Greenhouse Gas Impacts of Ethanol from Iowa Corn

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Motivation

- Is ethanol a low carbon fuel?
  - California low carbon fuel standard
  - Greenhouse gas criteria for biofuels in Energy Independency and Security Act
- If not, could it become one?

Why Another LCA of Corn Ethanol?

- Best practitioners of LCA know relatively little of production agriculture
  - rotation impacts on fertilizer application rates
  - tillage practices
  - displacement of corn and soybean meal by distillers grains in livestock rations
- Know even less of the response of agriculture to changes in prices

Marginal vs. Average Analysis

- “Point in time” LCA are inadequate to analyze biofuels and GHG incentives
- Increases in feedstock production will change production practices and land use
- Greenhouse gas emissions should be calculated for marginal corn, not average corn

How is marginal corn grown?

- Increase crop yields on same acres
  - more fertilizer and pesticides, better seeds
- Substitute corn for other crops
  - Change crop rotation from corn-soybeans to corn-corn
  - Replace cotton with corn
- Plant corn on previously idled land
  - Take land out of CRP
  - Plow up pasture land

Standard Method for Calculating Emissions at the Margin

1. Calculate greenhouse gas emissions under a baseline

2. Calculate greenhouse gas emissions under expanded biofuels production

3. Take the difference

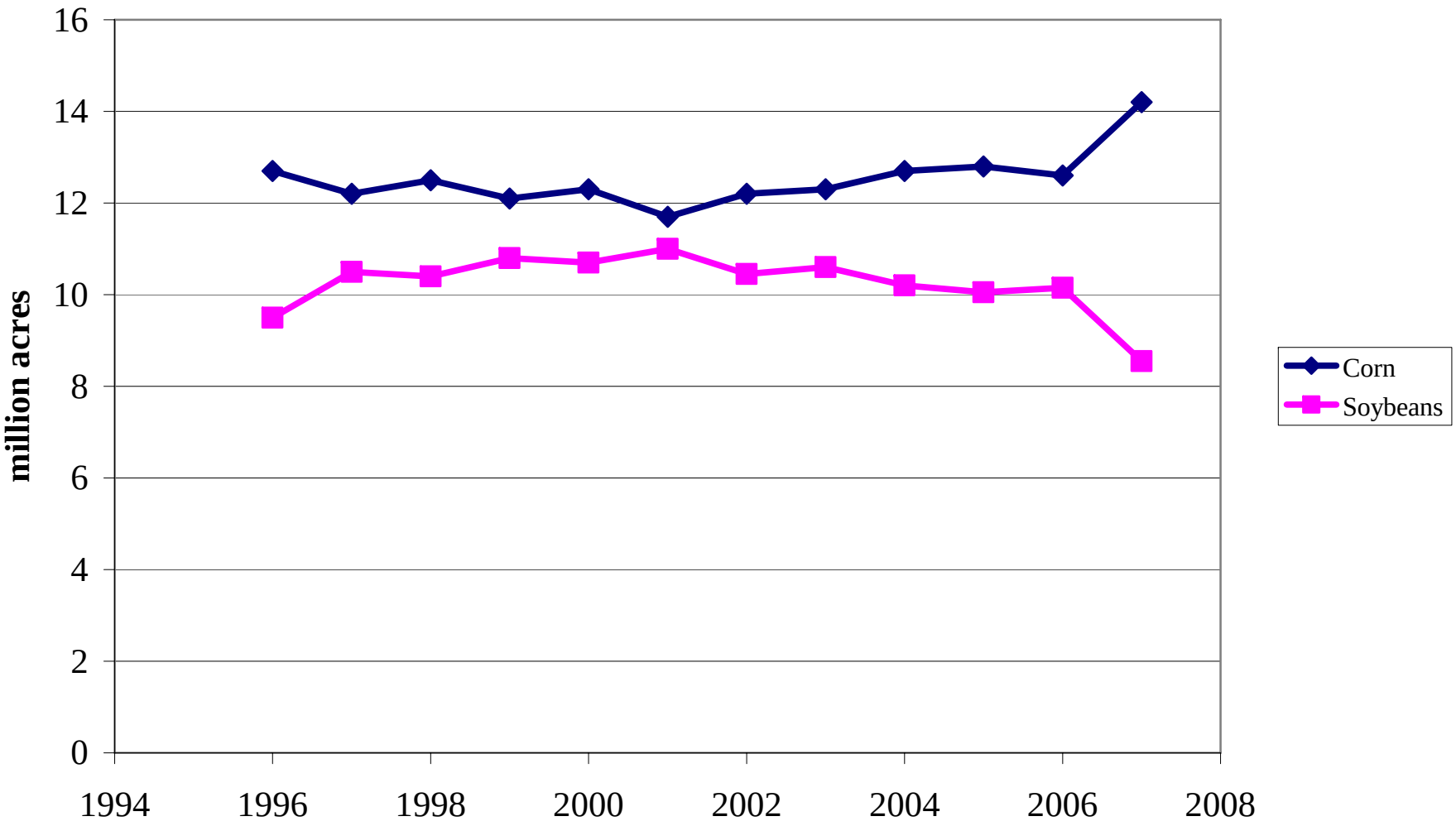
Key Issues

- What belongs in the baseline?
  - Will conversion of cropland happen without biofuels?
- Will new production practices be adopted in the scenario?
  - Higher land prices in Brazil will intensify cattle production and will increase pressure on undeveloped land

