Grains and sugar can be processed into ethanol**
- **Fats and oils can be made into biodiesel**

GHG Commodities

Forest_SoilSequest
Forest_AfforestSoilSequest
Forest_LitterUnder
Forest_AfforestLitterUnder
Forest_ContinueTree
Forest_AfforestTree

Forest_USpvtProduct
Forest_USExport
Forest_USFuelResidue
Forest_USpubProduct
Forest_USImport
Forest_USresidProduct
Forest_CANProduct
Forest_USFuelWood
Forest_CANresidProduct

Carbon_For_Fuel

Dev_Land

AgSoil_CropSequest
AgSoil_PastureSequest

Carbon_AgFuel
Carbon_Pest
Methane_Liquidmanagement
Methane_RiceCult
NitrousOxide_Manure
NitrousOxide_Nfixing
NitrousOxide_Volat
Carbon_Dryg
Carbon_Irrg
Methane_Manure
Methane_AgResid_Burn
NitrousOxide_Fert
NitrousOxide_CropResid
NitrousOxide_Leach
Carbon_Fert
Methane_EntericFerment
NitrousOxide_Sludge
NitrousOxide_Histosoil
NitrousOx_AgResid_Burn

Carbon_Ethl
Carbon_Biodiesel
Methane_Biodiesel
Carbon_CEth
Methane_BioElec
Methane_Ethl
Carbon_BioElec
Methane_CEth

NitrousOxide_BioElec
NitrousOxide_CEth
NitrousOxide_Biodiesel
NitrousOxide_Ethl

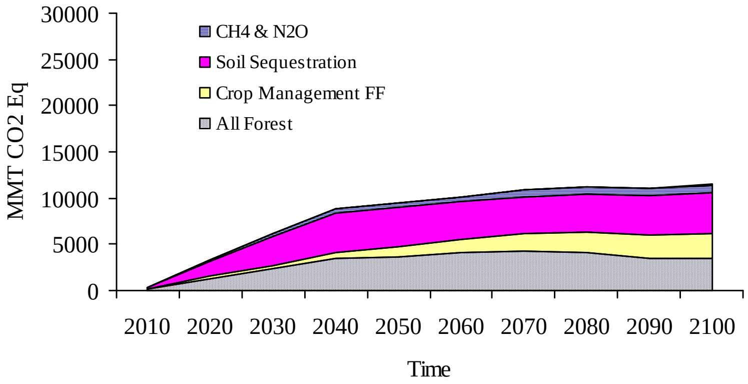
FASOMGHG Mitigation Options

Strategy	Basic Nature	CO2	CH4	N2O
Crop Mix Alteration	Emis, Seq	X		X
Crop Fertilization Alteration	Emis, Seq	X		X
Crop Input Alteration	Emission	X		X
Crop Tillage Alteration	Emission	X		X
Grassland Conversion	Sequestration	X		
Irrigated /Dry land Mix	Emission	X		X
Ferment Ethanol Production	Offset	X	X	X
Cellulosic Ethanol Production	Offset	X	X	X
Biodiesel Production	Offset	X	X	X
Bioelectric Production	Offset	X	X	X
Stocker/Feedlot mix	Emission	X		
Enteric fermentation	Emission	X		
Livestock Herd Size	Emission	X	X	
Livestock System Change	Emission	X	X	
Manure Management	Emission	X	X	
Rice Acreage	Emission	X	X	X
Afforestation	Sequestration	X		
Existing timberland Manage	Sequestration	X		
Deforestation	Emission	X		
Forest Product Choice	Sequestration	X		

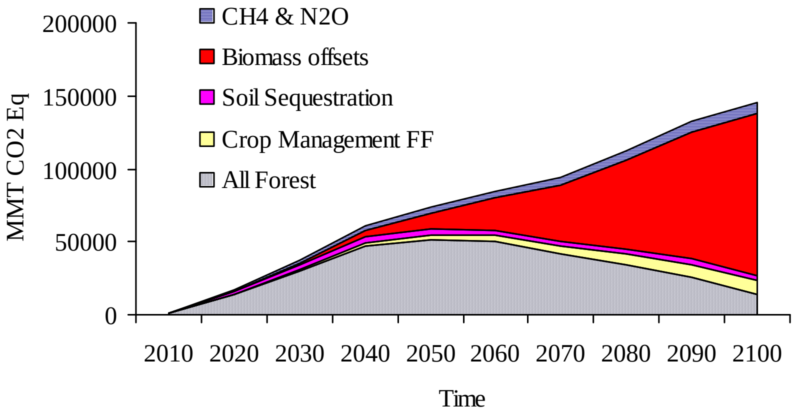
Will the dream persist ?

