

Regional GHG Mitigation Response and Leakage Effects:

Scenario Analysis of U.S. Forestry & Agricultural Activities

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Introduction & Overview of Analysis

- Assess net GHG mitigation potential in forestry & ag
- Use FASOM-GHG model
- Mitigation results from range of scenarios
 - vary price incentive (\$/tCO₂)
 - vary eligible activities (all vs. select)
 - vary GHG targets
 - vary payment approach
- Show regional mitigation potential across U.S.
- Implications of key issues (duration, leakage)
- Economic & environmental co-effects



Modeling Framework

Forestry and Agriculture Sector Optimization Model with Greenhouse Gases (FASOM-GHG)

Key Dimensions	Forest Sector	Ag Sector
Regions	11	63
Land Base	Private timberland, USFS FIA	All U.S. cropland, USDA NRI, Ag Census, NAS
Time Scale	Base yr = 2000, 100-yr simulations, 10-yr time steps	Same
GHG Accounting	Emissions/removals from all C pools (incl. products), FORCARB	Soil C, CENTURY CH ₄ , N ₂ O, IPCC FF CO ₂
Commodities	Sawlogs, pulpwood, timber from hard- & softwoods	48 primary 45 secondary





FASOM-GHG includes full range of forestry & ag activities and net GHGs

Strategy	Basic Nature	CO2	CH4	N2O
Afforestation	Sequestration	X		
Existing timberland/reforestation	Sequestration	X		
Deforestation	Emission	X		
Biofuel Production	Offset	X	X	X
Crop Mix Alteration	Emiss, Seq	X		X
Crop Fertilization Alteration	Emiss, 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
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

FASOM-GHG projects baseline against which all mitigation results are reported

Decade	Agricultural Soil Carbon Sequestration	Biofuel Offset	Forest Carbon Sequestration	Crop Management Fossil Fuels	Agricultural CH ₄ and N ₂ O Emissions	Total Net GHG Emissions
2010	32	-11	-436	197	489	270
2020	10	-11	-222	200	503	479
2030	-83	-11	-145	213	560	535
2040	-148	-11	-225	229	597	442
2050	-167	-11	-170	242	626	520

- Numbers in TgCO₂ eq./yr (+ emissions; - net sequestration).
- Declining rate of forest seq. over time; consistent with other projections.
- Forest sink smaller than reported in EPA inventory; no public lands here.
- Ag CH₄ & N₂O calibrated with EPA inventory and projections.
- Biofuels based on EIA 2003
- Soil C....?



Mitigation Scenarios with FASOM-GHG including ALL Activities & GHGs

Constant & Rising Price Scenarios, price signal begins in 2010

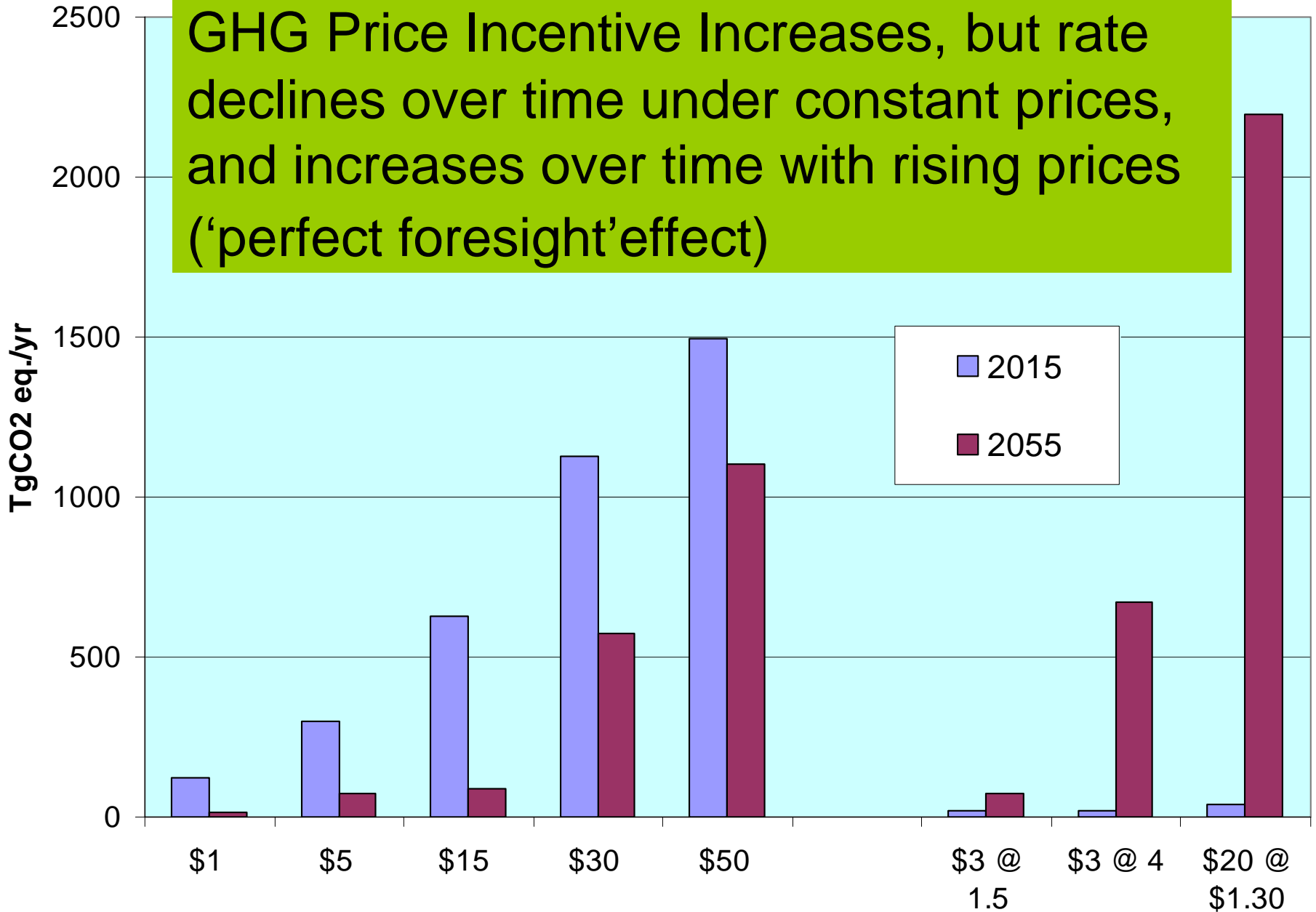
\$/tonne CO₂ eq. **\$/tonne C eq.** **Rising by...** **Capped at...**