A Focus on Iowa Corn

- Indicative of how most corn is produced in the U.S.
- Most marginal corn for ethanol production will come from the Corn Belt
- Good knowledge of Corn Belt production practices available at Iowa State.

Corn and Soybeans Planted Acres in Iowa

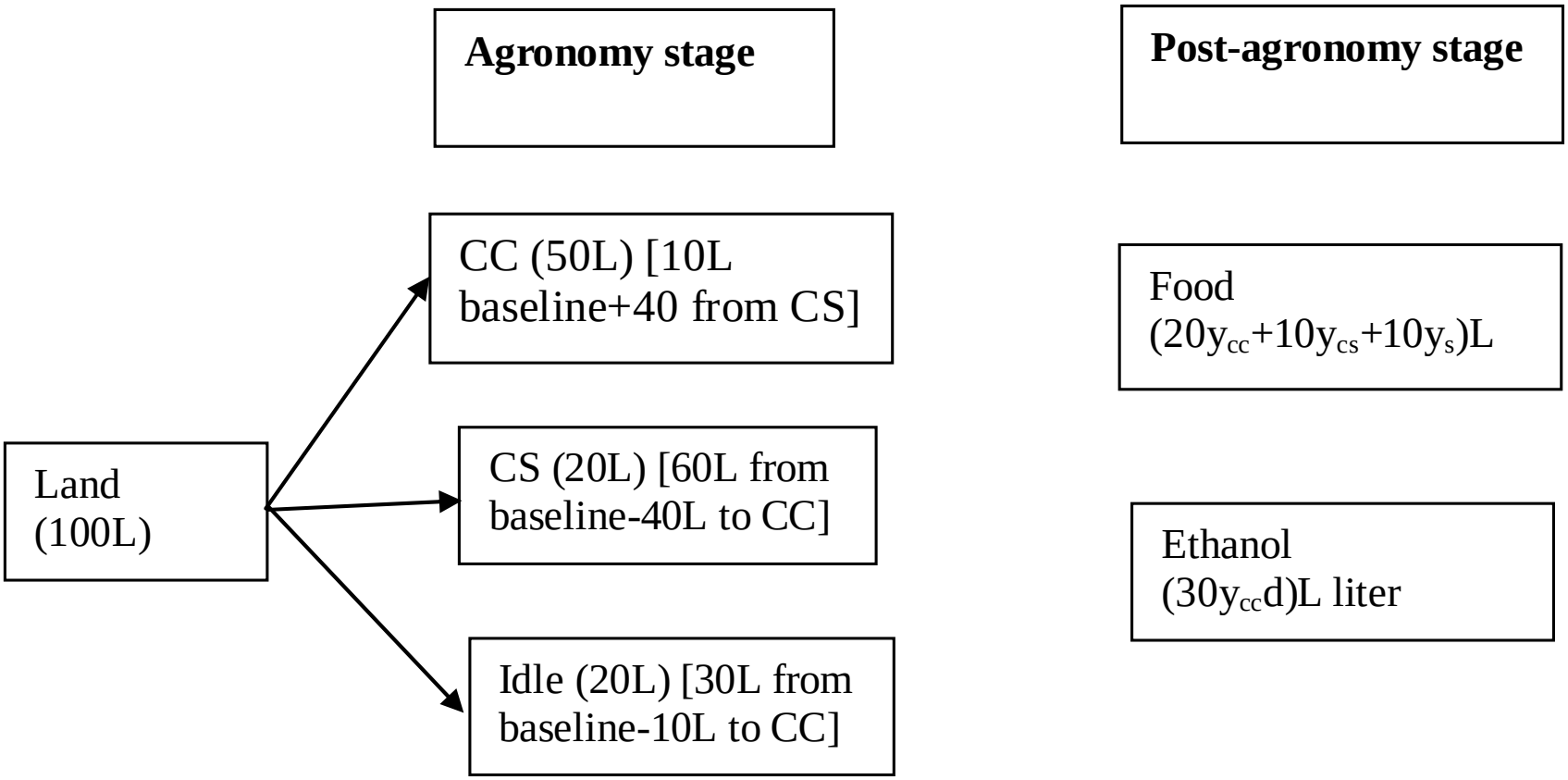


GHG emission factors

Emissions from

corn in corn-soybean rotation (kg/ha)
corn in corn after corn (kg/ha)
soybean in corn-soybean rotation (kg/ha)
idle land (kg/ha)
food use of corn (kg/ton)
food use of soybean (kg/ton)
ethanol prod. post-ag (kg/L)
gasoline (kg/L)

