# Biofuel Based GHG Mitigation and Energy Security Enhancement: An Analysis of Agricultural Contributions

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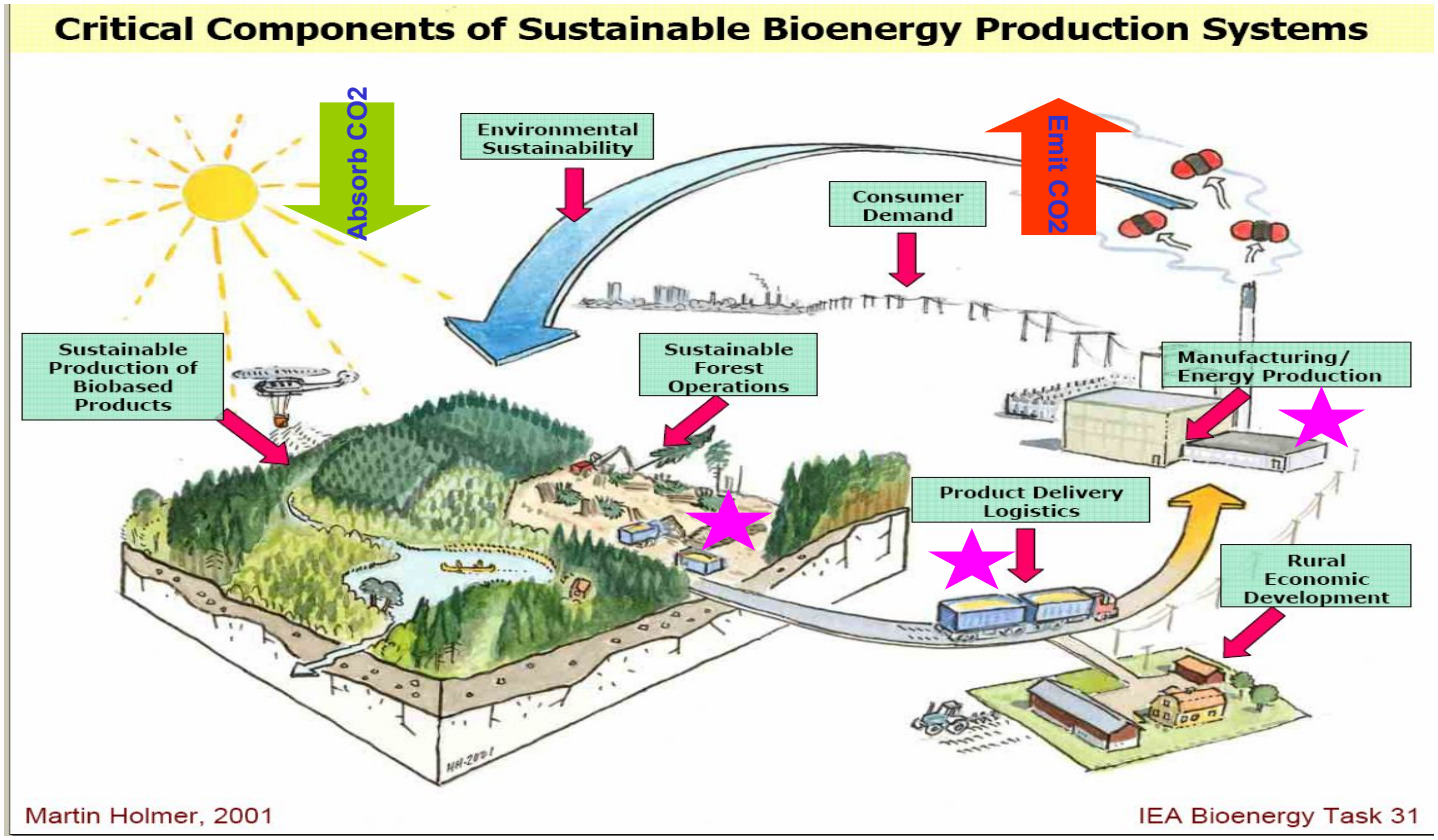
# Background

- **Biofuels offer a potential way of using abundant agricultural resources to help reduce dependence on fossil fuel contributing to**
  - **reductions in net greenhouse gas emissions**
    - **Carbon recycling**
    - **Enhanced sequestration – perennials, soils**
    - **Lower inputs**
    - **Offset by processing, production, transport**
  - **improved energy security**

# Biofuels and the Carbon Cycle




**Please Pretend the growing stuff includes crops**

**Feedstocks take up CO2 when they grow**

**CO2 emited 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

# Background

- So what? Biofuels have been known to society throughout history
- 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.
- Thus for biofuels to serve significant role as GHG offset or energy security enhancement then forces will have to arise that will make them competitive.