Some Results

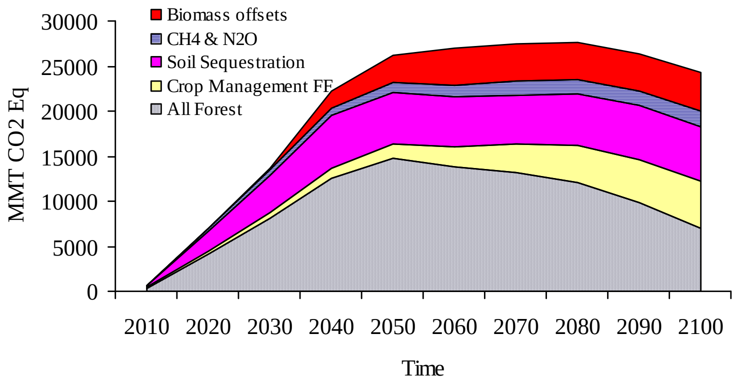
Dynamics and Saturation



Cumulative Contribution at a $5 per tonne CO2 Price



Cumulative Contribution at a $50 Price



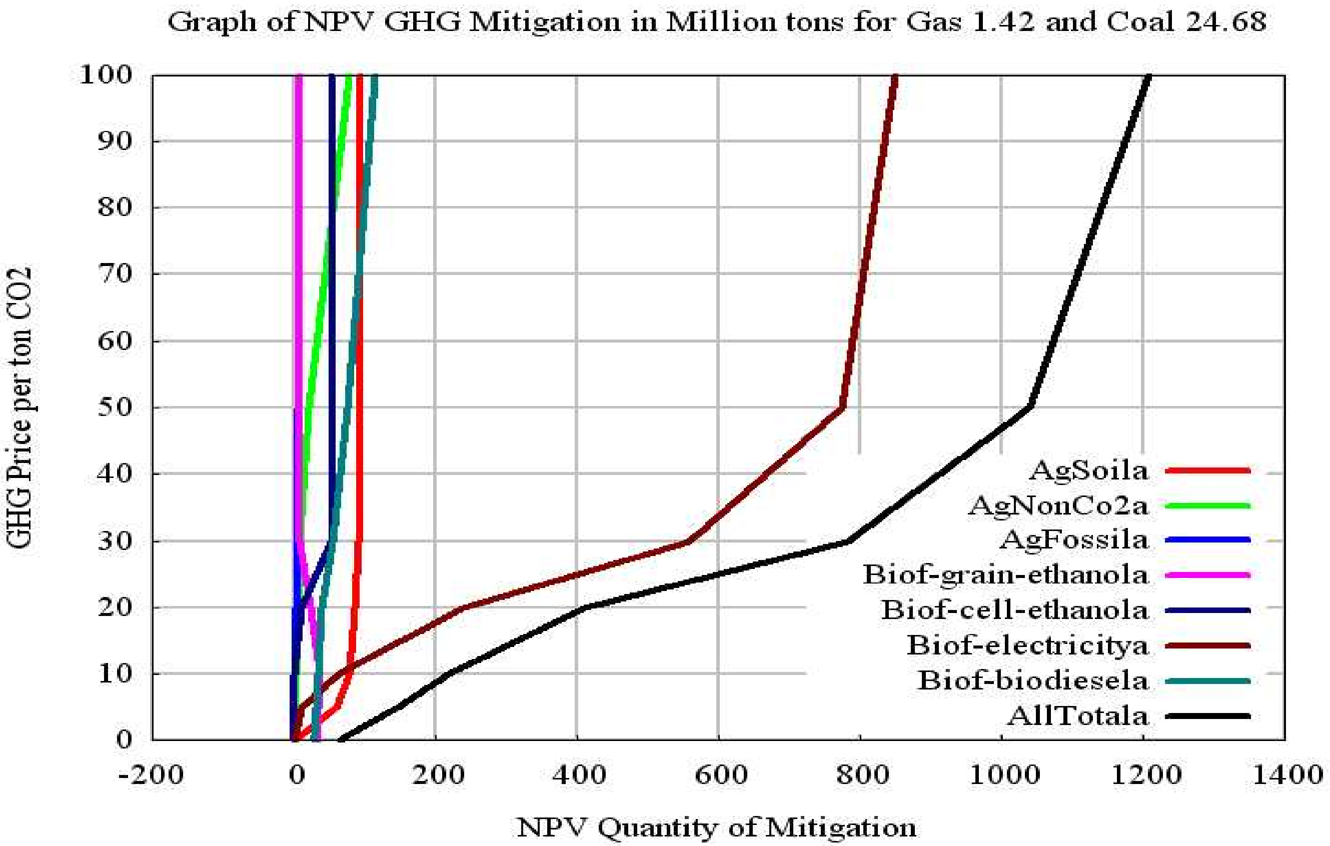
Cumulative Contribution at a $15 Price

Note

Effects of saturation on sequestration
Growing nonco2 and biofuels

