Biochar Economics:
A Cost-Effectiveness Analysis

David Timmons, Ph.D.
Economics Department and
School for the Environment
University of Massachusetts Boston

david.timmons@umb.edu

USBI 2016 Symposium
August 22-25, Corvallis, Oregon

The Plan

I. Climate Change Benefit-Cost Analysis

II. Climate Change Cost Effectiveness and
Biochar Cost as Social Cost of Carbon

III. Example of Biochar Cost
and Social Cost of Carbon Estimates

Climate Change Economics

Benefit-Cost Analysis:

Is $\frac{B_{\,avoiding\ climate\ change}}{C_{\,avoiding\ climate\ change}} > 1?$

Many assumptions:

- climate change effects and their costs
- discount rate for future costs
- distribution of effects
- ability to adapt
- cost of avoidance technology

Climate Change Economics

Social Cost of Carbon:

$/Mg C such that $\frac{B_{\,avoiding\ climate\ change}}{C_{\,avoiding\ climate\ change}} = 1$

Range of Estimates for Social Cost of Carbon, 211 studies (Tol 2008):

Median:	$47/Mg C
Mean:	$88/Mg C
Standard Deviation:	$243/Mg C
95th percentile:	$371/Mg C
99th percentile:	$1623/Mg C

Estimates embed all assumptions of B/C analysis.

Climate Change Economics

Cost – Effectiveness Analysis (e.g. Ackerman & Stanton 2013)

Starting assumption: climate change must be mitigated
Economic question: least costly mitigation methods

Mitigation cost: $/Mg C avoided

Climate Change Economics

Proposed Social Cost of Carbon (SCC)
based on Cost-Effectiveness Analysis:

SCC = cost in $/Mg C to remove carbon from atmosphere

Research question: What is the cost of atmospheric carbon removal using biochar in Massachusetts?

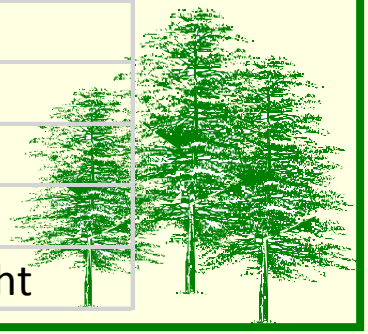
$$SCC = \frac{(capital\ \&\ operating\ cost - bio\ oil\ value - ag\ value)}{Mg\ C\ sequestered}$$

Biochar Cost Example

assumption:
same plant and
operating cost for
slow pyrolysis plant.

Fast pyrolysis plant (Bridgewater, 2002)

Assumptions:		1.50	Mg/hr capacity for 12% moisture content chips
		5,824	hours/year (7 days per week, 16 hours per day)
		12,133	Mg/year @ 40% moisture content
		8,736	Mg/year @ 12% moisture content
		7,688	Mg/year dry weight
		40	kWh electricity/Mg
	$	30.00	hourly wage, labor
	$	0.12	electricity price/kWh
	$	35.00	woodchip price/Mg, 40% moisture content
	$	5,526,806	capital cost
		25	year project life
		6.0%	discount rate
		10%	overhead and profit rate
Results:	$	1,233,186	total annual cost
	$	160	cost/Mg wood chip feedstock, dry weight



Biochar Benefit Example

Bio-Oil Value

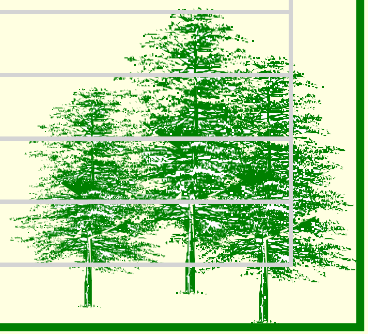
	41.9	crude oil energy value, GJ/Mg	
	18.0	bio-oil energy value, GJ/Mg, HHV	Bridgewater 2004
	43%	bio-oil proportion of crude oil energy	
$	50	assumed oil value/bbl	
	7.3	crude oil bbl/Mg	
$	367	assumed oil value/Mg	
$	158	bio-oil value/Mg	

Biochar Benefit Example

Biochar Agricultural Value

Present value (PV) savings = f(annual savings, discount rate, years)

	5.00	Mg/ha application	Gaunt 2008
	10%	reduction in fertilizer use for given yield	Gaunt 2008
$	154.38	fertilizer cost per acre, corn for grain	Penn State corn budget
$	381.47	fertilizer cost per hectare	
$	20.00	application cost/Mg	McCarl 2009
	$6.72	annualized application cost	
$	38.15	annual fertilizer savings per hectare	
$	31.43	net annual fertilizer savings per hectare	
$	6.29	annual fertilizer savings per Mg char	
	3%	discount rate	
	20	years benefit	
$	568	PV of fertilizer benefit per hectare	
$	114	PV fertilizer benefit per Mg	



Biochar Benefit Example

Biochar Products (Bridgewater 2004)

Percentage of feedstock dry weight		
	fast pyrolysis	slow pyrolysis
bio-oil	75%	30%
syn-gas	13%	35%
char	12%	35%
	100%	100%
Percentage of feedstock dry weight, net of process gas		
	fast pyrolysis	slow pyrolysis (calculated)
bio-oil	75%	30%
syn-gas	0%	22%
char	12%	35%
	87%	87%

Social Cost of Carbon

Carbon Sequestration Example

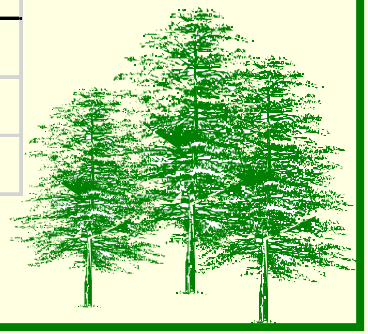
63%	carbon content biochar	Bridgewater
80%	stable portion	Bridgewater
50%	sequestered Mg C/Mg char	

Social Cost of Carbon

Summary of Example

	fast pyrolysis	slow pyrolysis
Bio-oil proportion	75%	30%
Bio-char proportion	12%	35%
Stable carbon proportion of biochar	50%	50%
Bio-oil value/Mg	$ 158	$ 158
Bio-char agricultural value/Mg	$ 114	$ 114
Pyrolysis cost/Mg feedstock (dry weight)	$ 160	$ 160
Bio-oil total value/Mg feedstock	$ 118	$ 47
Bio-char agricultural value/Mg feedstock	$ 14	$ 40
Net cost biochar/Mg feedstock	$ 29	$ 73
Net cost biochar/Mg biochar	$ 239	$ 210
Net cost stable C/Mg = Social Cost of Carbon	$ 473	$ 416

> Tol 95th percentile



Conclusions

- Cost of biochar carbon sequestration is one measure of the soical cost of carbon.

- Final cost estimate is sensitive to a number of parameters:
  - pyrolysis bio-oil and biochar portions
  - biochar stable carbon portion
  - bio-oil market value
  - biochar agricultural value, persistence, and discount rate for future benefits
  - pyrolysis capital and operating costs
  - biomass feedstock cost

- Goal: identify supply curve (or at least most likely costs) for biochar use in Massachusetts.

Biochar Economics:
A Cost-Effectiveness Analysis

David Timmons, Ph.D.
Economics Department and
School for the Environment
University of Massachusetts Boston

david.timmons@umb.edu

USBI 2016 Symposium
August 22-25, Corvallis, Oregon