Greenhouse Gas Benefits from the Utilization of Forest Waste for Energy or Biochar

Bruce Springsteen
Placer County Air Pollution Control District

California Forests and Greenhouse Gas Reduction Webinar Series

April 24, 2015

Forest Waste
GHG Assessment Framework

Greenhouse gas reduction fund

Forest project type

Fuel reduction
Forest pest control
Reforestation
Improved forest management
Urban forestry

Excess forest biomass wastes – tops, limbs, brush, stumps

Biomass project

Processing and transport

Bioenergy

Biochar

Baseline, No project

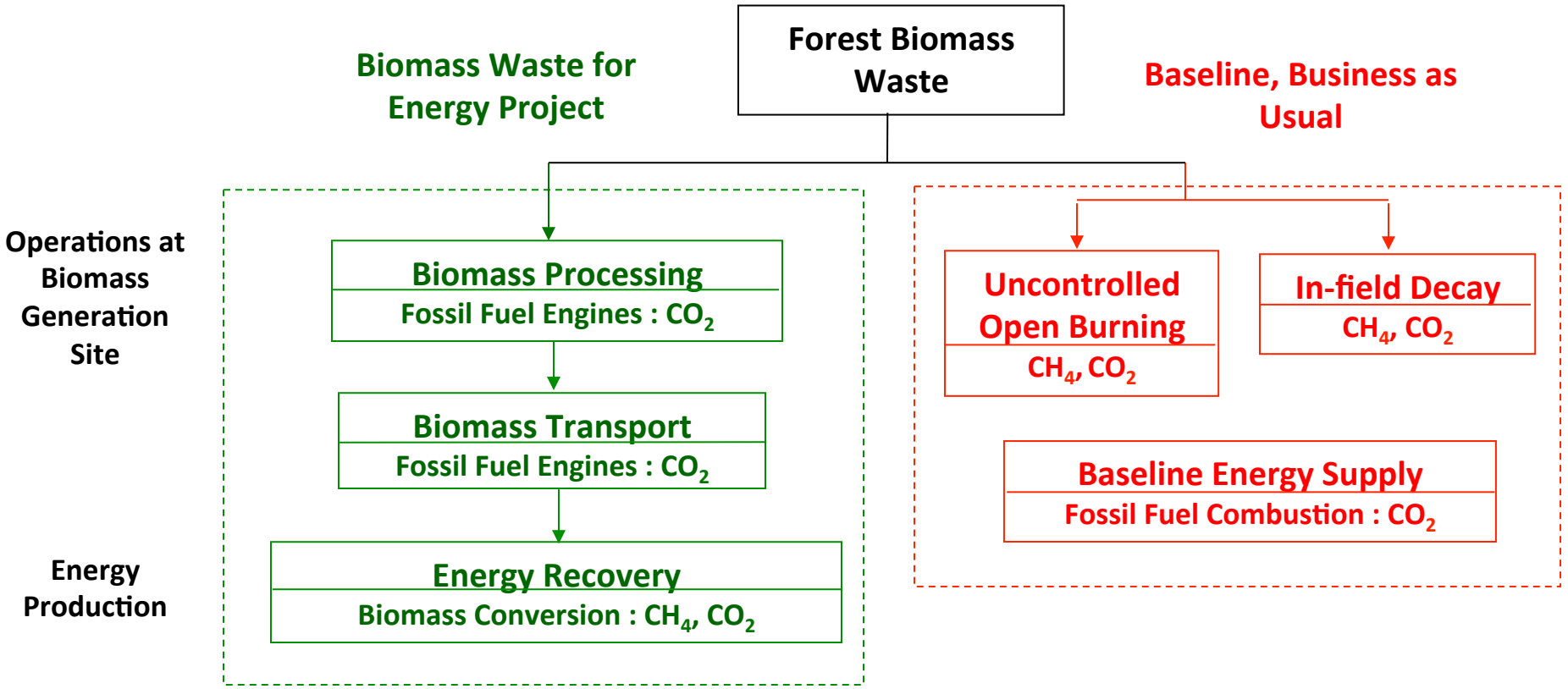
Open pile burn, in field decay

Fossil fuel energy

Forest Waste for Energy Project GHG Accounting Protocol

- Utilize excess forest biomass wastes for production of renewable energy as alternative to baseline business as usual (open burning or chip and scatter in field)
- Greenhouse gas benefits result from:
  - Avoided methane from open pile burning or in-field decomposition
  - Renewable biomass energy displaces fossil fuels
- Biomass Waste for Energy Greenhouse Gas Project Offset Accounting Protocol, Version 6.3, January 2013
  - Peer reviewed. Support from California Board of Forestry, USFS, and Cal Fire, Sierra Nevada Conservancy, California Air Districts including San Joaquin, South Coast, Mendocino, Butte, and Feather River
  - Approved into the California Air Pollution Control Officers Association (CAPCOA) Greenhouse Gas Exchange
  - http://www.placer.ca.gov/~/media/apc/documents/APCDBiomass/BiomassWasteForEnergyProject.pdf or http://www.ghgrx.org/