Source Lee, H.C., B.A. McCarl and D. Gillig, "The Dynamic Competitiveness of U.S. Agricultural and Forest Carbon Sequestration," 2003.

Portfolio Composition



Energy prices increases with CO2 price

Ag soil goes up fast then plateaus and even comes down

Why – Congruence and partial low cost

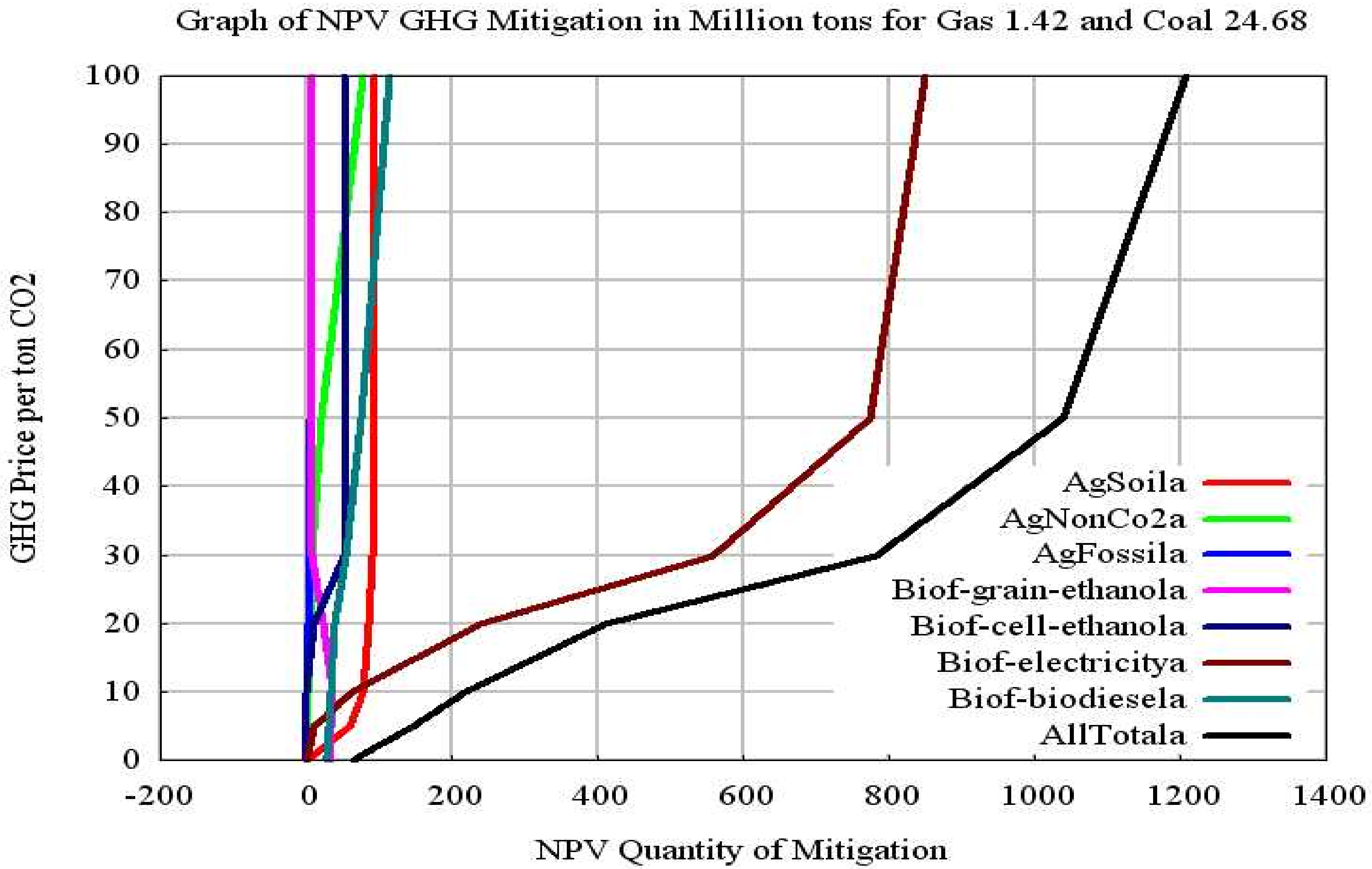
Lower per acre rates than higher cost alternatives

