A TECHNO-ECONOMIC EVALUATION OF THE FINANCIAL TRADE-OFF BETWEEN THE PRODUCTION OF BIOCHAR, BIOFUEL, AND METHANOL VIA PYROLYSIS UNDER UNCERTAINTY

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STUDY OBJECTIVES

- Performed a complete techno-economic evaluation of the financial trade-off between the production of biochar, biofuel, and methanol via pyrolysis pathways under uncertainty.
  - Analyzed two fast pyrolysis pathways and three slow pyrolysis pathways from literature.
  - Determined starting carbon prices, and a baseline minimum carbon price for each scenario modeled.

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SIGNIFICANCE

ENVIRONMENTAL

- PPM threshold
- Increased global temperatures
- Increased importance of specified energy pathway development

DOMESTIC ENERGY POLICY

- Marginal decarbonization versus negative emissions (federal efforts)
- Interest from policy makers and investors
- Slow pyrolysis versus fast pyrolysis; market value

INTRODUCTION

BROWN AND WRIGHT'S (2014)[1] FAST PYROLYSIS MODEL

- Discounted cash flow rate of return calculations to determine the net present value for each scenario
- Scenario inputs and their adjusted values
- Annual cost projections for energy commodities
- Inflation factors based on public price indeces
- Uncertainty from running scenario-specific Monte Carlo Analysis

Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5
Fast pyrolysis to biochar Costs: Wright and Brown (2007)[1]	Fast pyrolysis to fuels & biochar Costs: Brown et al. (2011)[2]	Slow pyrolysis to biochar Costs: Brown et al. (2011)[2]	Slow pyrolysis to biochar & methanol under 300°C Costs: Shabangu et al. (2014)[3]	Slow pyrolysis to biochar and methanol under 450 °C Costs: Shabangu et al. (2014)[3]

SCENARIOS:

TABLE #1 - FINANCIAL ASSUMPTIONS

Financial assumptions	Scenario 1 ($MM)[1]	Scenario 2 ($MM)[2]	Scenario 3 ($MM)[2]	Scenario 4 ($MM)[3]	Scenario 5 ($MM)[3]
Capital Cost	206.0	396.8	122.1	486.5	634.7
Fixed capital investment	171.8	368.5	113.4	451.0	588.4
Fixed operating cost	10.4	16.7	8.5	19.5	25.4
Fuel gas	-5.0	-	-11.9	-	-
Hydrogen cost	27.8	22.7	-	-	-
Other variable cost	10.9	1.9	10.1	41.7	41.7
Electricity cost	-5.6	-12.8	-	-	-
Biochar cost	-15.4	-	-37.5	-20.6	-5.2

TABLE #2 - TECHNICAL INPUTS

Technical Inputs	Scenario 1[1]	Scenario 2[2]	Scenario 3[2]	Scenario 4[3]	Scenario 5[3]
Cost basis year	2016	2016	2016	2016	2016
Feedstock (Mg/day)	2000	2000	2000	2192	2192
Operating hours per year	7872 (90.1%)	7900 (90.43%)	7900 (90%)	8000 (91.58%)	8000 (91.58%)
Net power required (MW)	-11.5	-28.2	0.0	0.0	0.0
Fuel gas required (MMBTU/hr)	-110	0	-283.54	0.0	0.0
H2 use (kg/day)	2041	2045	0.0	0.0	0.0
Gasoline production (MGY)	58.2	28.7	0.0	11.9	29.8
Diesel fuel production (MGY)	0.0	28.7	0.0	0.0	0.0
Net biochar CO2e (MT/hr)	-32	0.0	-77	-42.38	-10.69

METHODOLOGY

OVERVIEW

- This study updates the Brown and Wright (2014) fast pyrolysis model to 2016 USD.
- The updated model incorporates Renewable Identification Number (RIN) D5 (advanced biofuel) prices under uncertainty
- The current modeling methodology calculates D3 (cellulosic biofuel) prices as a function of D5 prices and cellulosic biofuel waiver credit values.