1	3.67		
5	18.35		
15	55.05		
30	110.10		
50	183.50		
3	11.01	1.5% / yr	
3	11.01	4% / yr	\$30/tCO ₂
20	73.40	\$1.30/tCO ₂ /yr	\$75/tCO ₂

Note: Rising price paths and caps are similar to those chosen by Stanford Energy Modeling Forum-21

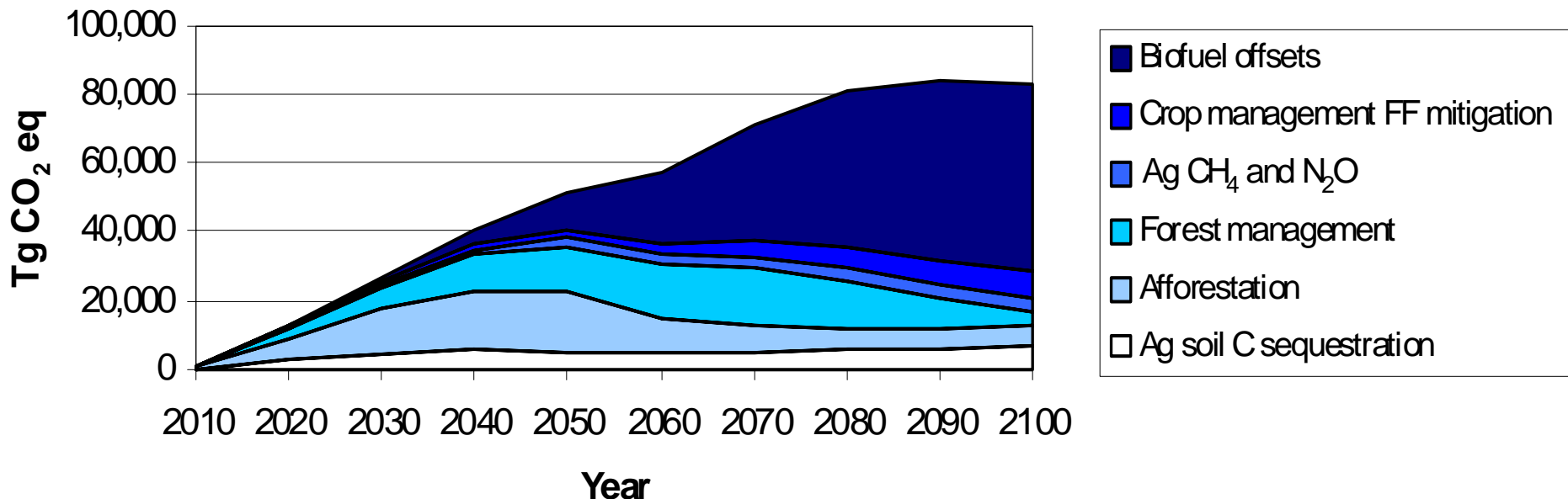


Average Annual Mitigation Increases as GHG Price Incentive Increases, but rate declines over time under constant prices, and increases over time with rising prices ('perfect foresight' effect)



Cumulative Mitigation Results Over Time Show...