Figure 2. Illustration of SWA—change from baseline



$$\Delta TE_{SWA} = Ld[40(y_{cc} - 0.5y_{cs}) * \Delta E_{SWA,cs\_cc} + 10y_{cc} * \Delta E_{SWA,idle} + 20(y_{cs} - y_{cc}) * \Delta E_{SWA,\,food}]$$

$$= \Delta TE_{LCA,c\_cc} + 40L * (0.5\hat{E}_{ag,s\_cs} + 0.5\hat{E}_{ag,c\_cs} - 0.5\frac{y_{cs}}{y_{cc}}\hat{E}_{ag,c\_cc}$$

$$- \hat{E}_{conv,cs\_cc} + 0.5y_s * E_{post,s}) + 10L * (\hat{E}_{ag,idle} - \hat{E}_{conv,idle\_cc})$$

$$+ 20(y_{cs} - y_{cc})L * (\frac{1}{d}E_{post,\,food\_c} + \frac{1}{y_{cc}d}\hat{E}_{ag,c\_cc}),$$

where $\Delta TE_{LCA,c\_cc} = 30y_{cc}dL * (E_{LCA,gas} - E_{LCA,c\_cc}) = 30y_{cc}dL * (E_{LCA,gas} - E_{ag,c\_cc} - E_{post,eth})$

Model for emissions from ethanol

- EBAMM 1.1, by Farrell et al., (2006)
  - Published along with Science article

- Biorefinery stage: Not focus of our study. We use a 2010 projected weighted average over
  - Dry vs wet mill
  - Dry vs wet distiller grains with solubles (DGS)
  - Coal vs natural gas

One Change from EBAMM and GREET

- Each bushel of corn processed into ethanol produces 17 pounds of distillers grains
- Each pound of distillers grains displaces 0.57 pounds of corn and 0.47 pounds of soybean meal in a least-cost feed ration
  - Credit = .356 kg CO2 per kg of corn and .3321 kg CO2 per kg of soybean meal
- 1.04 pounds of displacement per pound,
  - GREET uses 1.9 pounds.

Crop sequences in Iowa

- Two main disadvantages of continuous corn
  - Possible lower yields (10-15%) under old seed technology
  - Higher nitrogen application rate (+56 kg/ha)