MODELING

- The harmonization process is used to combine data from a variety of literature sources and to provide researchers with a comparable scenario-to-scenario analysis.
- Steps taken to achieve data harmonization:
  - Identify the peer-reviewed literature that contains the technical and monetary assumptions needed for the specific analysis
  - Identify the cost basis year of all monetary assumptions
  - Adjust the monetary assumptions to a common cost basis year (2016 USD) to harmonize the data, and account for inflation using the Chemical Engineering Plant Cost Index (CEPCI)
  - Convert all technical assumptions to the same units

MODELING

- Monte Carlo Simulation - Output probability distributions were developed through 10,000 modeling runs.
- Stochastic analysis:
  - These cash flows are used to create probability distribution curves using Microsoft Excel and Oracle's Crystal Ball Modeling Software for Monte Carlo simulations
  - 95% confidence interval
- Special VisualBasic Code - Determined each scenario-specific baseline's minimum carbon price.
- Abatement Mechanism:
  - This analysis assumes an abatement mechanism gives abatement credits for t/CO2e sequestered from biochar
  - The abatement credits are equal to the carbon price

RESULTS & DISCUSSION

FIGURE #1 - SCENARIO 1: FAST PYROLYSIS TO BIOCHAR

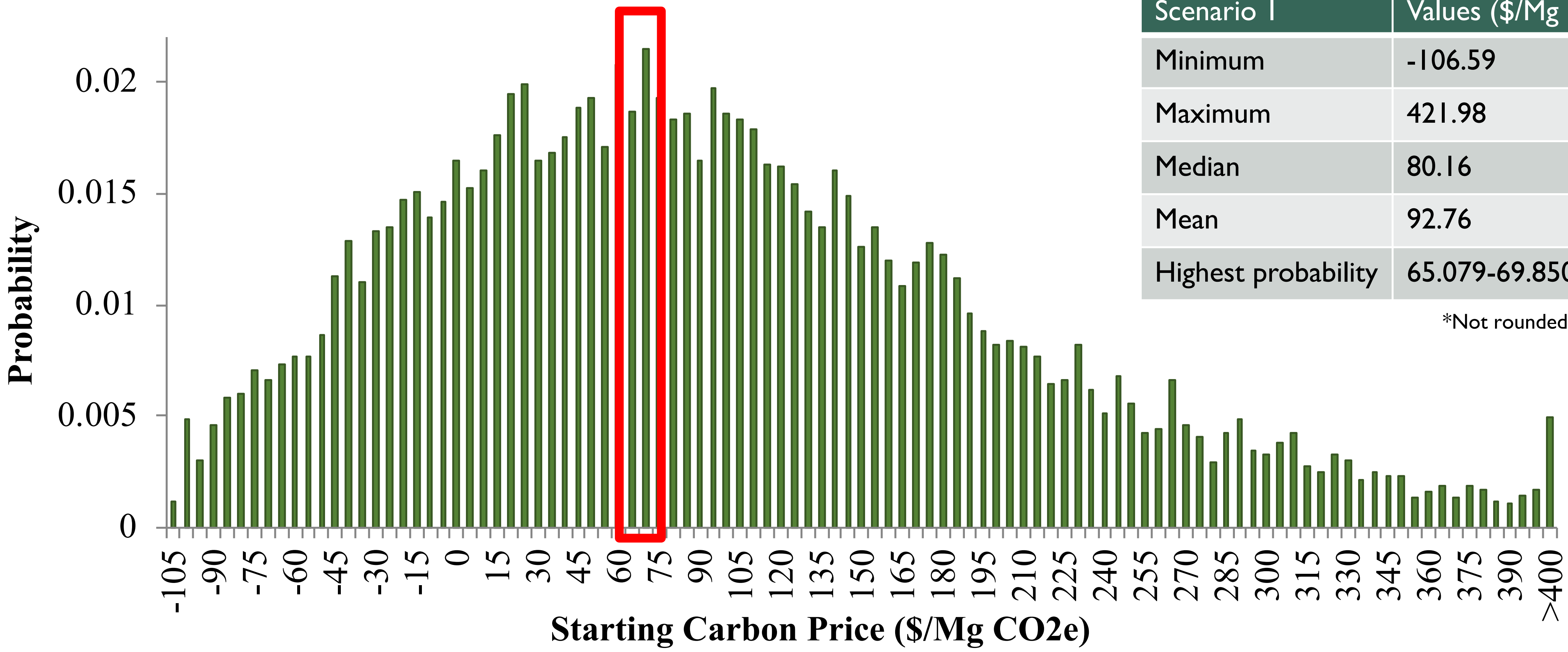

Table #3 - Starting carbon price values for Scenario 1

Scenario 1	Values ($/Mg CO2e)
Minimum	-106.59
Maximum	421.98
Median	80.16
Mean	92.76
Highest probability	65.079-69.850*

*Not rounded to show range

FIGURE #2 - SCENARIO 2: FAST PYROLYSIS TO FUELS AND BIOCHAR

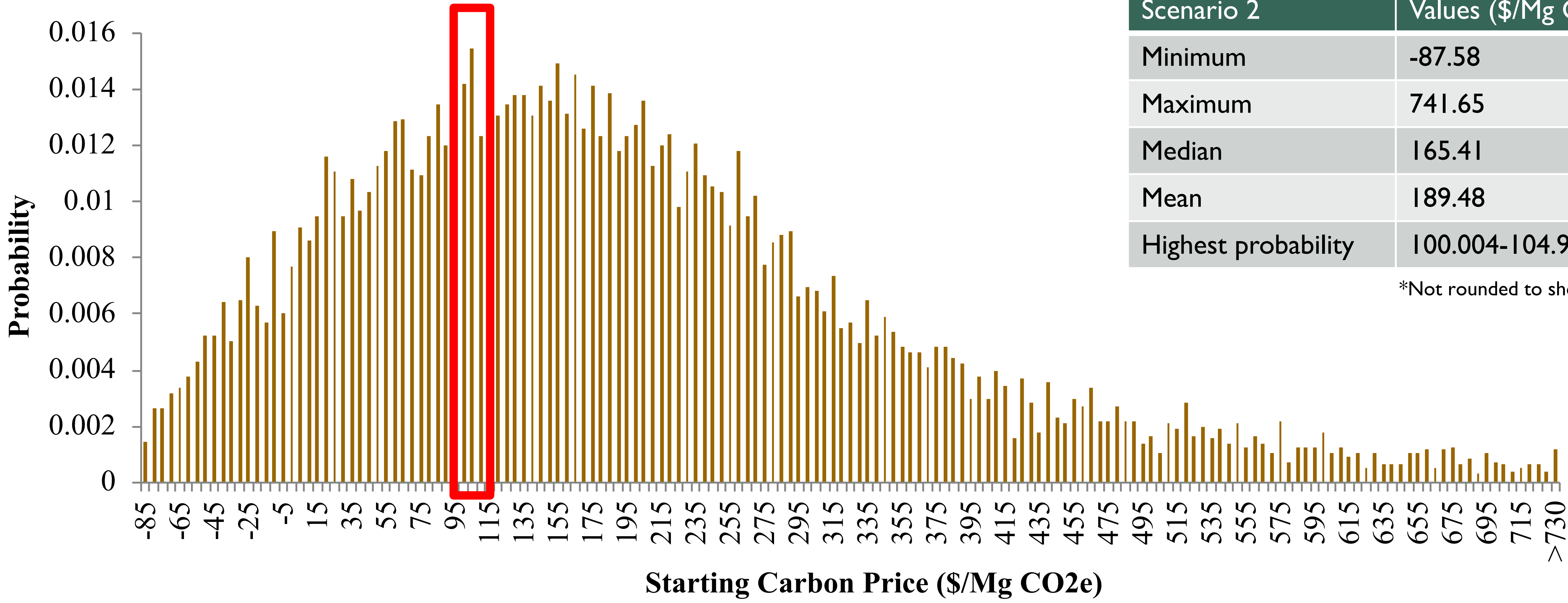

Table #4 - Starting carbon price values for Scenario 2

Scenario 2	Values ($/Mg CO2e)
Minimum	-87.58
Maximum	741.65
Median	165.41
Mean	189.48
Highest probability	100.004-104.950*