Biofuel takes higher price but takes off

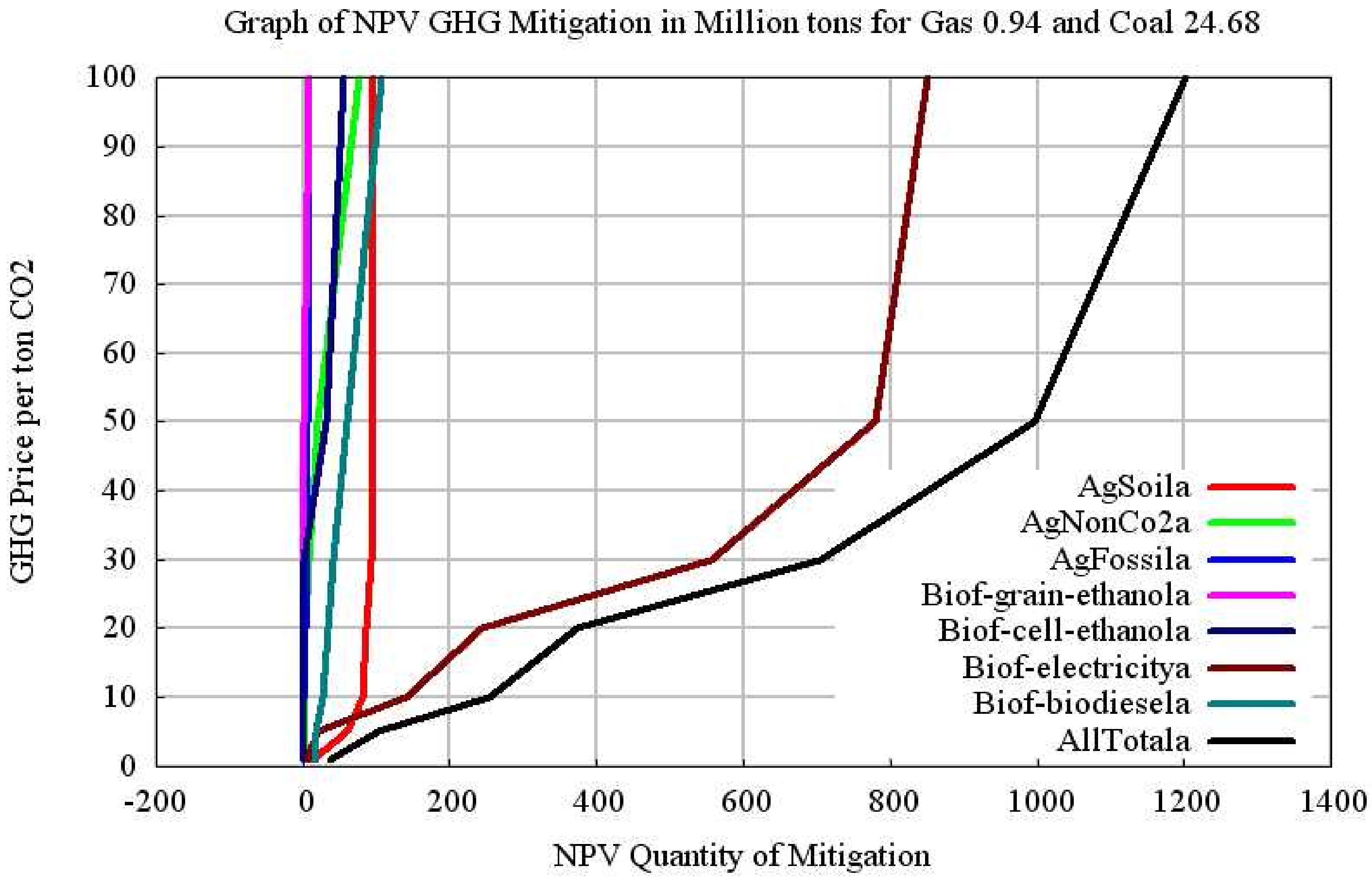
Electricity gives big numbers due to plant expansion