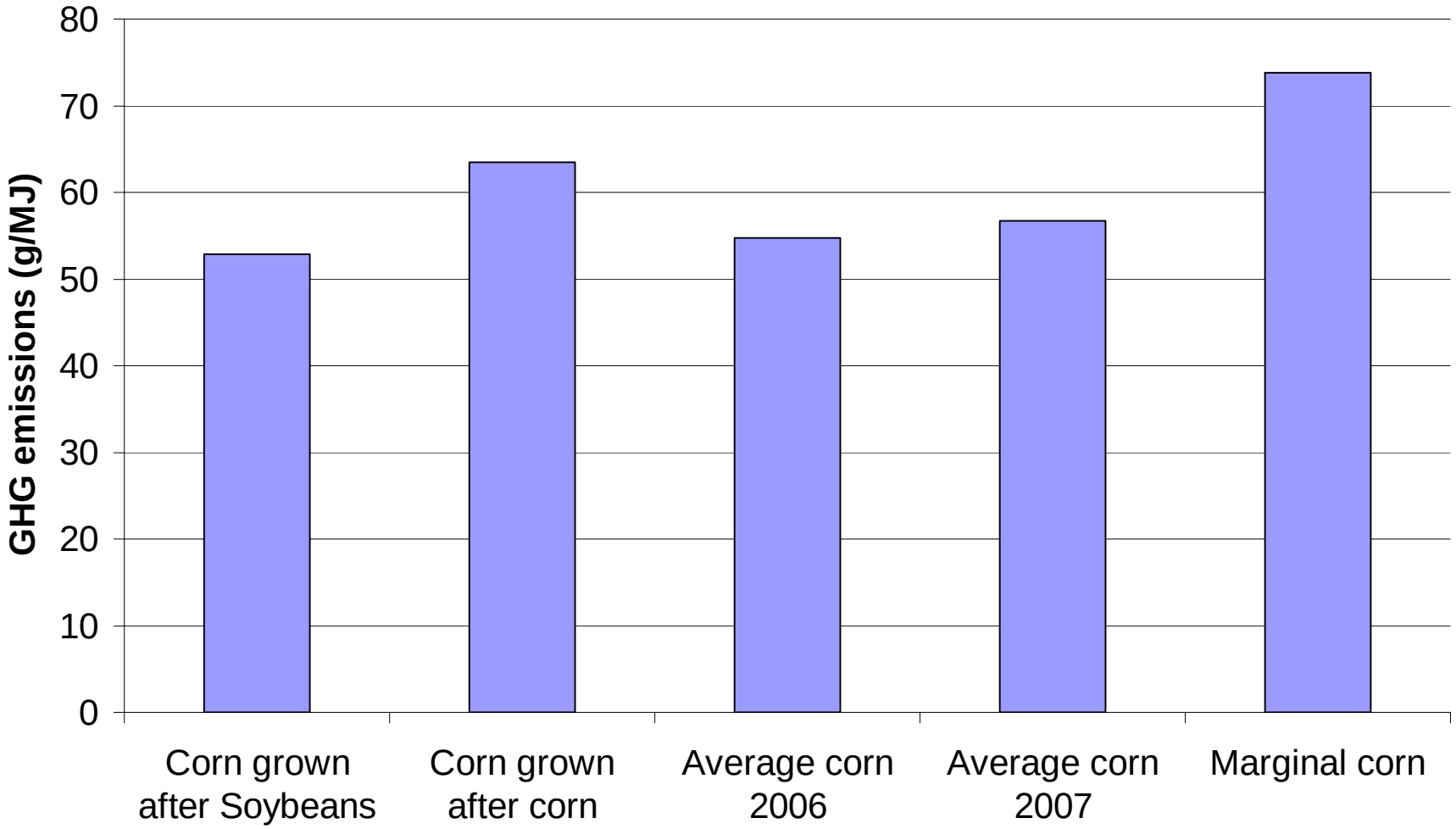
LCA GHG Emissions from Iowa Corn

	Continuous Corn	Corn Soybean
Emissions Kg CO2e/L	2.0	1.66
Reduction from gasoline	32%	44%

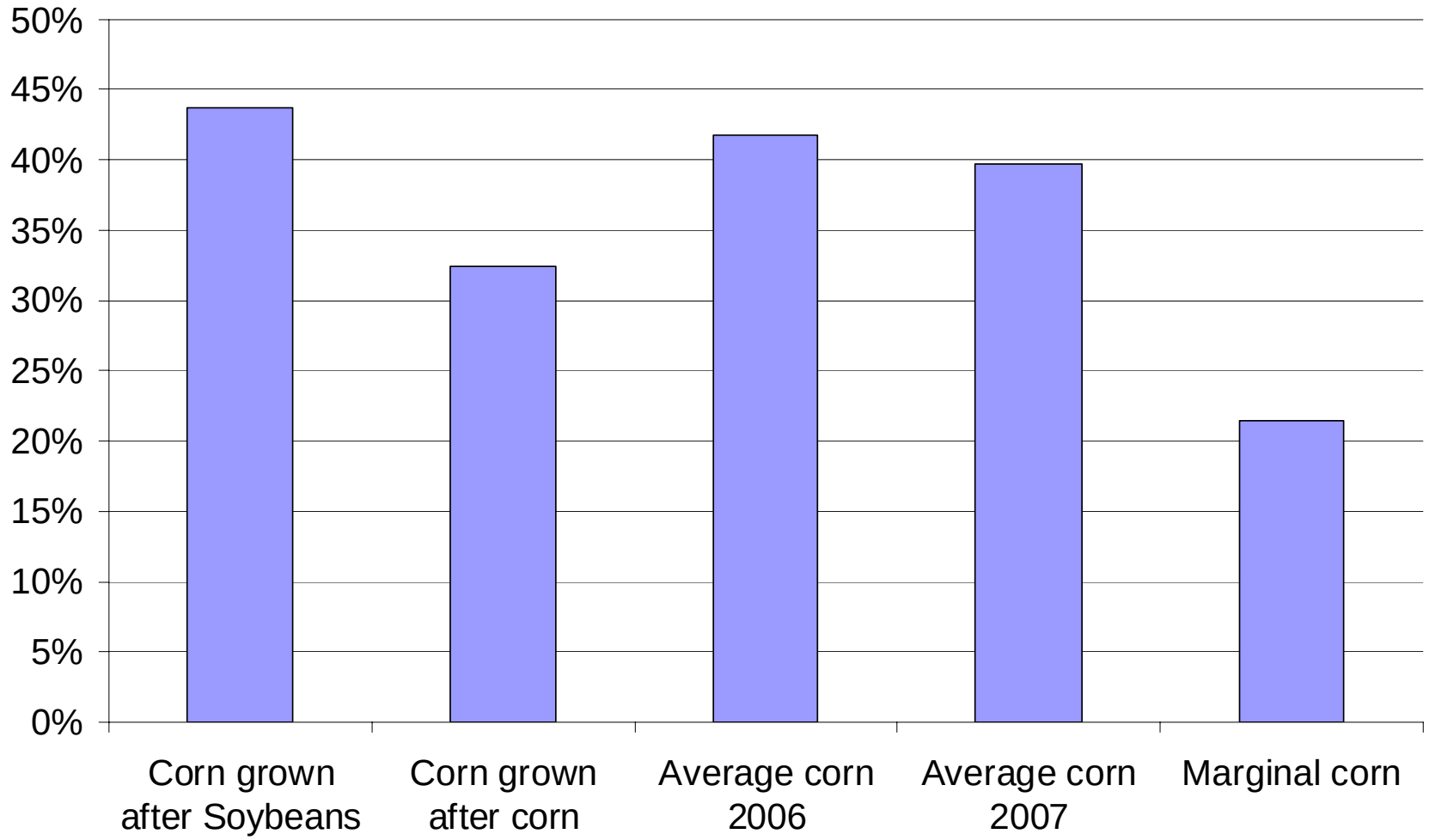
What Number to Use?