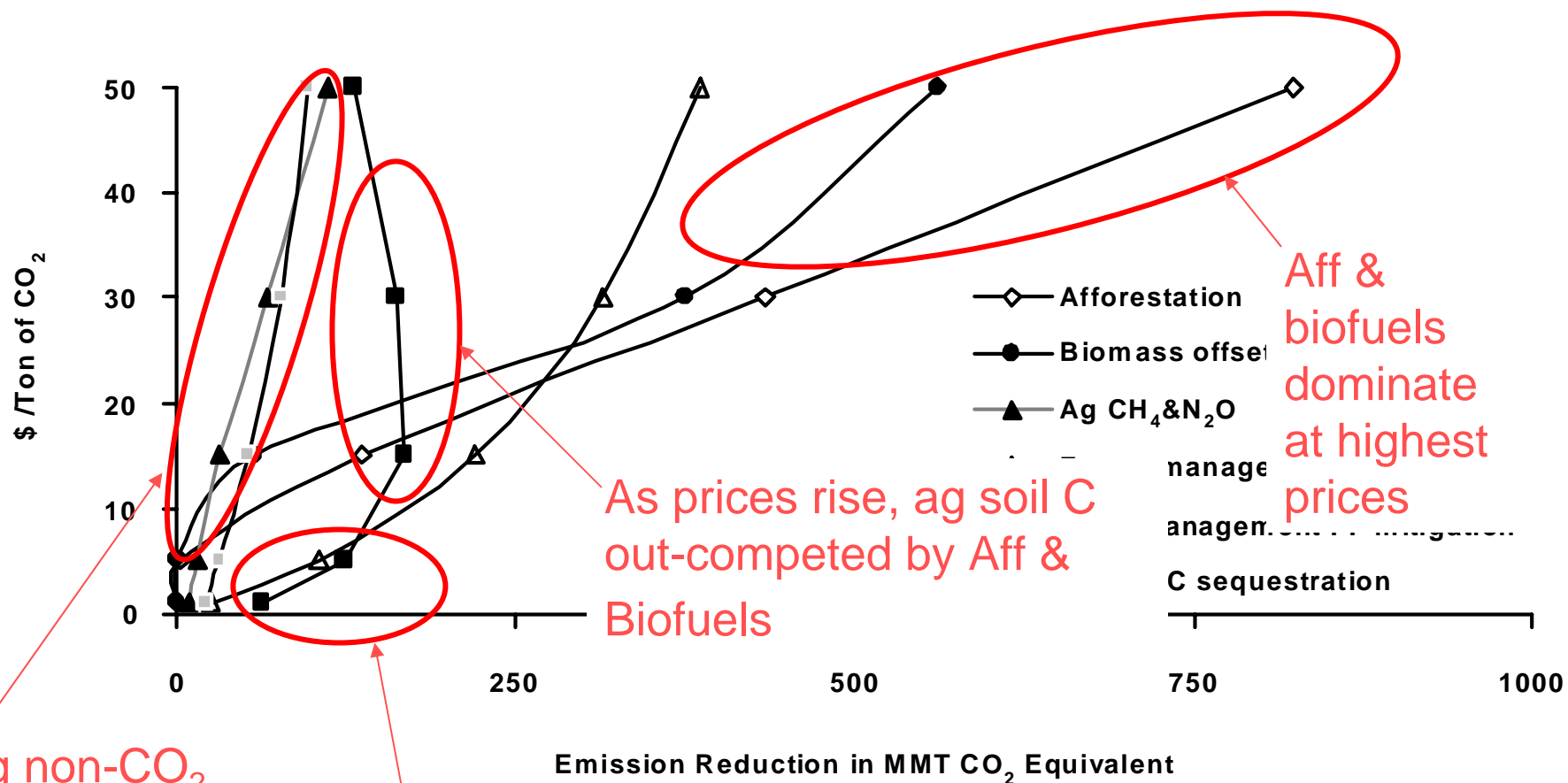
\$30/tCO₂ constant scenario



- Cumulative mitigation continues to increase, even if annual mitigation rates decline.
- As C-seq. options saturate, permanent emission reduction options (biofuels, ag non-CO₂) contribute more to portfolio.



Mitigation Contributions by Options show...