Other small and slowly increasing

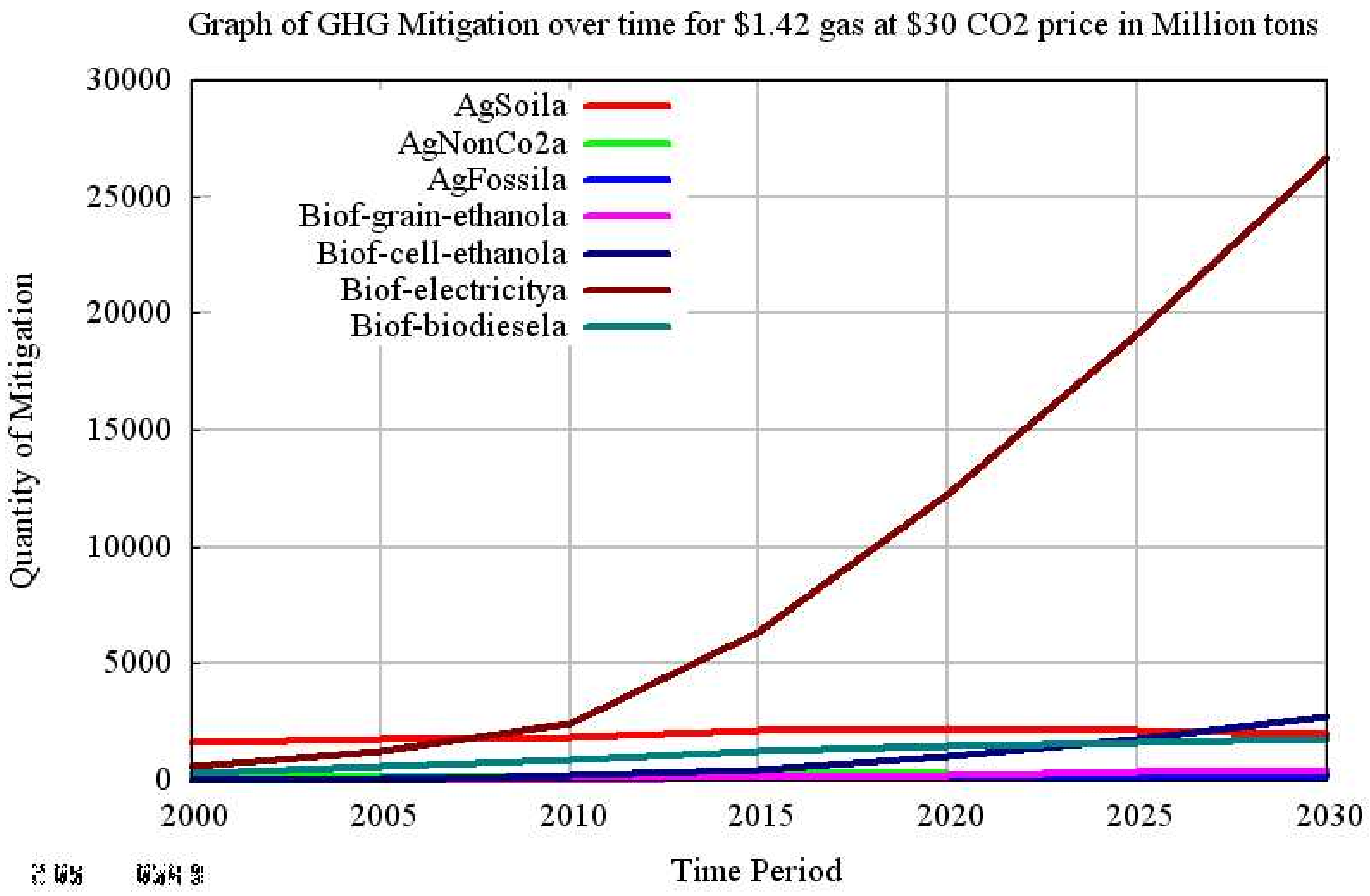
Portfolio Composition



Portfolio Composition



Dynamic Portfolio Composition



More biofuels over time

In at zero carbon price

Biofuel Portfolio Composition

	Gas price 0.94				Gas price 2.00			
Lower carbon dioxide price	-1	10	30	50	-1	10	30	50
Upper carbon dioxide price	10	30	50	5000	10	30	50	5000
Corn into ethanol through wet milling	xx	xx	xx	xx	xx	xx	xx	xx
Corn into ethanol through dry milling	xx	xx	xx	xx	xx	xx	xx	
Make wheat into ethanol				xx				xx
Make sorghum into ethanol	xx	xx	xx		xx	xx		
Make sugarcane Bagasse into ethanol				xx		xx	xx	xx
Make corn residues into ethanol				xx		xx	xx	xx
Make wheat residues into ethanol								xx
Make sorghum residues into ethanol				xx				
Make rice residues into ethanol				xx				xx
Make soybean oil into biodiesel	xx	xx	xx	xx	xx	xx	xx	xx
Make corn oil into biodiesel			xx	xx	xx	xx	xx	xx

GHG offset and energy price send similar signals

Cellulosic at higher prices, switchgrass and residue

Will the dream persist ?

Final remarks

Why else might the dream come true

- Alleviates problems with
  - Permanence
  - Additionality
  - Uncertainty
  - Transactions cost
  - Engineering solution
  - Leakage???
- Helps in some co benefits, causes other co costs
- Much more elastic demand curve helps farm income

GHGs and Money

If we cap GHG emissions biofuel prices and demand will rise

Biofuels will likely not create items sold in carbon market

Fossil energy production or consumption will require emission permits raising price to consumers of fossil fuel use