- Weighted average?
  - 2006 or 2007?
- How about emissions from marginal corn?
  - (Take the change in emissions from corn from 2006 to 2007 and attribute all to increased ethanol production that can be obtained from the increased corn production.

Estimates of GHG Emmisions from Ethanol Produced from Iowa Corn



Reductions in GHG Emmisions from Ethanol Produced from Iowa Corn



Not “the” Answer

- What about the credit from reduced soybean production?
- Are there any changes in food use?
- What about more cultivation of idle land in Iowa? In Indonesia?

Two Examples Focusing on Iowa Corn and Ethanol

- Comparison of greenhouse gas emissions from changes in land use from 2006 to 2007
- Change all of Iowa to corn-corn from corn-soybean production

➢ Ethanol production obtained from increased corn production

Example 1

- Baseline: 2006 economy
- Scenario: 2007 economy

	Baseline	Scenario
	Million hectares	
Corn-Corn	0.99	2.23
Corn-Soybean	8.22	7.12
Total Cropped	9.21	9.35
Non-tilled	0.14	0.00

Example 1

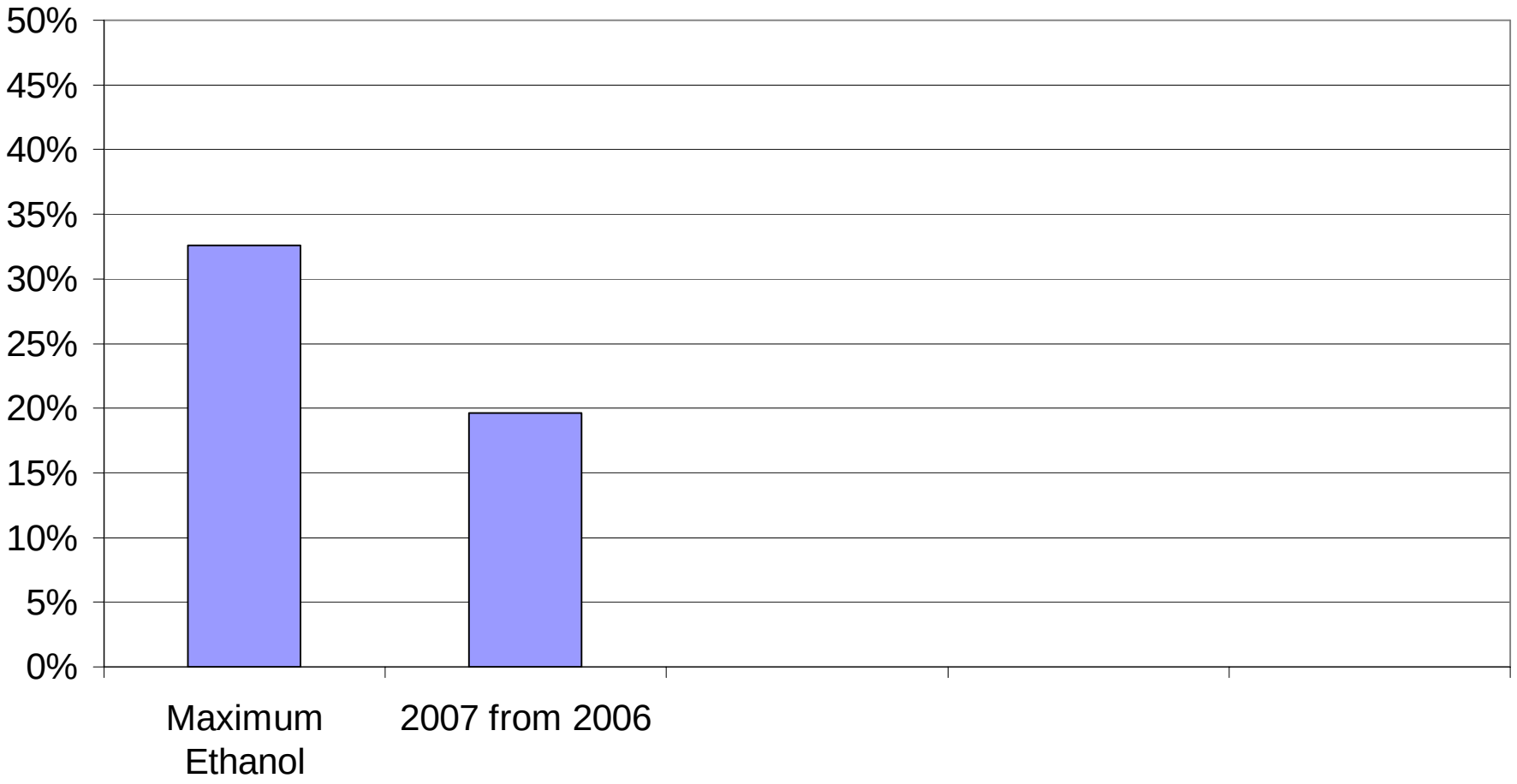
- Baseline: All corn-soybean rotation
- Scenario: All corn-corn