Ag non-CO₂ and ag ff CO₂ remain small but steadily increase

Forest management & ag soil C dominate at low prices

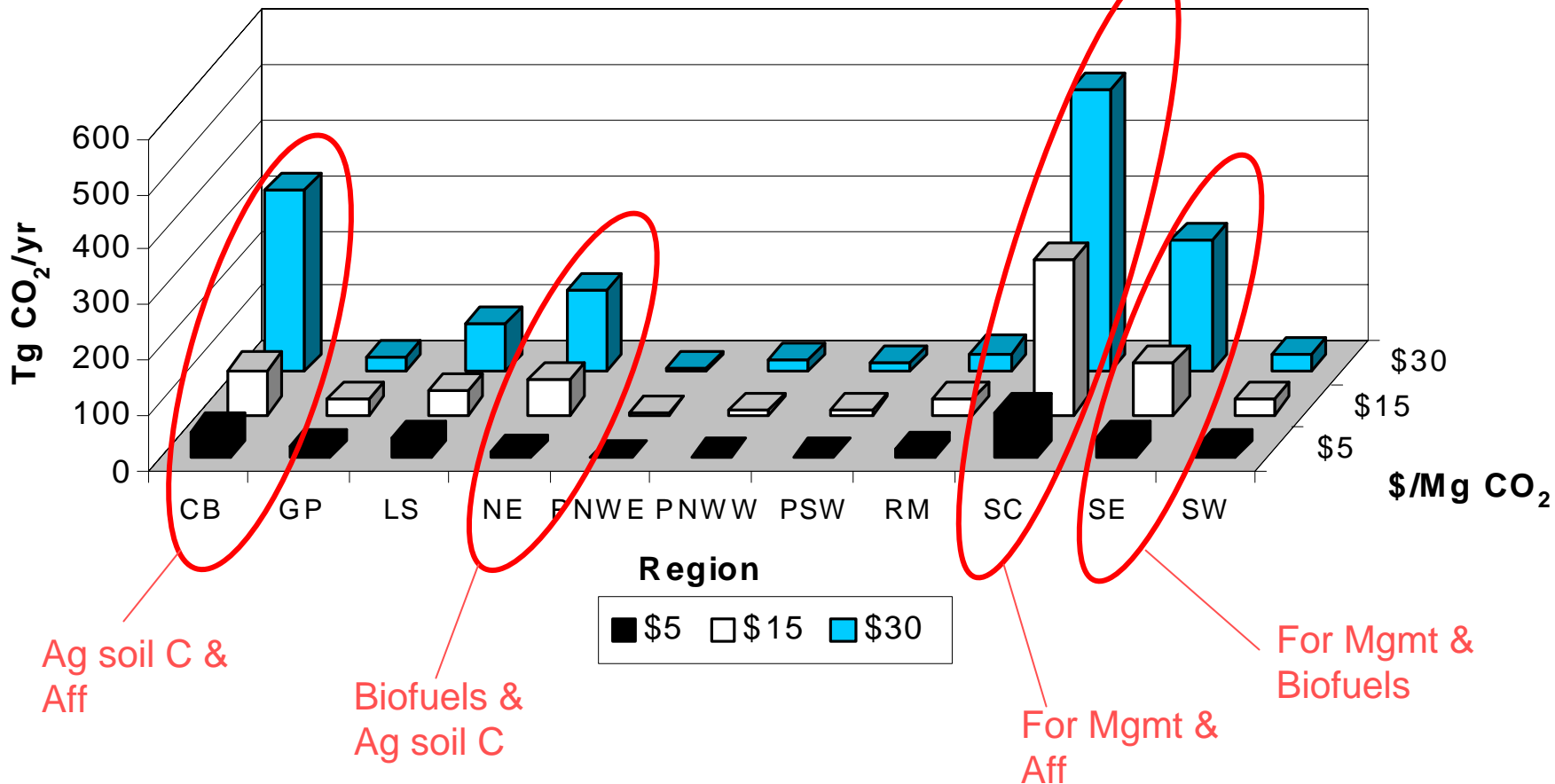
As prices rise, ag soil C out-competed by Aff & Biofuels

Aff & biofuels dominate at highest prices



Regional Mitigation Potential Varies Across U.S.

Results in TgCO₂ eq./year, annualized over 2010 - 2100.



- Corn Belt (IL, IN, IA, MO, OH)
- Northeast (CT, DE, ME, MD, MA, NH, NJ, NY, PA, RI, VT, WV)
- South-Central (AL, MS, LA, E-TX, E-OK, AR, TN, KY)
- Southeast (VA, NC, SC, GA, FL)



Mitigation Scenarios with FASOM-GHG for SELECT Activities

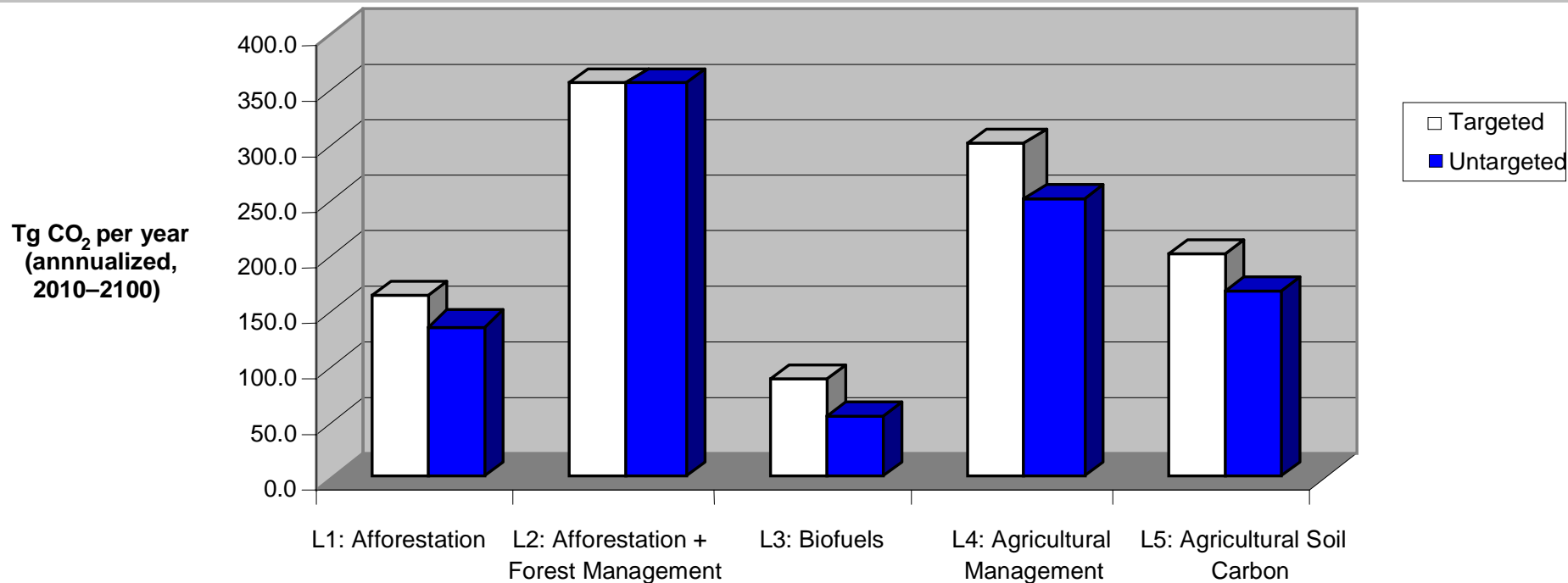
Scenario: Pay only for...	GHG price (\$/t CO ₂)		
	\$15	\$3 @ 1.5%	\$3 @ 4%
Afforestation	165	2	13
Afforestation + Forest Management	355	68	96
Biofuels	90	0	174
Agricultural Management	301	192	178
Agricultural Soil Carbon	202	136	107

