Estimating the Levelized Cost to Sequester Carbon (\$/ton CO_2e) in Four Different Types of Forest Carbon Sequestration Projects

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Topics

- The Analytic Challenge
- EPRI Model Overview
- Forest Carbon Accounting
- Quantitative Results & Summary

The Analytic Challenge

- How can electric companies decide on the best approach to use to invest in forest carbon sequestration projects?
- How can they calculate the cost-effectiveness of different ways to implement forest carbon sequestration projects so they can be compared?
- EPRI recently developed a computer simulation model to estimate the cost-effectiveness forest carbon sequestration projects.

Forest Carbon Management Options

- **No Harvest**
  - Buy land & plant trees
  - Retain ownership for 100 years
  - No timber harvest allowed
- **Donate**
  - Buy land & plant trees
  - Donate land in year 5 to land management agency or non-profit
  - Company retains carbon rights over 100 years
- **Thin**
  - Buy land &plant trees
  - Retain ownership for 100 years
  - Thin forest in year 50, 60, and 70
- **Harvest**
  - Same as “Thin”
  - “Optimal” final timber harvest between years 71-100.

GHG-CAM v1.0 Overview

- Greenhouse Gas Cost Analysis Model (GHG-CAM v1.0)
  - Excel®-based spreadsheet model
  - Incorporates “Real Options Calculator” (ROC[1]) add-in
  - Developed by EPRI in conjunction with Cinergy Corp. in 2004
- Version 1.0 includes three analysis “modules”
  - Biomass Cofiring
  - Heat Rate Improvement
  - **Forest Carbon Sequestration**
- Version 1.1 now in development includes:
  - New Wind Generation
  - New Solar Generation

[1]The “ROC” is available from Onward, Inc. at www.onwardinc.com.

GHG-CAM Purpose

- Analyzes and compares on a **financial basis** different GHG emissions reduction actions.
  - Calculates the **present value after-tax net income** of the proposed project, including the expected future value of carbon "credits" and any required carbon "buyback" for thinning and harvest.
  - Calculates the **GHG emissions reductions** for each GHG abatement action over a defined project time horizon.
  - Calculates the cost-effectiveness of each abatement action on the basis of the **levelized cost** of emissions reductions (\$/ton CO_2e).
- Analysis Methods
  - Based on modern finance & statistical methods
  - Uses advanced discounted cash flow (DCF) approach
  - Monte-Carlo simulation is used to reflect uncertainty in the "real" values of key variables (e.g., carbon prices, electricity prices,…)
  - Calculates real option values, and derives optimal exercise strategy

GHG-CAM Analysis “Perspectives”