# 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

# Biofuel feedstocks

- **Agricultural and forestry products:**
  - **Grains -Corn, Wheat, Sorghum, Rice**
  - **Sugar Cane**
  - **Timber**
- **Production residues:**
  - **Crop Residue**
  - **Logging Residue**
  - **Manure**
- **Processing products and by products:**
  - **Corn Oil**
  - **Rendered Animal Fat**
  - **Milling Residue**
- **Energy crops:**
  - **Switchgrass**
  - **Willow**
  - **Hybrid Poplar**

# 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, residues 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

# Offset Rates Computed Through Lifecycle Analysis

## Net Carbon Emission Reduction (%)

| Biomass | Ethanol | Electricity | Biodiesel |
|---|---|---|---|
| Corn | 44 | | 11 |
| Soybeans | | | 96 |
| Rice | 6 | | |
| Wheat | 42 | | |
| Sugar | 71 | | |
| Switchgrass | 81 | 87 | |
| Hybrid Poplar | 72 | 89 | |
| Willow | 74 | 94 | |
| Log Residue | 69 | 91 | |
| Bagasse | 86 | 95 | |
| Corn Residue | 84 | 91 | |
| Wheat Residue | 79 | 88 | |
| Barley Residue | 56 | 64 | |
| Mill Residue | 76 | 95 | |
| Manure | | 88 | |

**Electricity offsets higher when cofired – Efficiency and less hauling**

**Ethanol offsets are in comparison to gasoline**
**Power plants offsets are in comparison to coal.**

# Finally Biofuel Economics

- **Has historically not been an economic proposition but at today's energy prices it looks better.**
- **In U.S. ethanol subsidies used to amount to over 50% of product sale price.**
- **Bolstered by sugar program**
- **Today payoff for subsidized plants (Corn to ethanol) is 3 years.**
- **Production capacity will soon be 4 x grater than 2001**
- **Unsubsidized plants not arising (Capital/price risk)**

# What will make Biofuels economic

- Rising energy prices
  - Scarcity
  - Energy Security
  - Trade disruption
- Rising GHG prices
- Lower costs of delivered feedstock because of higher yields, improved production practices, lower transport needs
- Improved energy recovery efficiency

# Project Assessment

- Amulti-period analysis of ag potential response (no forest )
- Today agricultural in 30 year setting
- Examines overall and component responses at varying carbon equivalent and energy prices with technology soon
  - Varies coal, carbon and gasoline price
- Simultaneous assessing across all agricultural GHG mitigation strategies including biofuels
- Simultaneous modeling of agricultural markets and other agricultural environmental problems

# GHG Activities in Analysis

- Multiple GHG mitigation strategy setup
- Detailed GHG emission accounting
  - Forest carbon
  - Soil carbon
  - N2O
  - CH4
  - Fuel use carbon emissions
- National GHG balance
- GWP weighted sum of all GHG accounts
- GHG Policy implementation

# 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 |
| Biofuel 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 (not today) | Sequestration | X | | |
| Existing timberland Management | Sequestration | X | | |
| Deforestation | Emission | X | | |

# Biofeedstock Option

- Fast growing trees or switchgrass
- Crop residues
- Conventional crops
- Feedstock for electrical power plants or liquid fuel production
- Offsets fossil fuels $\rightarrow$ recycles emissions
- Requires land $\rightarrow$ Opportunity cost
- Counts production/processing emissions
- Sustainable, verifiable

# Why not just biofuels

**We consider biofuel net contribution to GHG emissions considering carbon dioxide, nitrous oxide and methane not biofuels in isolation**