*Not rounded to show range

FIGURE #3 - SCENARIO 3: SLOW PYROLYSIS TO BIOCHAR

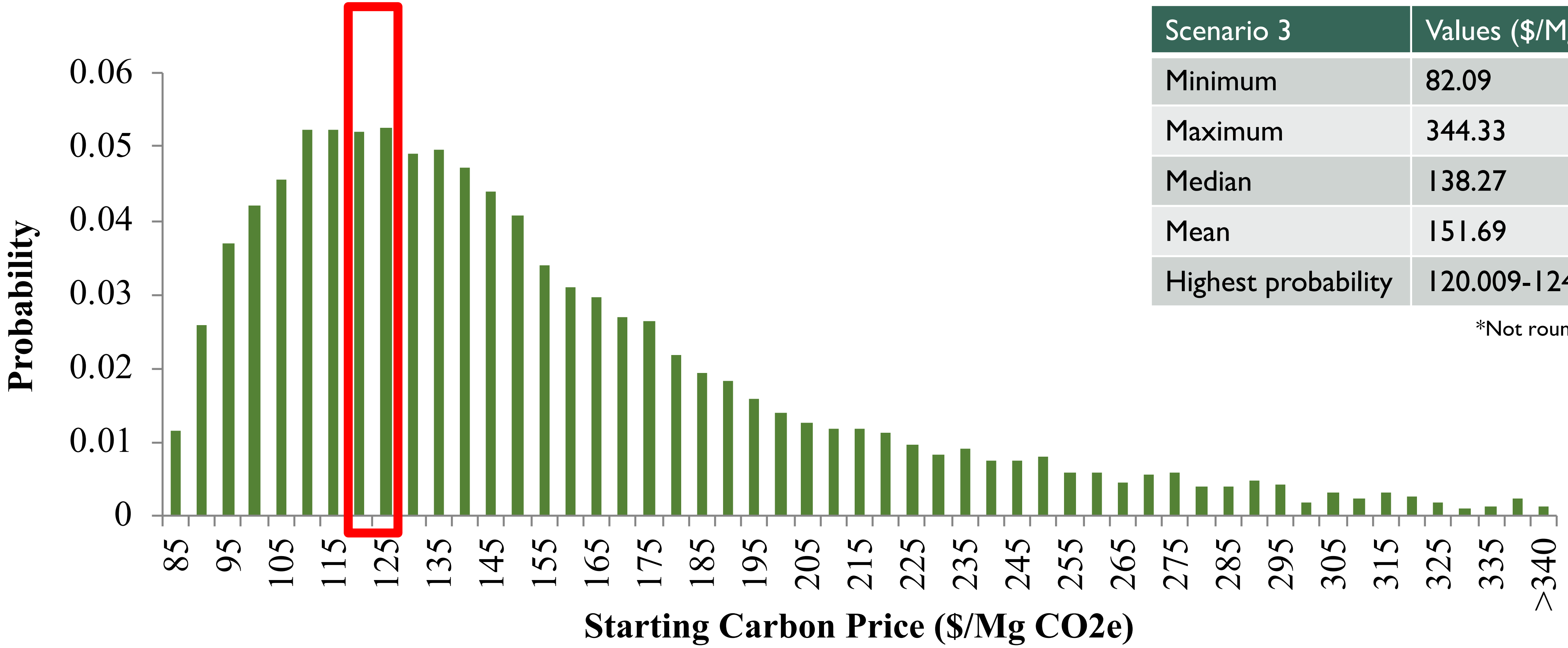

Table #5 - Starting carbon price values for Scenario 3

Scenario 3	Values ($/Mg CO2e)
Minimum	82.09
Maximum	344.33
Median	138.27
Mean	151.69
Highest probability	120.009-124.980*