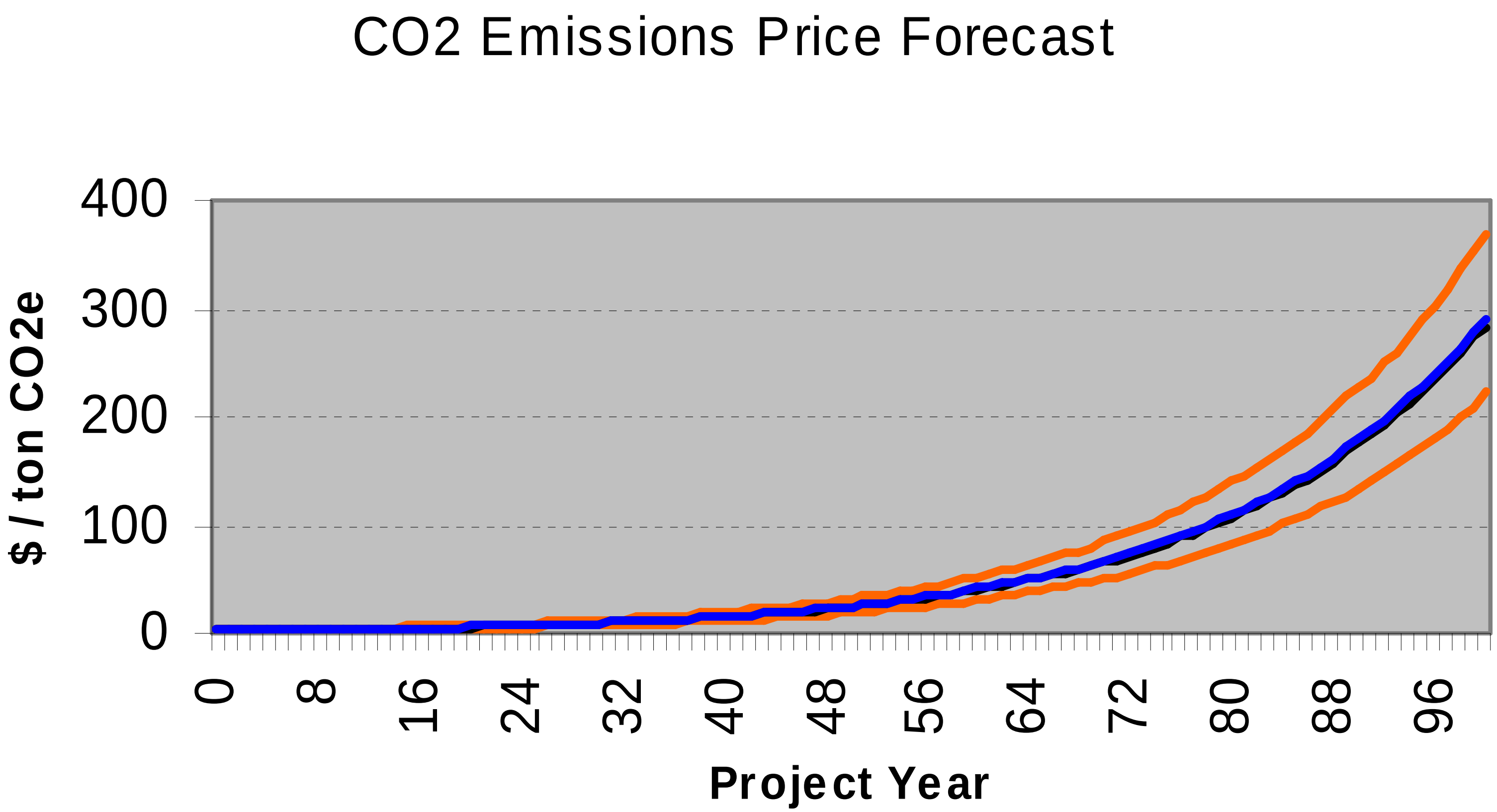
- Deterministic
  - Uses “best guess” estimates for key uncertain variables
  - Results are shown as a single number (e.g., \$10/ton CO_2e)
  - Includes \$0 and \$+ expected future carbon prices
- Stochastic
  - Describes key uncertain variables probabilistically
  - Monte-Carlo simulation is used to generate uncertain input values
  - Outputs include: expected value, range, frequency, and value at risk
  - Includes \$0 and \$+ expected future carbon prices
- Real Options
  - Same features as stochastic analysis perspective
  - Project value also includes real option value and key price uncertainties
  - Determines optimal option “exercise” strategy to implement project
  - Expected future carbon prices is the “monitored” forecast

Forward Prices (1 of 2)

- GHG-CAM incorporates user-defined forward prices for fuels, commodities and emissions allowances, including:
  - **Expected carbon prices** (\$/ton CO_2e)
  - **Expected timber prices** (\$/mbf)
  - Biomass fuel prices (\$/MMbtu)
  - Wholesale electricity prices (\$/MWh)
  - NO_x allowance prices (\$/ton)
  - SO_2 allowance prices (\$/ton)
  - Coal fuel prices (\$/MMbtu)

- To incorporate key uncertainties into forward prices over the time horizon of a proposed GHG abatement project (e.g., 100 years), GHG-CAM uses sophisticated statistical tools to generate probability-based forward price curves.
  - User-defined statistical process (GBM, EMR, MR, other)
  - User-defined statistical parameters (stnd. dev./ volatility, half-life, etc.)

Forward Prices (2 of 2)



Note: This is solely an illustration and does not represent the official views of EPRI.

Notes:

— Blue Line: Mean Price

— Black Line: Median Price

— Orange Lines: 10-90 confidence interval

Forest Carbon Accounting

- Based on regional per-acre data (Birdsey 1996[1])
- Carbon accounting is done across all acres planted
- Calculates dollar cost of carbon “buyback” when the forest is thinned or harvested
- Is based on “net carbon sequestered”
- The quantity of carbon expected to be sequestered in the forest is discounted back to its present value when calculating levelized cost.