**We examine relative desirability as compared to other GHG mitigation strategies**

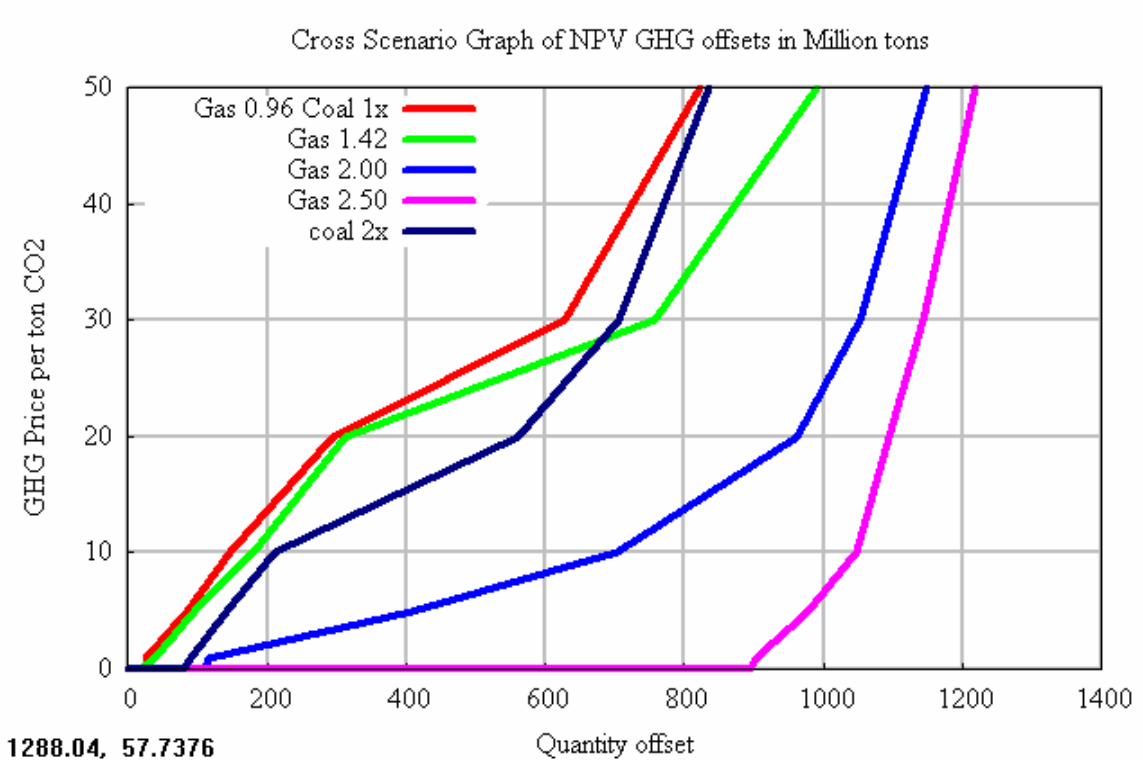
**Why?**

**incredible interrelatedness of ag economy**

**opportunity cost of resources**

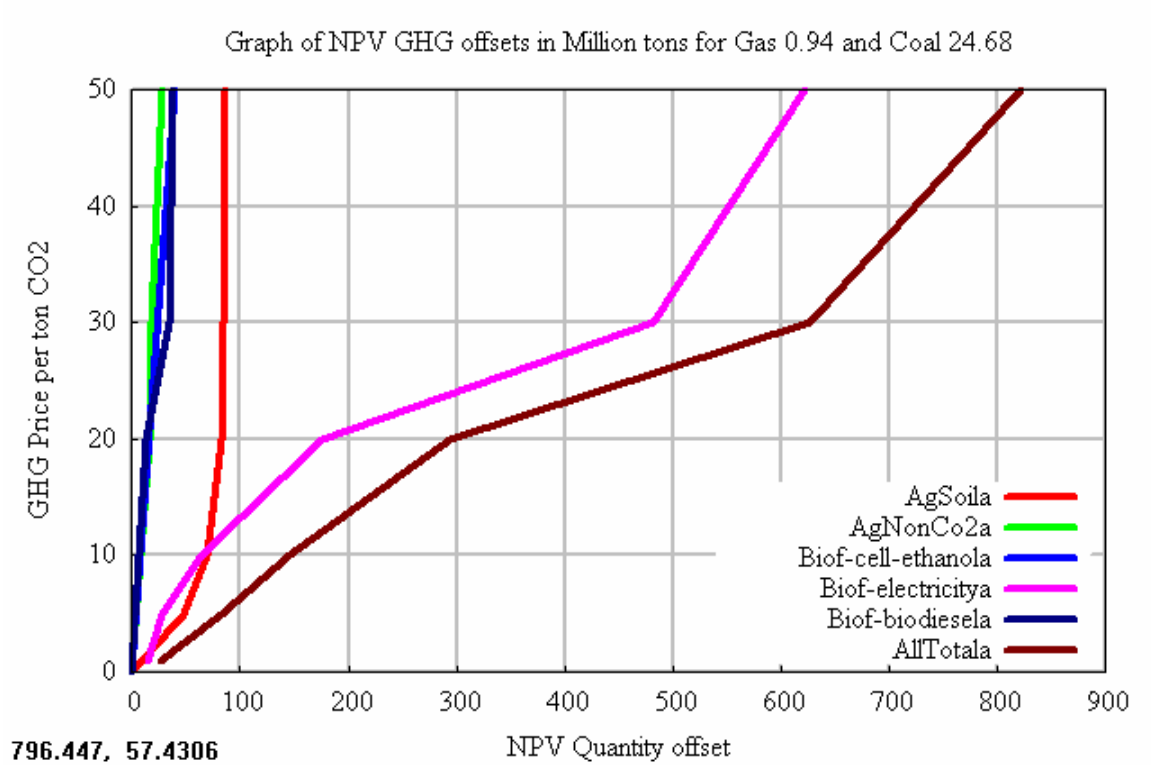
**Land to crops to feed to cattle all involved with GHG**