Results in TgCO₂ eq./year, annualized over 2010 - 2100.



Mitigation Potential of SELECT Activities vs. Same Activities under All-Activity Scenarios

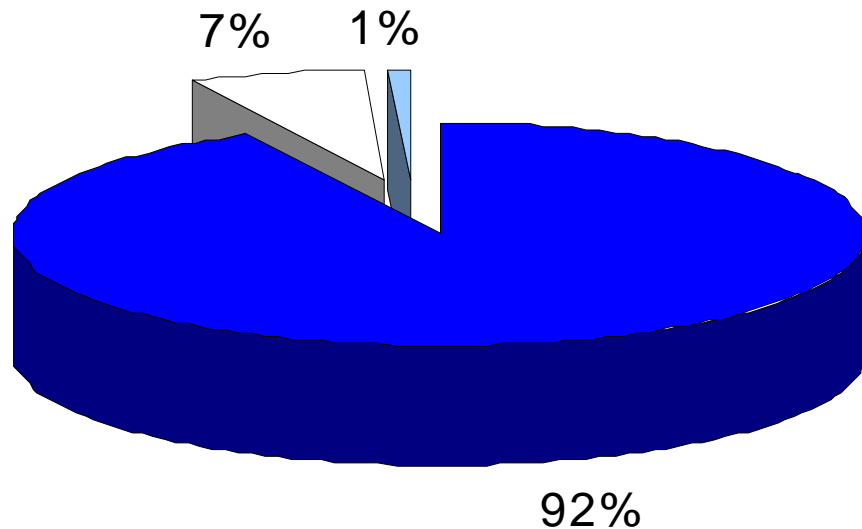
GHG Mitigation by Activity: Targeted Payments vs. Untargeted Payments (\$15/t CO₂)



- When only select activity is paid for, mitigation potential is higher.
- Select activity is not competing with other activities, as in other scenarios.
- Aff & For Mgmt compete for mitigation, so this combo shows no difference.

Regional Mitigation Potential for Pay-for-Afforestation-Only Scenario

GHG Mitigation from Targeted Afforestation Payments at \$15/tCO₂ by Region

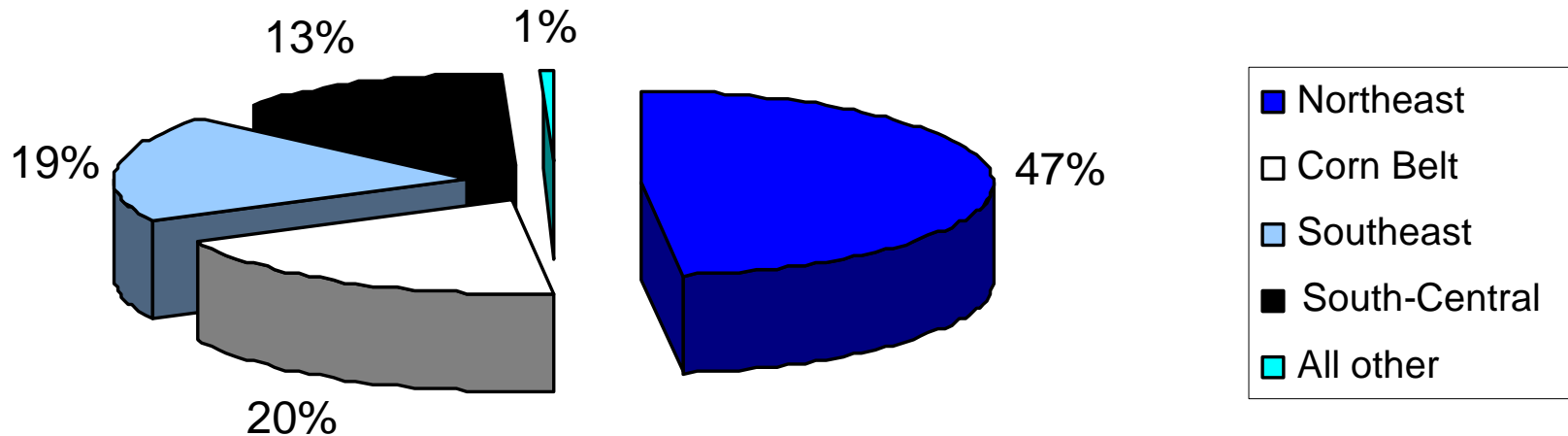


- South-Central (SC)
- Rocky Mountains (RM)
- Pacific Southwest (PSW)