Notes: 1. Birdsey, Richard A., "Carbon Storage for Major Forest Types and Regions in the Coterminous United States", in Forests and Global Change, Vol. 2: Forest Management Opportunities for Mitigating Carbon Emissions, ed. Sampson, Neil, R. and Dwight Hair, American Forests, Washington DC 1996, Appendix 4, Table 26, p. 361.

Forest Carbon Project Example

- Location: Corn Belt
- Species: Mixed Hardwoods
- Management: Even-Aged
- Site Index: All Sites
- Data Source:
  - Richard Birdsey (1996), USDA Forest Service
  - Land Type: “Regional estimates of timber volume and forest carbon for managed timberland”
  - Species and Management Intensity: “Corn Belt, mixed hardwoods, former pasture, even-aged management, all sites”

Example "Birdsey" Data

Regional Estimates of Timber Volume and Forest Carbon for Managed Timberland,
Corn Belt, mixed hardwoods, former cropland, even-aged management, all sites

Age of Trees	**Without Harvest**				**With Harvest**						
	Timber	***Carbon Storage***			***Timber***		***Carbon Storage***				
	Standing Volume	Carbon in Live Vegetation	Other Organic Carbon	Total Carbon	Standing Volume	Harvested Timber Volume	Carbon in Live Vegetation	Other Organic Carbon	Carbon in Logging Debris	Carbon in Harvested Timber	Post Harvest Total Carbon
	/2	/3	/4						/5	/6	
(years)	(cu ft /ac)	(1,000 lbs / acre)			(cu ft /ac)	(cu ft /ac)	(1,000 lbs / acre)				
0	0	0	37	37	0	0	0	37	0	0	37
5	298	16	41	57	298	0	16	41	0	0	57
10	746	36	45	81	746	0	36	45	0	0	81
15	1,194	57	49	106	1,194	0	57	49	0	0	106
20	1,693	80	53	133	1,694	0	80	53	0	0	133
25	2,193	103	57	160	2,193	0	103	57	0	0	160
30	2,673	125	61	186	2,673	0	125	61	0	0	186
35	3,152	147	65	212	3,152	0	147	65	0	0	212
40	3,624	168	69	237	3,624	0	168	69	0	0	237
45	4,096	190	73	263	4,096	0	190	73	0	0	263
50	4,543	210	77	287	3,900	644	181	77	5	2	265
55	4,991	231	81	312	4,347	0	201	81	3	2	287
60	5,405	250	84	334	4,131	630	192	84	7	4	287
65	5,819	269	88	357	4,545	0	211	88	4	4	307
70	6,199	287	90	377	4,269	657	198	90	7	6	301
75	6,580	305	93	398	4,649	0	216	93	4	5	318
80	6,925	321	95	416	4,350	644	202	95	7	7	311
85	7,270	337	96	433	4,695	0	218	96	4	7	325
90	7,585	351	98	449	5,010	0	233	98	3	7	341
95	7,900	366	99	465	5,325	0	247	99	2	6	354
100	8,187	379	100	479	0	5612	2	100	77	25	204
105	8,475	392	101	493	298	0	16	89	45	22	172
110	8,743	404	102	506	746	0	36	90	27	21	174
115	8,993	416	103	519	1,194	0	57	91	16	20	184
120	9,123	422	104	526	1,694	0	80	92	9	20	201

Source: Birdsey, Richard A., "Carbon Storage for Major Forest Types and Regions in the Coterminous United States", in Forests and Global Change, Vol. 2: Forest Management Opportunities for Mitigating Carbon Emissions, ed. Sampson, Neil, R. and Dwight Hair, American Forests, Washington DC 1996. Washington DC 1996, Appendix 4, Table 25, p. 360.