	Baseline	Scenario
	Million hectares	
Corn-Corn	0.00	9.21
Corn-Soybean	9.21	0.00
Total Cropped	9.21	9.21
Non-tilled	0.00	0.00

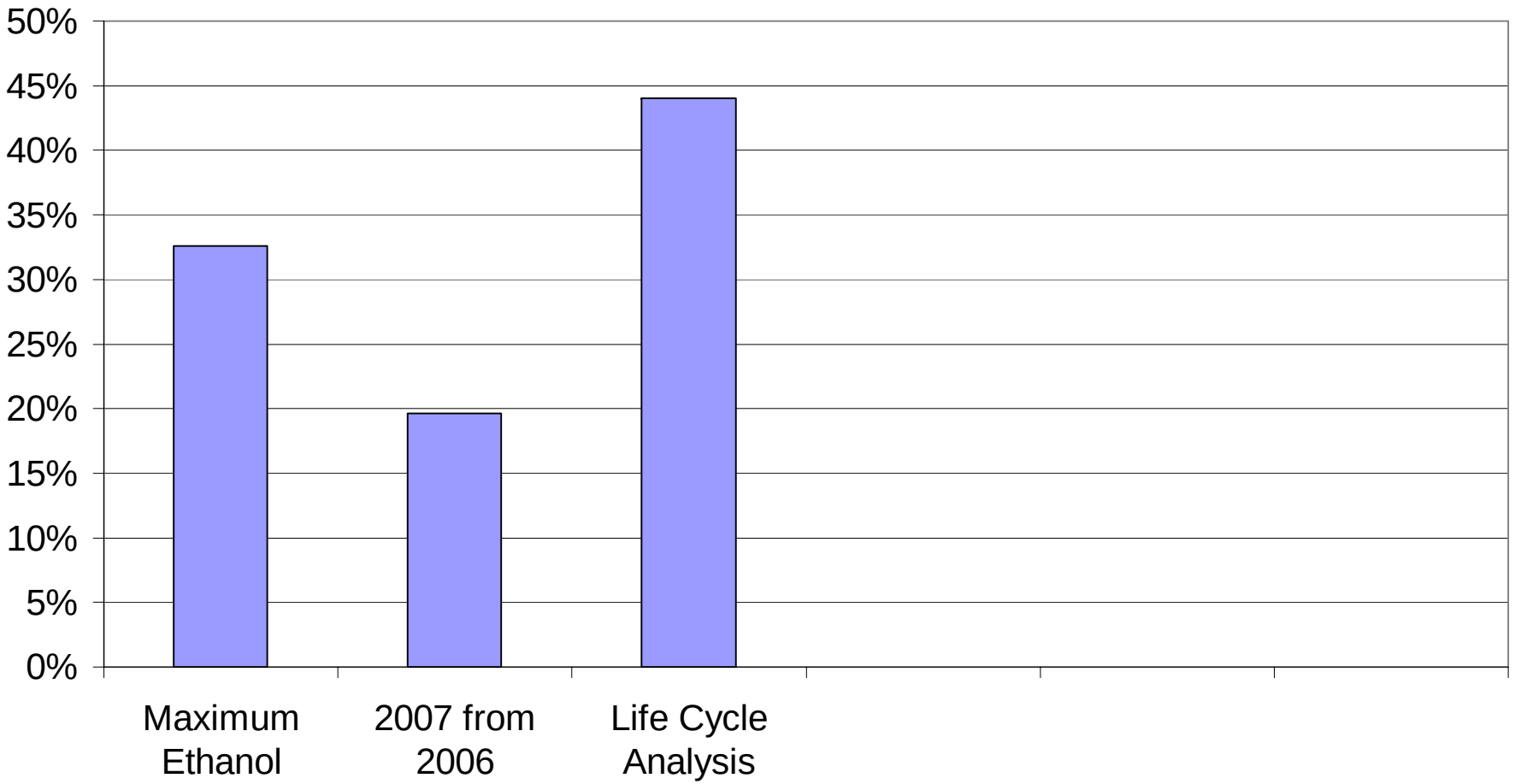
Soil Carbon

- Soil carbon change due to a change in crop rotation is negligible
- Soil carbon change involving idle land can be large and varies with different land