*Not rounded to show range

FIGURE #4 – SCENARIO 4: SLOW PYROLYSIS TO BIOCHAR AND METHANOL 300 °C

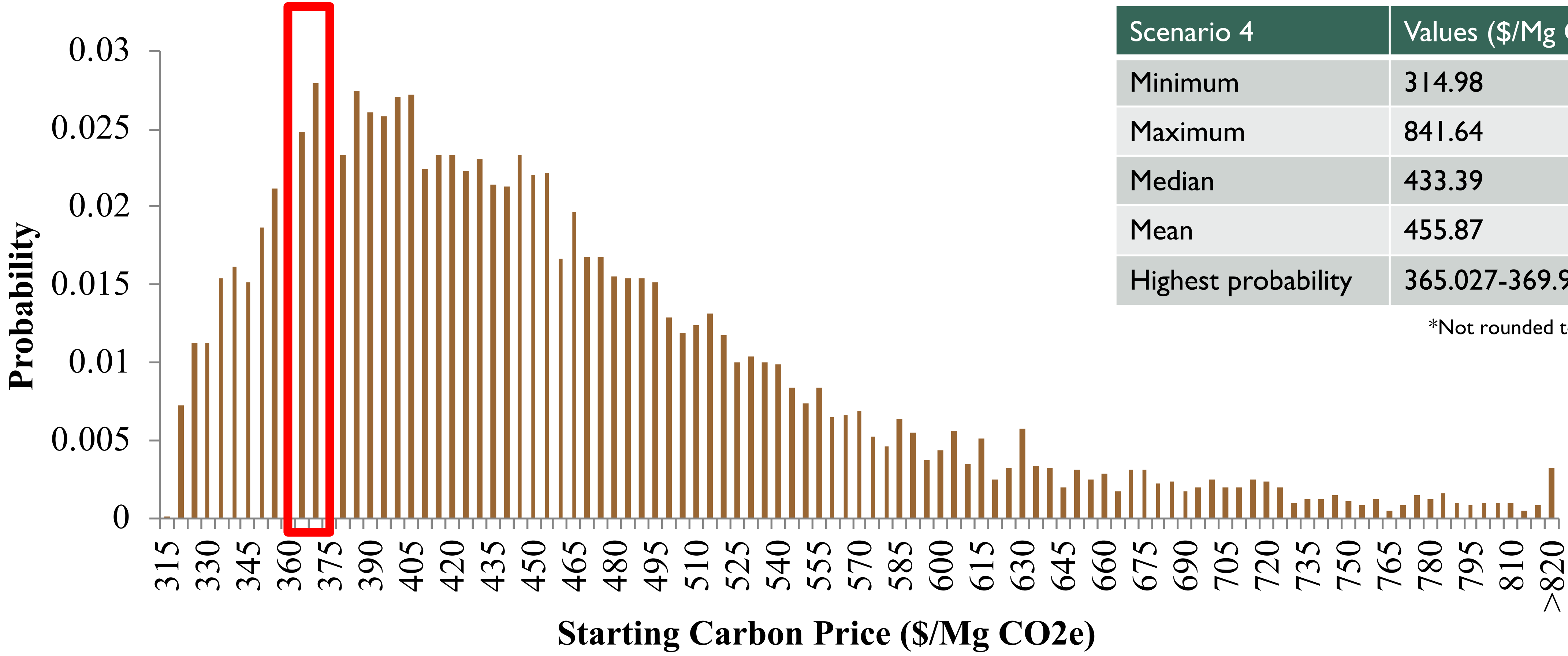

Table #6 - Starting carbon price values for Scenario 4

Scenario 4	Values ($/Mg CO2e)
Minimum	314.98
Maximum	841.64
Median	433.39
Mean	455.87
Highest probability	365.027-369.977*