Project Specific Assumptions

Project Specific Assumptions	No Harvest	Donate Land	Thinning	Harvest
Tons C to Tons CO2e	3.67	3.67	3.67	3.67
Option period (Yrs)	NA	5	50	71-100
Project Lifetime (Yrs)	100	100	100	100
Local Property Tax Rate	2.50%	2.50%	2.50%	2.50%
Receive Tax Benefits for Donation?	No	No	No	No
GHG Buyback (%)	0%	0%	50%	50%
# of Acres Planted	500	500	500	500
Construction Period (Years)	0	0	0	0
Annual Forest Management Cost ($ / acre)	$5.00	$5.00	$5.00	$5.00
Annual Fire Protection Cost ($ / acre)	$0.00	$0.00	$0.00	$0.00
Annual Insurance Cost ($ / acre)	$0.75	$0.75	$0.75	$0.75
Annual Carbon Monitoring Cost ($ / acre)	$0.50	$0.50	$0.50	$0.50
Annual Carbon Verification Cost ($ / acre)	$0.50	$0.50	$0.50	$0.50
Annual Carbon Certification Cost ($/ acre)	$0.75	$0.75	$0.75	$0.75
Expected Net Lumber Price (Thinning) **($ / mbf)**	NA	NA	$370.00	$370.00
Expected Net Lumber Price (Harvest) **($ / mbf)**	NA	NA	$370.00	$370.00

Note: Yellow-colored cells are user-defined.
Red-colored cells are user-defined but in a different location in the model.
Black-colored cells are locked to user input.

Forest Carbon Module Scenarios (1 of 3)

- "Base Case"
  - **No Harvest:** Company buys land, plants trees and retains ownership for 100 years; no timber harvest.
- Multiple "Project Cases:"
  - **Donate:** Company buys land, plants trees, and donates land in year 5 to a qualified land management agency or non-profit; company retains carbon rights over 100 years.
  - **Thin:** Company buys land, plants trees and retain ownership. Forest is thinned in year 50, 60, and 70.
  - **Harvest:** Same as "Thin", and forest is "optimally" harvested between year 71-100.
- "All Options" Case
  - Base case is No Harvest
  - ROC determines optimal forest management regime based on all available management options (i.e., Donate, Thin and Harvest)

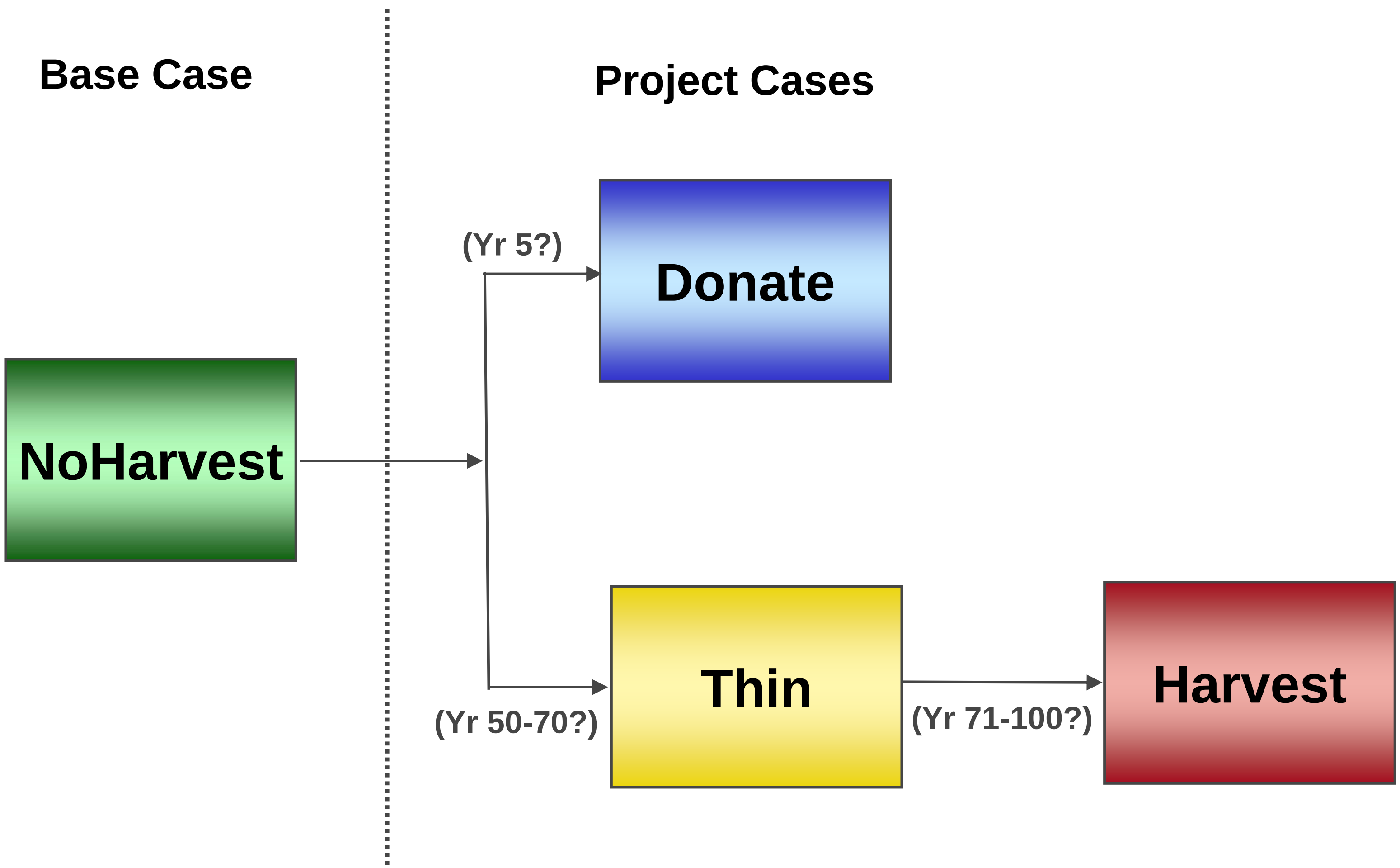
Forest Carbon Scenarios (2 of 3)