  - Never tilled or forested land is in equilibrium and not sequestering carbon
  - Newly idled land (such as CRP) has built-up carbon and is sequestering carbon
  - 2.47 ton/ha/year (sequestration) used by CCX
  - Double this to account for annualized lost carbon

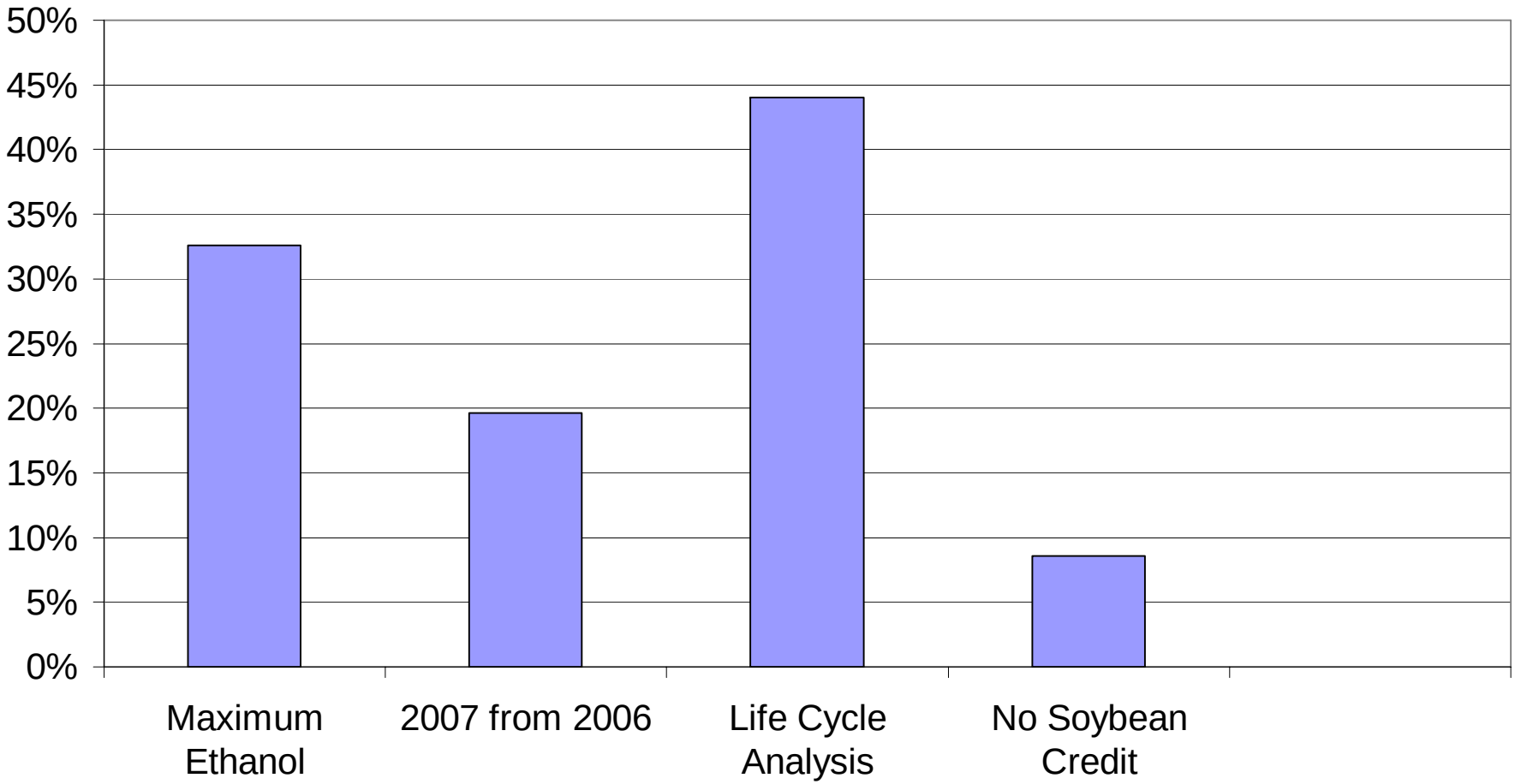
Percent Reduction In Greenhouse Gas Emissions