Regional Mitigation Potential for Pay-for-Biofuels-Only Scenario

GHG Mitigation under Targeted Payments for Biofuel Offsets at \$3, Rising at 4% per Year: By Region



Leakage Estimates for Select Activity Scenarios

Targeted Mitigation Activities	A GHG Effects of Selected Payment (Tg CO ₂)	B Net GHG Effects of All Activities (Tg CO ₂)	C Leakage Rate ^a (%)
Afforestation Only			
\$15/t CO ₂ constant price	165	118	28.4
\$3/t CO ₂ with 1.5% rising price	2	1	54.1
\$3/t CO ₂ with 4% rising price	13	9	34.5
Afforestation + Forest Management			
\$15/t CO ₂ constant price	355	373	-5.0
\$3/t CO ₂ with 1.5% rising price	68	72	-5.6
\$3/t CO ₂ with 4% rising price	96	100	-3.9

^aLeakage % calculation: $C = (A-B)/A * 100$

- Aff-only scenario has highest leakage estimates among select activity scenarios.
- Leakage is dramatically reduced when For Mgmt added to Aff Only scenario.

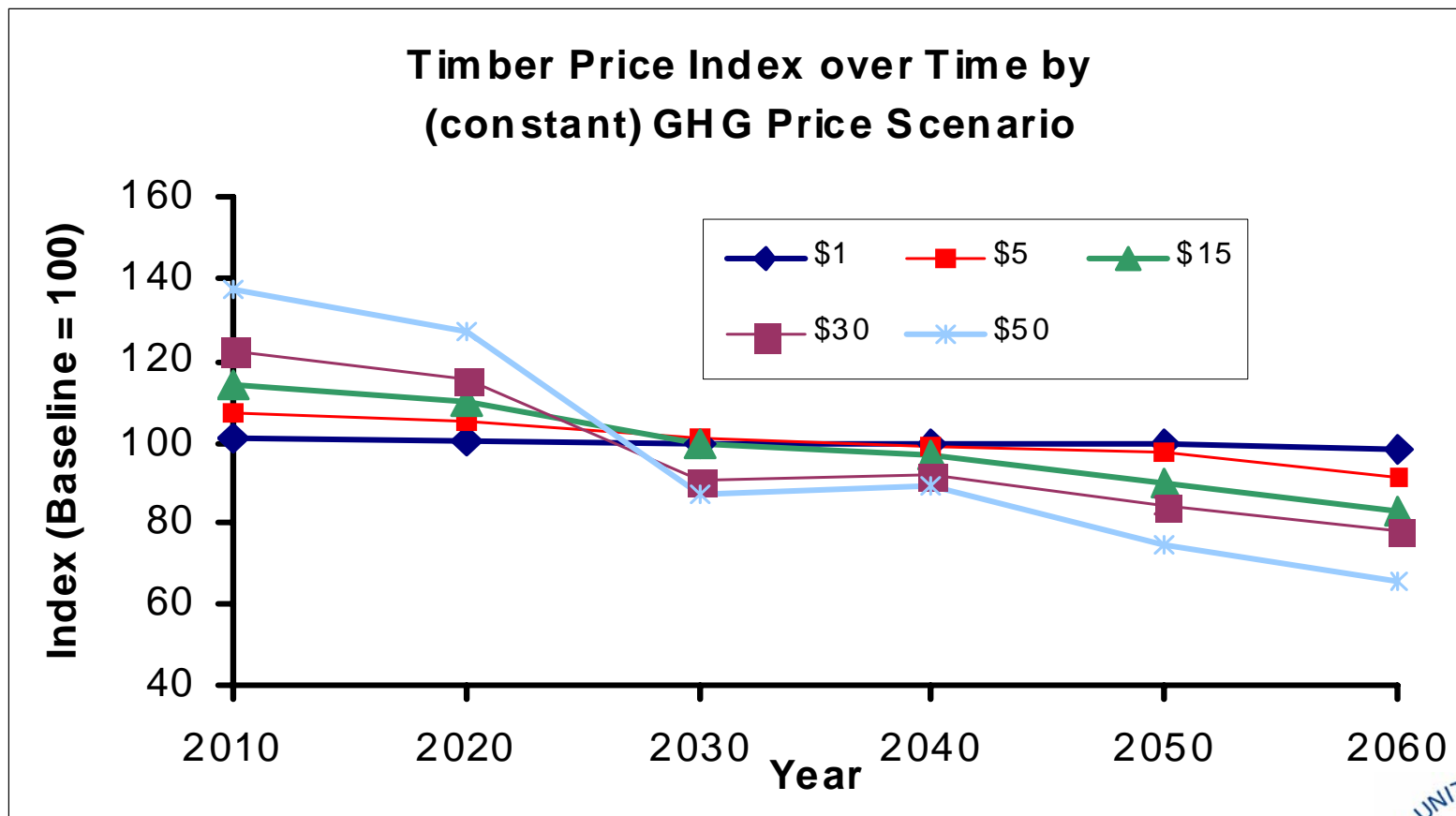
Leakage Estimates for Select Activity Scenarios