*Not rounded to show range

FIGURE #5 – SCENARIO 5: SLOW PYROLYSIS TO BIOCHAR AND METHANOL 450 °C

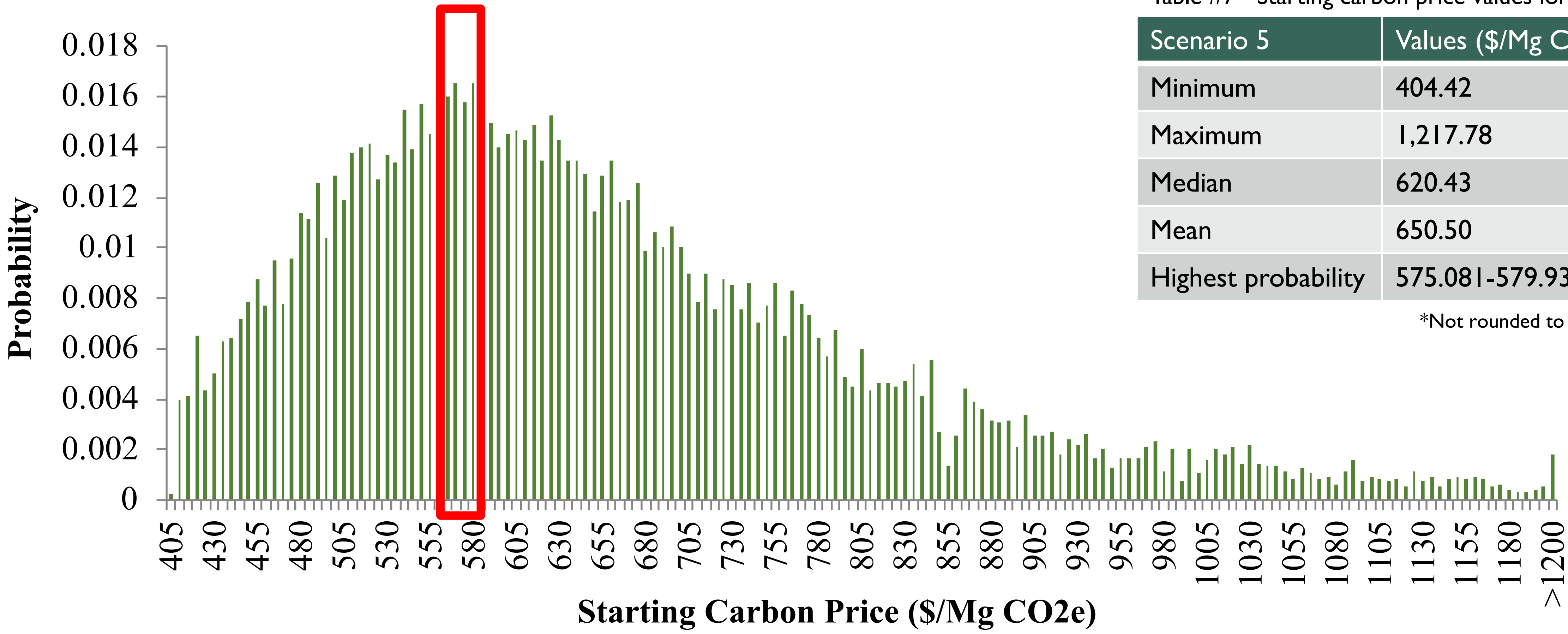

Table #7 - Starting carbon price values for Scenario 5

Scenario 5	Values ($/Mg CO2e)
Minimum	404.42
Maximum	1,217.78
Median	620.43
Mean	650.50
Highest probability	575.081-579.939*

*Not rounded to show range

TABLE #8 - STARTING CARBON PRICE SCENARIO COMPARISON

	Scenarios	Range ($/Mg CO2e)	Median ($/Mg CO2e)	Mean ($/Mg CO2e)
1	Fast pyrolysis to biochar	-$106.58 to $421.98	80.16	92.76
2	Fast pyrolysis to fuels and biochar	-$87.58 to $741.65	165.41	189.48
3	Slow pyrolysis to biochar	$82.09 to $344.33	138.27	151.69
4	Slow pyrolysis to biochar and methanol (300 °C)	$314.98 to $841.64	433.39	455.87
5	Slow pyrolysis to biochar and methanol (450 °C)	$404.42 to $1,217.78	620.43	650.50

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BASELINE MINIMUM CARBON PRICE