# GHG CO2 Eq Offset Volume




**Note offsets increase with energy price and carbon dioxide price**

# Portfolio Composition




**Note the energy prices are those at zero CO2 price and effective price increases with CO2 price**

**Ag soil goes up fast then plateaus and even comes down**

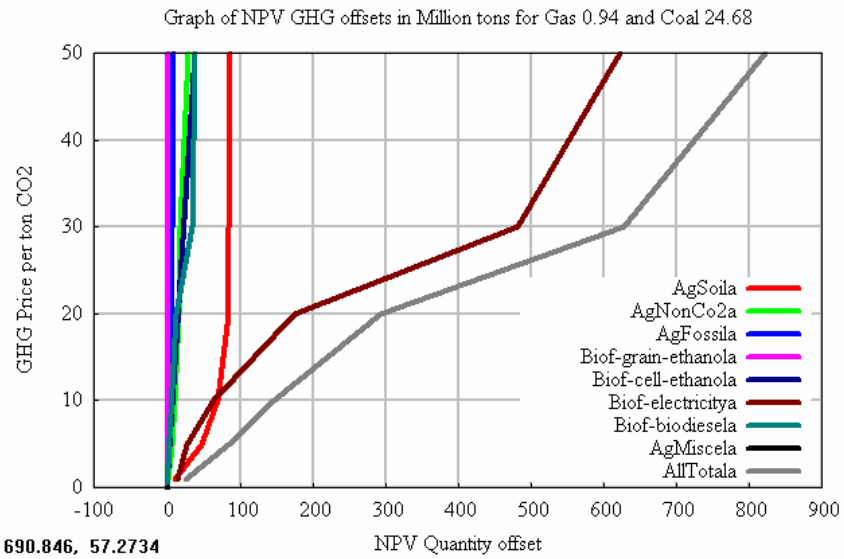
**Why – Congruence and partial low cost**

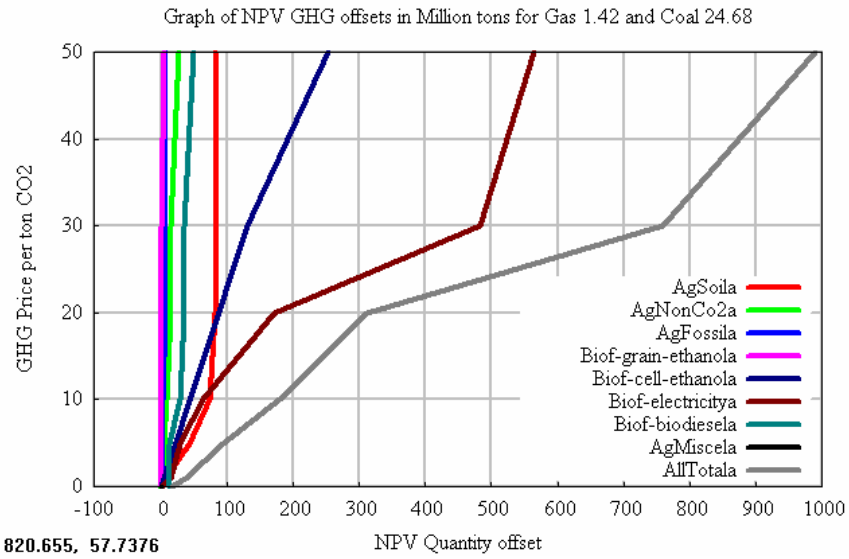
**Lower per acre rates than higher cost alternatives**

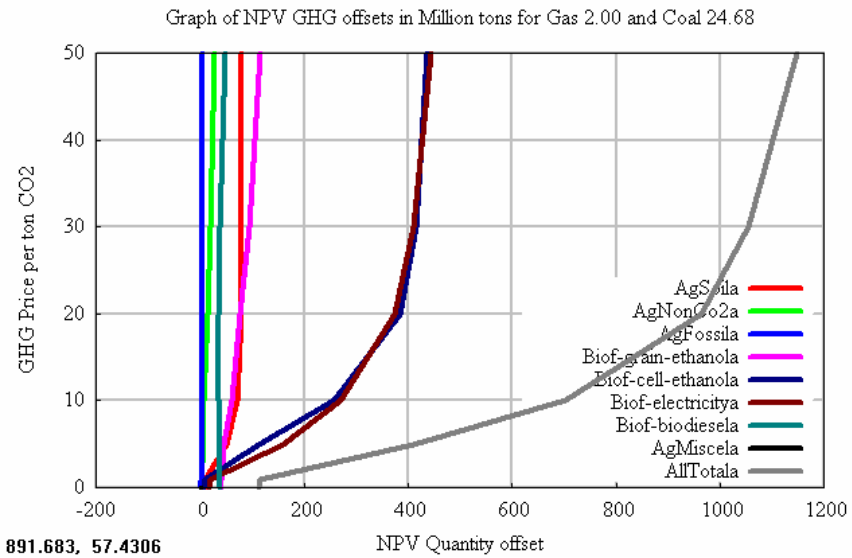
**Biofuel takes higher price but takes off**