- Donate, Thin and Harvest are "real options"
  - For an electric company that owns forest land, these land management action are real options that can be "exercised" anytime during the forest rotation.
  - The "exercise price" for each of these real option is the present value of the discounted capital costs associated with conducting the specific activity.

- Option Exercise Rules
  - "Donate" option only can be exercised in project year 5.
  - "Thin" option only can be exercised in year 50.
  - "Harvest" option can be exercised in any year 71-100.

- Carbon "Buyback"
  - "Buyback" refers to the amount of CO_2e an electric company may need to purchase, or otherwise acquire, to "net out" the CO_2e released into the atmosphere from timber harvesting and related post-harvest activities.
  - GHG-CAM incorporates carbon buyback for thinning and final timber harvests.
  - Users can choose buyback percentage (e.g., 0-100% buyback).

Forest Carbon Module Scenarios (3 of 3)



Analytic Results

Summary of Analytic Results -- Forest Carbon Sequestration	Stochastic				Real Option
Scenario	No Harvest	Donate Land	Thin	Harvest	AllOptions
Expected Carbon Price Year 0 ($/ton CO2e)	**$3.00**	**$3.00**	**$3.00**	**$3.00**	**$3.00**
PV Gross Margin (After-Tax)	$ (459,434)	$ (319,278)	$ (379,340)	$ (381,857)	$ (321,242)
GHG Emissions Reductions (tons CO2e)					
GHG Emissions Reductions (2010-2012)	13,212	13,212	13,212	13,212	13,212
GHG Emissions Reductions (2004-2104)	405,535	405,535	302,775	302,270	405,535
PV GHG Emissions Reductions (2004-2104)	59,852	59,852	58,452	58,452	59,852
Levelized GHG Abatement Cost (After-Tax) PV $ Net Income / PV Ton CO2e (2004-2104)	**$ (7.68)**	**$ (5.33)**	**$ (6.49)**	**(6.53)**	**$ (5.37)**

- **Analysis Perspectives** – Final results are displayed for deterministic, stochastic, and real-options analysis perspectives.
- **Carbon Prices** – Final results also are displayed based on:
  - $0 / ton CO2e expected future carbon prices (“compliance cost” perspective)
  - $+ / ton CO2e expected future carbon prices (“market” perspective)