Targeted Mitigation Activities	A GHG Effects of Selected Payment (Tg CO ₂)	B Net GHG Effects of All Activities (Tg CO ₂)	C Leakage Rate ^a (%)
Biofuels			
\$15/t CO ₂ constant price	90	86	3.8
\$3/t CO ₂ with 1.5% rising price	0	-1	—
\$3/t CO ₂ with 4% rising price	174	176	-1.3
Agricultural Soil Carbon			
\$15/t CO ₂ constant price	202	201	0.7
\$3/t CO ₂ with 1.5% rising price	136	139	-1.7
\$3/t CO ₂ with 4% rising price	107	107	0.5

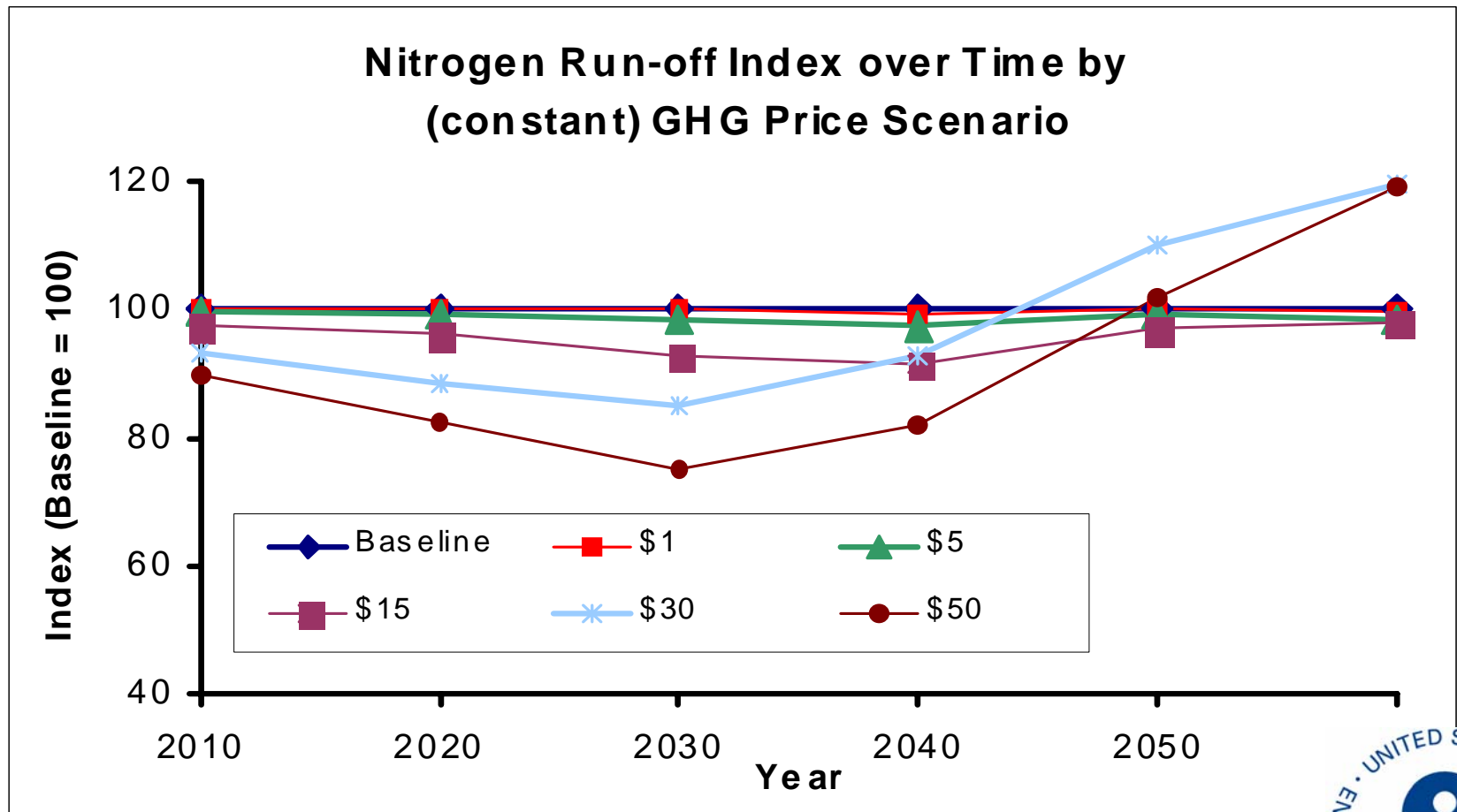
^aLeakage % calculation: $C = (A-B)/A * 100$

- Leakage estimates for both Biofuel- & Ag Soil C-only scenarios are minimal.