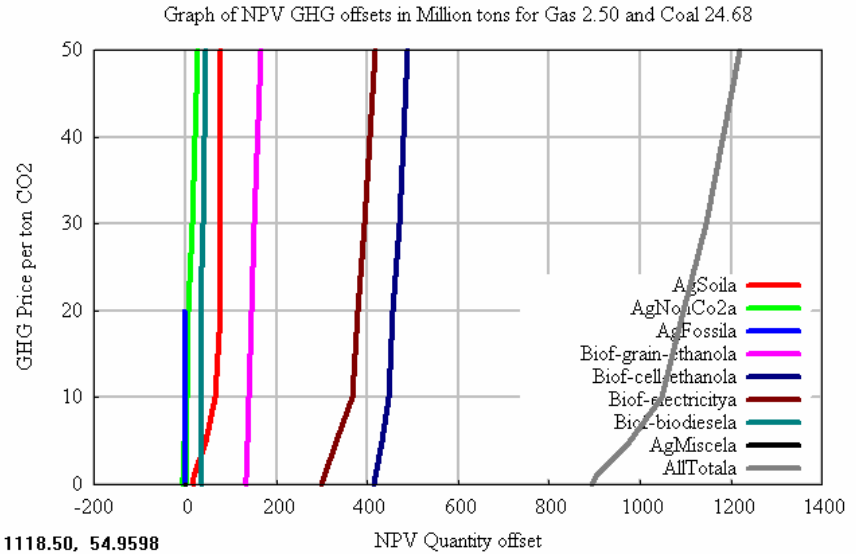
**Other small and slowly increasing**

# Portfolio Composition



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