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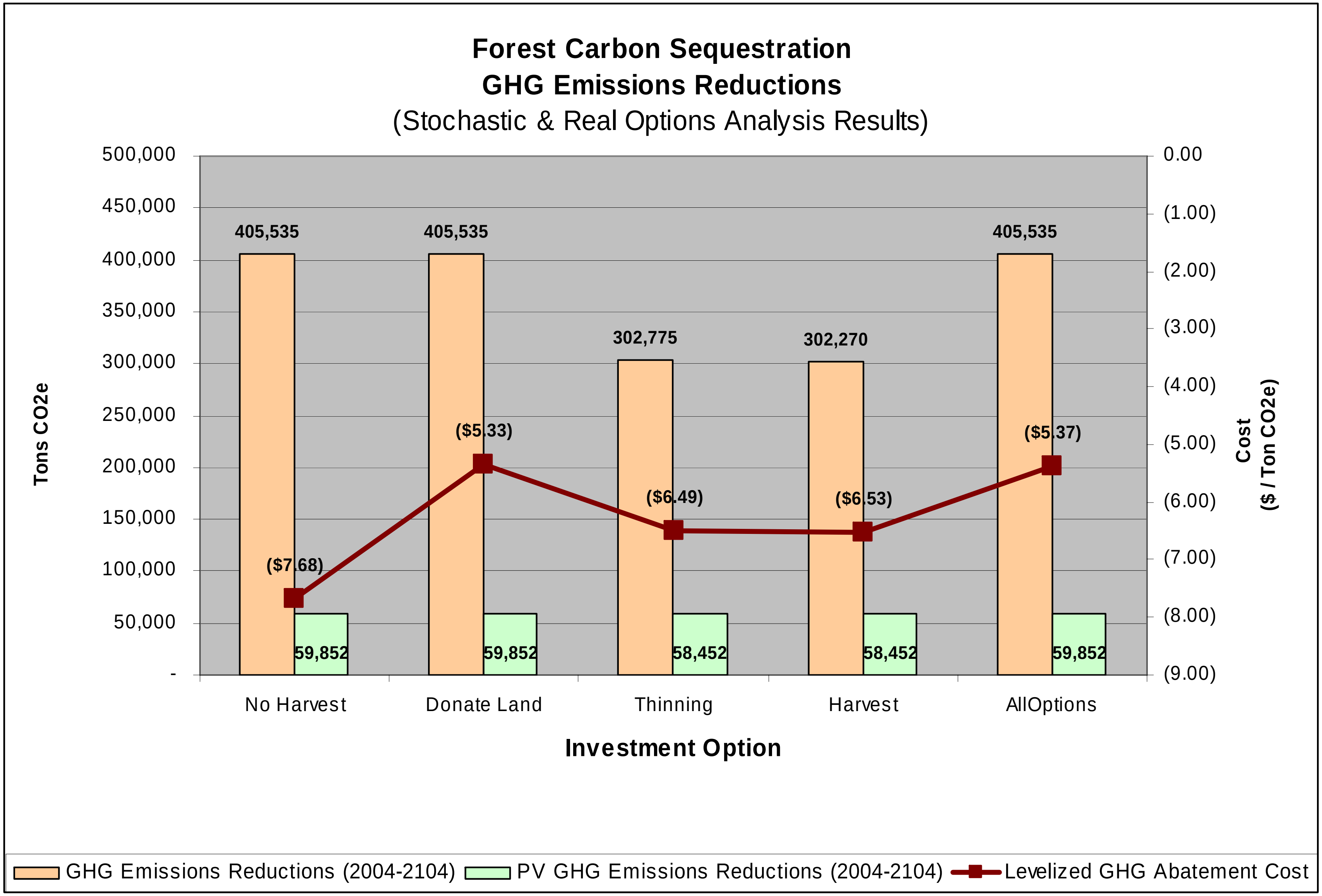
GHG Emissions Reductions



Summary

- Forest C sequestration leads to **indirect** GHG emissions offsets
  - C sequestration is relatively slow during the early years of the rotation.
  - Discounting reduces the present value of the “back loaded” C sequestration that takes place in the later years.

- “Levelized cost” provides a powerful, analytically consistent metric that can be used to compare different GHG emissions reduction options. Levelized cost” depends on which analysis “perspective” is used.

- “Donate” appears to be the best option for forest sequestration in our example of mixed hardwoods planted in the Midwest U.S.
  - Levelized cost = ~$5.33 **loss** of net income per ton CO_2e ($5.33/ton CO_2e).
  - This option would be exercised100% of the time.
  - Levelized cost is between $6-$8.00/ton CO_2e for the *No Harvest, Thin* and *Harvest* scenarios.

- Real options analysis can help an electric company to select the optimal strategy for implementing each type of GHG abatement.

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