Biofuel combustion will likely not require such permits and price will rise on a BTU or other basis to price of fossil fuel

Biofuel manufacturers will have to pay higher price for fossil fuels or use biofuel products in energy production thus offsetting GHG earnings by emissions or reduced production

Money to be made more for larger offsets

Negative emissions with Carbon Capture and Storage

Findings

- Biofuels could play an important part in a GHGE mitigating world if price was above $5 per ton of carbon dioxide or if energy price is higher.
- At low prices opportunity cost of resources exceeds value of feedstocks generated.
- Competitiveness in GHG arena arises because biofuels continually offset fossil fuel emissions in comparison to changing tillage which saturates
- Cellulosic lignin goes into electricity generation
- Tradeoffs with food and fuel and exports if we produce biofuels
- Strong degree of income support
- Raises Consumer Food Costs

Big questions

- Will society choose to reward biofuel carbon recycling?
- Will energy prices remain high in short run?
- Will ethanol and biodiesel subsidies persist?
- When will cellulosic ethanol be producible at scale?
- Can we increase biofuel feedstock yields?
- Can we increase energy recovery efficiency from biofeedstocks?
- Will we switch farm subsidies to energy or carbon subsidies?
- Will food technical progress remain high?
- Will we think about this as we plot future of energy?
- Will the science community expand the definition of biofuels away from corn ethanol?

For more information

http://agecon2.tamu.edu/people/faculty/mccarl-bruce/biomass.html