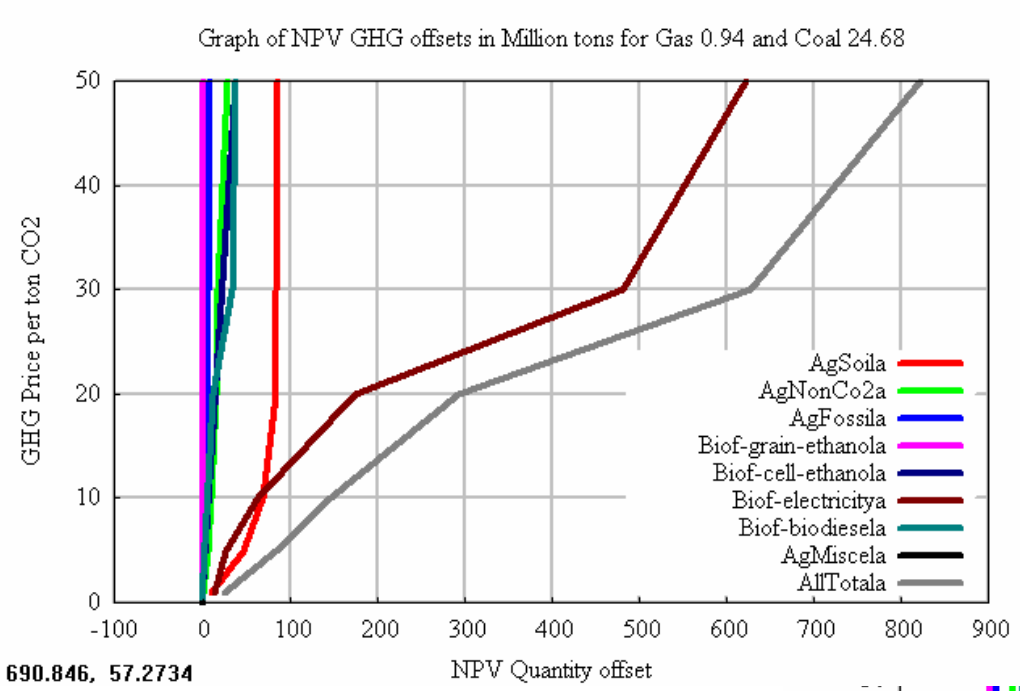
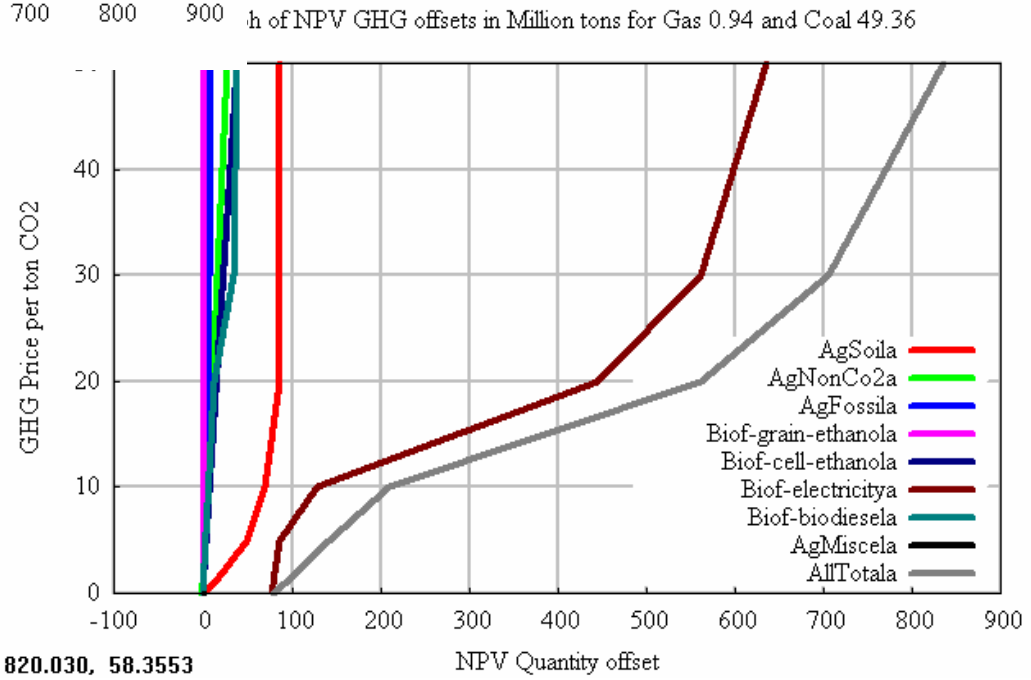
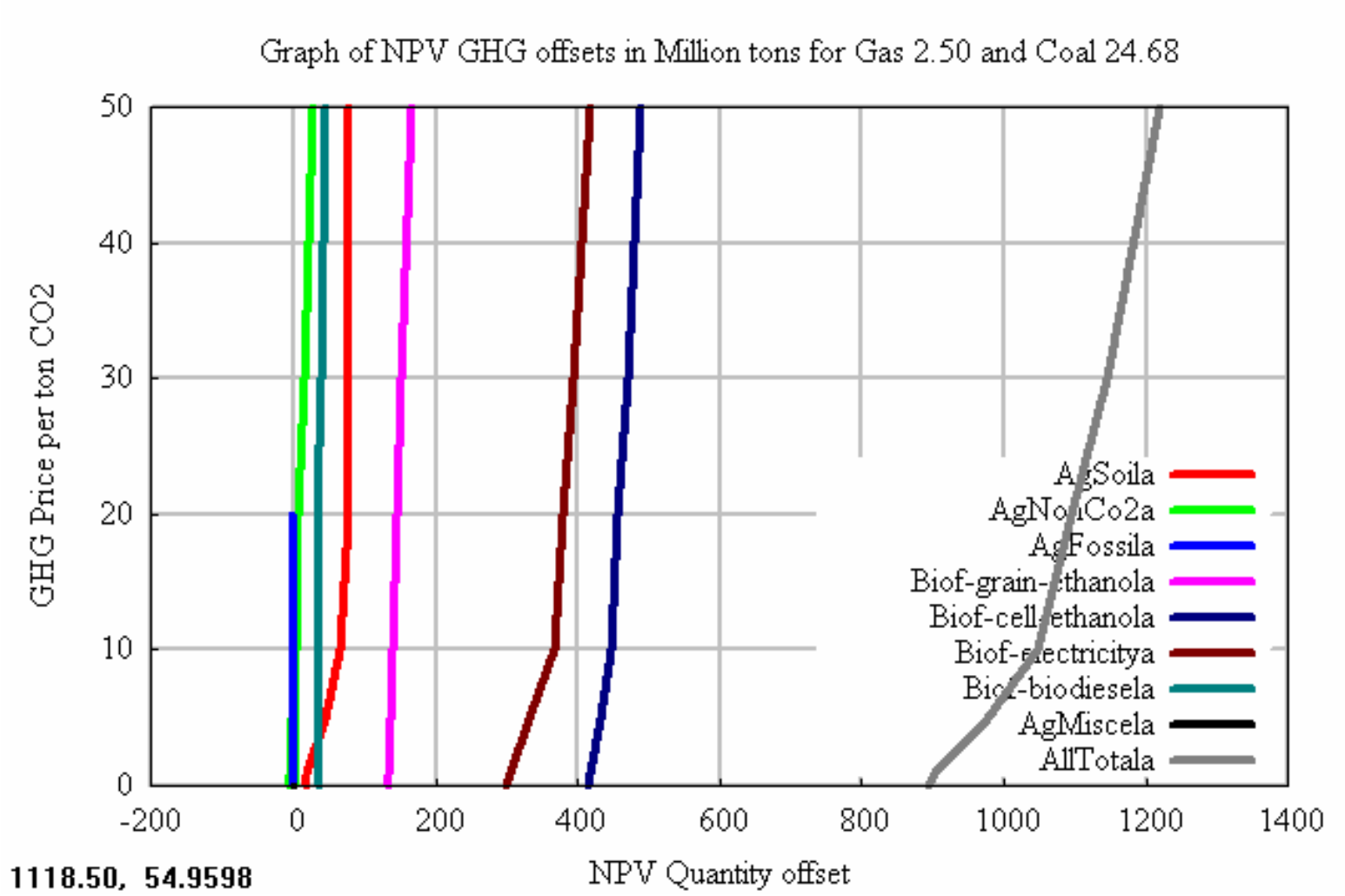