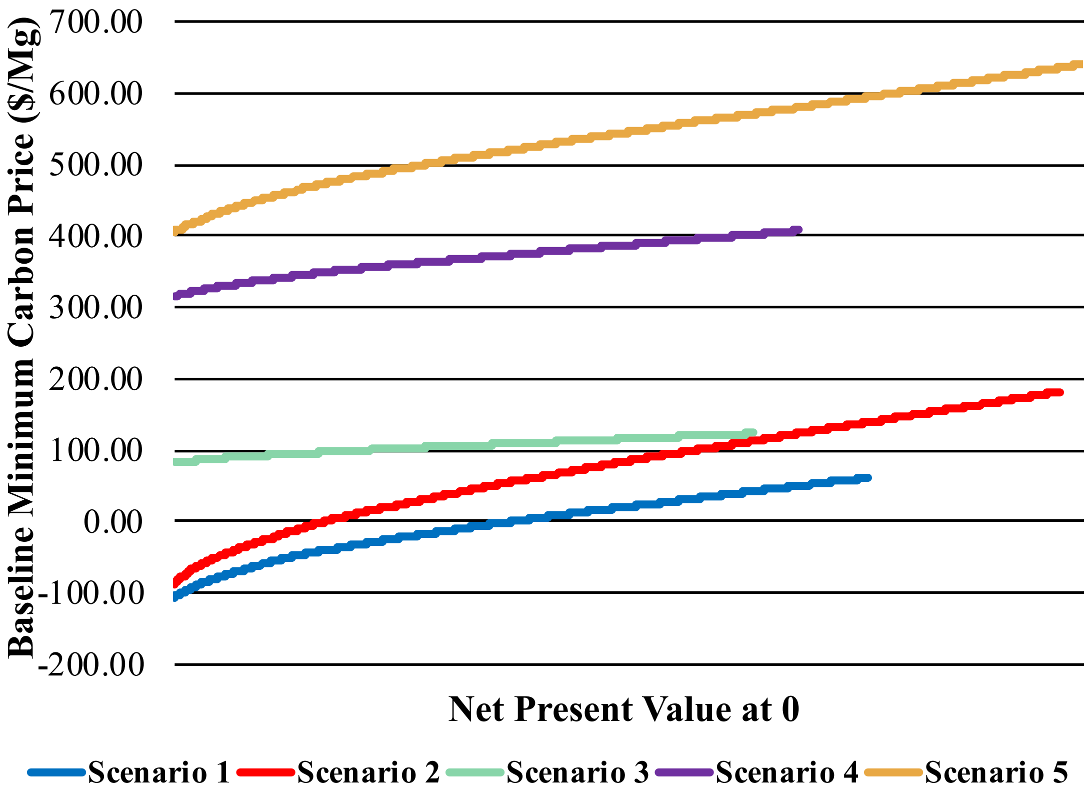

Figure #6 - Baseline minimum carbon price to achieve a net present value equal to zero

Table #9 - Baseline minimum carbon price ($/Mg) when NPV is equal to zero

Net present value at zero		Baseline minimum carbon price ($/Mg)
Scenario 1	Fast pyrolysis to biochar	$61.38
Scenario 2	Fast pyrolysis to fuels and biochar	$182.03
Scenario 3	Slow pyrolysis to biochar	$123.48
Scenario 4	Slow pyrolysis to biochar & methanol (300 °C)	$407.91
Scenario 5	Slow pyrolysis to biochar & methanol (450 °C)	$642.40

CONCLUSION

- Scenario 1 (fast pyrolysis to biochar) has the lowest baseline minimum carbon price.
- Scenario 5 (slow pyrolysis to biochar and methanol) has the highest baseline minimum carbon price at $642.40/Mg.
- Based on the scenarios modeled, it is possible to achieve a lower baseline minimum carbon price for a slow pyrolysis pathway over that of a fast pyrolysis pathway.
- The carbon price point where the slow pyrolysis pathway is equal to the fast pyrolysis pathway falls in the range of $123.49-$182.02/Mg.

THANK YOU FOR LISTENING! QUESTIONS?

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3. Shabangu S, Woolf D, Fisher EM, Angenent LT, Lehmann J. Techno-economic assessment of biomass slow pyrolysis into different biochar and methanol concepts. Fuel. 2014 Jan;117:742–8.