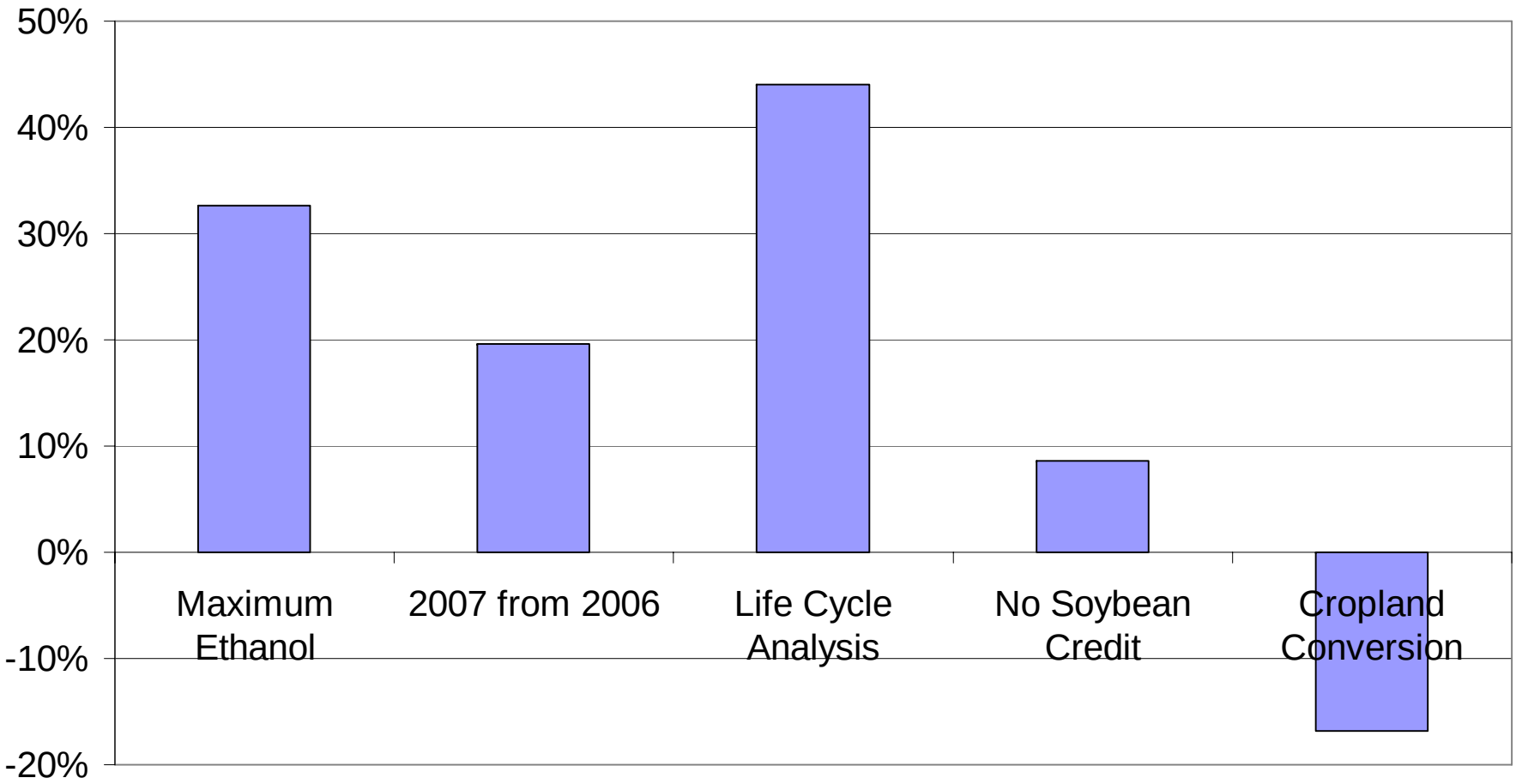
Percent Reduction In Greenhouse Gas Emissions



Percent Reduction In Greenhouse Gas Emissions



Percent Reduction In Greenhouse Gas Emissions



Implications

- LCA is necessary but not sufficient for understanding changes in GHG emissions
- Information requirements for accurate analysis daunting
- Land use changes are most important
  - How much is attributable to biofuels?
  - Time frame of conversion important
- Benefits of a carbon tax in terms of information cost savings much lower for biofuels than for power generation because of the importance of nitrogen fertilizer practices and land use