# Expensive $2.50 gas Portfolio Composition




**More biofuels**

**In at zero carbon price**

# Biofuel Portfolio Composition

Use of biofuel strategies for selected price ranges

| | -- Coal 24.68 Gas 0.94 -- | | | | -- Coal 24.68 Gas 2.50 -- | | | |
|---|---|---|---|---|---|---|---|---|
| Lower price | -1 | 10 | 30 | 50 | -1 | 10 | 30 | 50 |
| Upper price | 10 | 30 | 50 | 5000 | 10 | 30 | 50 | 5000 |
| Make corn into ethanol through wet milling | xx | xx | xx | xx | xx | xx | xx | xx |
| Make corn into ethanol through dry milling | | | | | xx | xx | xx | xx |
| Make sugar into ethanol | | | | | | | | xx |
| Make wheat into ethanol | | | | xx | xx | xx | xx | xx |
| Make wheat into ethanol | | | | | | | | xx |
| Make wheat into ethanol | | | | | | | | xx |
| Make sorghum into ethanol | | | | | xx | xx | xx | xx |
| Make barley into ethanol | | | | | | | xx | xx |
| Make oats into ethanol | | | | | | | | xx |
| Make rice into ethanol | | | | | xx | xx | xx | xx |
| Make switchgrass into ethanol | | | | | xx | xx | xx | xx |
| Make sugarcane Bagasse into ethanol | | | | xx | xx | xx | xx | xx |
| Make corn residues into ethanol | | | | xx | xx | xx | xx | xx |
| Make wheat residues into ethanol | | | | xx | xx | xx | xx | xx |
| Make sorghum residues into ethanol | | | | xx | xx | xx | xx | xx |
| Make barley residues into ethanol | | | | | xx | xx | xx | xx |
| Make rice residues into ethanol | | | | xx | xx | xx | xx | xx |

**Corn at all prices but not unsubsidized**

**Cellulosic at higher prices, switchgrass and residue**

**Lignin by product into electricity**

# Biofuel Portfolio Composition

Use of biofuel strategies for selected price ranges

| | -- Coal 24.68 Gas 0.94 -- | | | |
|---|---|---|---|---|
| Lower price | -1 | 10 | 30 | 50 |
| Upper price | 10 | 30 | 50 | 5000 |
| Total | | | | |
| Make switchgrass into electricity 5% cofiring | xx | xx | | |
| Make switchgrass into electricity 10% cofiring | xx | | | |
| Make switchgrass into electricity 15% cofiring | xx | xx | | |
| Make switchgrass into electricity 20% cofiring | xx | xx | xx | xx |
| Make switchgrass into electricity | | xx | xx | xx |
| Make willow into electricity | | | | xx |
| Make lignin into electricity | | | | xx |
| Make sugarcane Bagasse into electricity | xx | xx | xx | xx |
| Make corn residues into electricity | | | xx | xx |
| Make wheat residues into electricity 20% cofiring | | | xx | xx |
| Make wheat residues into electricity | | xx | xx | xx |
| Make sorghum residues into electricity 20% cofirin | | | | xx |
| Make sorghum residues into electricity | | | xx | xx |
| Make barley residues into electricity 20% cofiring | | | | |
| Make barley residues into electricity 15% cofiring | | | | |
| Make barley residues into electricity | | xx | xx | xx |
| Make oats residues into electricity 10% cofiring | | | | |
| Make oats residues into electricity 15% cofiring | | | | |