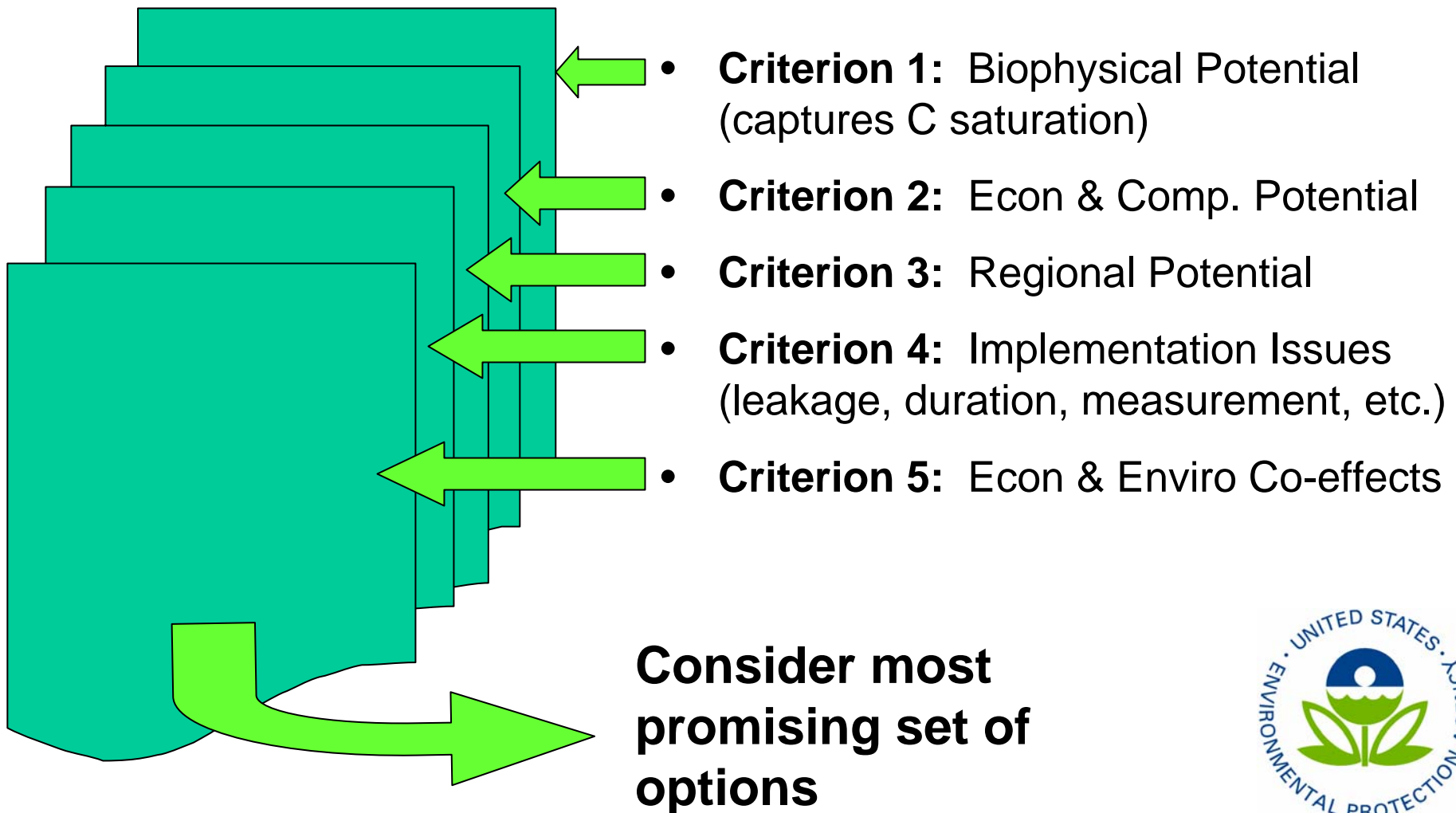
Mitigation Actions Induced by GHG Incentives Have Economic Co-effects



Mitigation Actions Induced by GHG Incentives Have Environmental Co-effects



Important to Evaluate Options Using Multiple Criteria, from biophysical potential to implementation issues, to co-effects



Key Observations to Date

- GHG mitigation potential (at 'mid' prices, \$5-15/tCO₂) appears significant over next few decades: 4 - 9% current U.S. GHG emissions.
- Carbon saturation has declining effect on annual mitigation rate, though cumulative mitigation steadily increases; saturation also causes portfolio shift towards permanent-reduction options over time.
- Ag soil C & For Mgmt are lower cost options; Aff & Biofuels dominate at higher prices.
- Corn Belt, Southeast, South-Central & Northeast offer largest mitigation potential.
- Empirical evidence of leakage when eligible activities are limited; Aff-only scenario shows highest leakage; others minimal.
- Economic & environmental co-effects can be significant and may help guide regional/activity selection for mitigation actions.