**Cofiring ratio increases with price**

**Residues Show at higher prices**

**Sugarcane bagass at all prices**

Annualized Gain in Welfare in billion 2000$

| CO2 price | 0 | 1 | 5 | 10 | 20 | 30 | 50 | 100 |
|---|---|---|---|---|---|---|---|---|
| **United States Agriculture** | | | | | | | | |
| Gas 0.96 Coal 1 | | 0.03 | 0.13 | 0.91 | 3.36 | 9.13 | 23.72 | 73.93 |
| Gas 1.42 | -1.01 | 0.05 | 0.24 | 1.10 | 3.83 | 10.82 | 28.49 | 88.04 |
| Gas 2.00 | 0.12 | 0.23 | 1.31 | 4.42 | 14.17 | 24.96 | 47.77 | 111.62 |
| Gas 2.50 | 16.50 | 0.94 | 4.75 | 9.90 | 20.92 | 32.27 | 56.17 | 120.66 |
| coal 2x | 1.40 | 0.09 | 0.40 | 1.25 | 6.09 | 12.66 | 27.92 | 78.26 |
| **Rest of the World Agriculture** | | | | | | | | |
| Gas 0.96 Coal 1 | | -0.01 | -0.05 | -0.27 | -0.76 | -1.47 | -1.68 | -2.83 |
| Gas 1.42 | -0.06 | | -0.09 | -0.25 | -0.75 | -1.31 | -1.97 | -4.21 |
| Gas 2.00 | -1.51 | -0.05 | -0.28 | -0.81 | -1.65 | -2.34 | -3.51 | -4.08 |
| Gas 2.50 | -4.89 | -0.02 | -0.13 | -0.29 | -0.62 | -0.90 | -1.24 | -1.26 |
| coal 2x | -0.50 | -0.01 | 0.04 | -0.03 | -1.04 | -1.11 | -1.23 | -2.34 |
| **Total Globally Agriculture** | | | | | | | | |
| Gas 0.96 Coal 1 | | 0.01 | 0.08 | 0.63 | 2.60 | 7.66 | 22.04 | 71.10 |
| Gas 1.42 | -1.07 | 0.04 | 0.15 | 0.86 | 3.07 | 9.51 | 26.53 | 83.83 |
| Gas 2.00 | -1.39 | 0.18 | 1.03 | 3.61 | 12.52 | 22.62 | 44.27 | 107.54 |
| Gas 2.50 | 11.61 | 0.92 | 4.62 | 9.61 | 20.31 | 31.38 | 54.92 | 119.40 |
| coal 2x | 0.90 | 0.08 | 0.43 | 1.22 | 5.05 | 11.56 | 26.70 | 75.92 |

Agricultural Index Numbers

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| AllFarmProd Production | | | | | | | | |
| Gas 0.96 Coal 1x | 100 | 100 | 98 | 97 | 94 | 92 | 89 | 86 |
| Gas 1.42 | 100 | 100 | 99 | 97 | 95 | 92 | 90 | 88 |
| Gas 2.00 | 100 | 100 | 98 | 97 | 95 | 94 | 92 | 89 |
| Gas 2.50 | 99 | 99 | 99 | 98 | 97 | 95 | 92 | 90 |
| coal 2x | 100 | 99 | 98 | 97 | 94 | 92 | 89 | 86 |
| AllFarmProd Price | | | | | | | | |
| Gas 0.96 Coal 1x | 100 | 100 | 101 | 102 | 105 | 110 | 114 | 128 |
| Gas 1.42 | 100 | 100 | 101 | 102 | 106 | 111 | 116 | 146 |
| Gas 2.00 | 109 | 109 | 111 | 115 | 123 | 128 | 143 | 180 |
| Gas 2.50 | 140 | 140 | 141 | 143 | 150 | 157 | 168 | 214 |
| coal 2x | 103 | 103 | 103 | 103 | 111 | 111 | 114 | 128 |
| AllFarmProd Export | | | | | | | | |
| Gas 0.96 Coal 1x | 100 | 100 | 99 | 97 | 93 | 88 | 84 | 69 |
| Gas 1.42 | 99 | 99 | 98 | 97 | 93 | 89 | 80 | 55 |
| Gas 2.00 | 90 | 89 | 88 | 83 | 75 | 67 | 51 | 30 |
| Gas 2.50 | 55 | 55 | 54 | 53 | 50 | 46 | 40 | 26 |
| coal 2x | 97 | 97 | 97 | 96 | 88 | 87 | 83 | 68 |
| AllCrops Production | | | | | | | | |
| Gas 0.96 Coal 1x | 100 | 100 | 100 | 99 | 98 | 98 | 100 | 106 |
| Gas 1.42 | 100 | 100 | 100 | 99 | 98 | 99 | 103 | 111 |
| Gas 2.00 | 101 | 101 | 101 | 102 | 104 | 107 | 109 | 115 |
| Gas 2.50 | 107 | 107 | 107 | 108 | 110 | 111 | 114 | 118 |
| coal 2x | 100 | 100 | 99 | 99 | 98 | 99 | 100 | 106 |

# Conclusions

- Biofuels could play an important part in a GHGE mitigating world if price was above $5 per ton of carbon doixide 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
- Biofuels may also yield other ancillary benefits.
- Big questions: Will society choose to reward their carbon recycling characteristics and Will energy prices remain high?

# Conclusions

- Crop residues not so good
- Biodiesel is small
- Electricity dominates
- Even switches over at high CO2/gas price combo
- Cogeneration ethanol/crop lignin

# Limitations

- No forest as of now
- Manure burning and animal rendering missing
- Power plant market penetration limitation
- No biofeedstock technology experiments

All of above to be fixed soon

- Host of other sins – for example
  - foresight,
  - US only

# For more information

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