Forest Waste for Energy Project Boundary



$$GHG_{Reduction} = GHG_{Open\ Burn} + GHG_{Decay} + GHG_{Baseline\ Energy} - GHG_{Biomass\ Energy} - GHG_{Biomass\ Processing} - GHG_{Biomass\ Transport}$$

Forest Waste for Energy Project Monitoring and Calculations

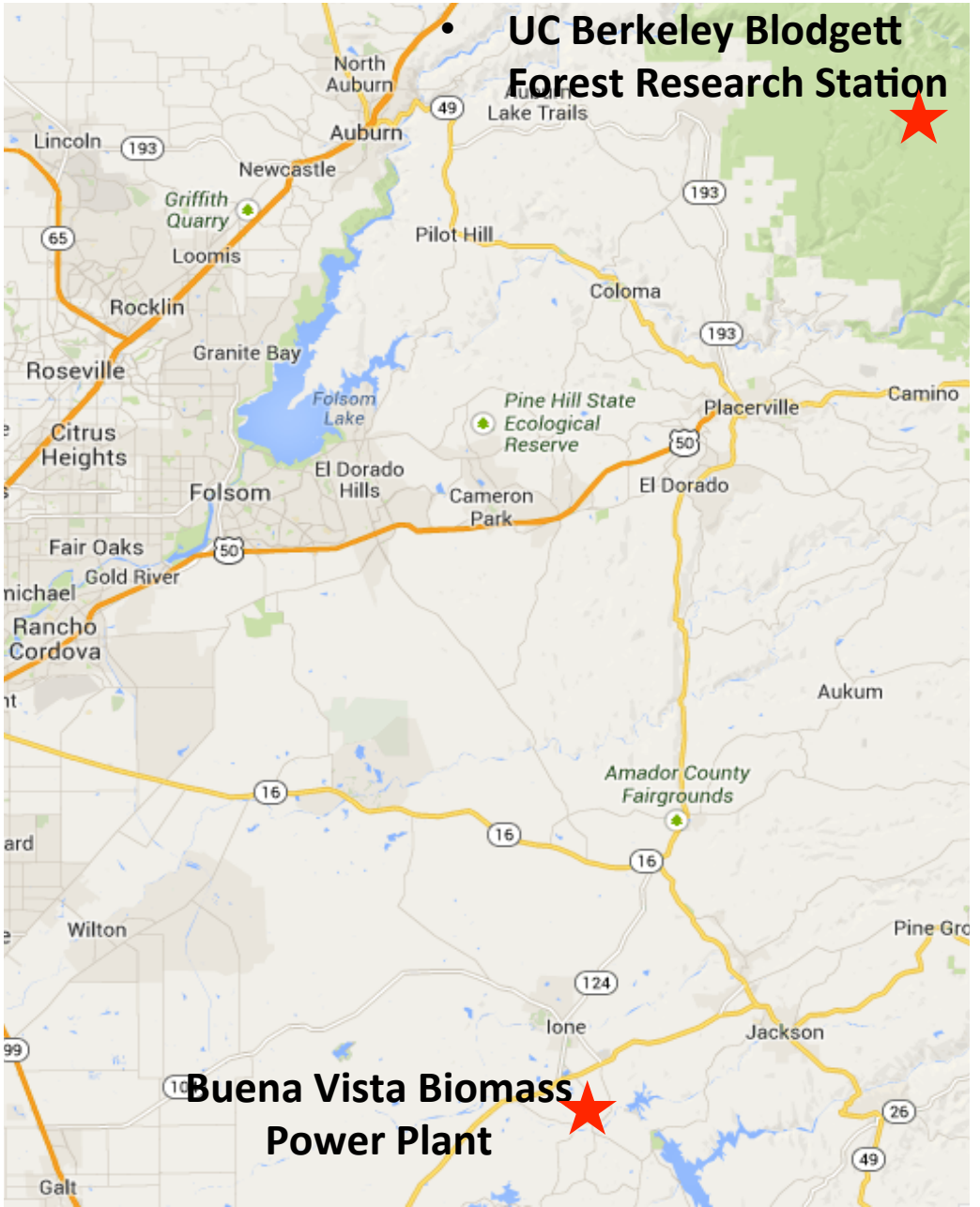
- Grinding
  - Grinder and excavator/loader fuel usage
  - Grinder and loader engine emission factors
- Transport
  - Chip van fuel usage or total miles traveled
  - Chip van engine emission factors
- Other
  - Water trucks
  - Equipment / personnel transport
- Energy facility
  - Biomass waste delivered, wet tons
  - Moisture content of biomass waste
  - Energy content of biomass waste
  - Energy facility emission factors
  - Heat rate of energy facility -- net useful energy production per unit of biomass waste energy input
    - Electricity
    - Heat
    - Cogeneration

Baseline (No Project) Calculations

- Open pile burn
  - Biomass consumption burnout efficiency
  - Methane and carbon dioxide emission factor
- Infield decomposition / decay
  - Methane and carbon dioxide emission factor
- Displaced fossil fuel energy
  - Electricity
    - Combined cycle natural gas
    - Local utility blend
    - Marginal supply
  - Heat
    - Natural gas or electricity
  - Cogeneration

SSO Forest Waste Energy Project, 2008

Blodgett Forest Waste Energy Project, 2013

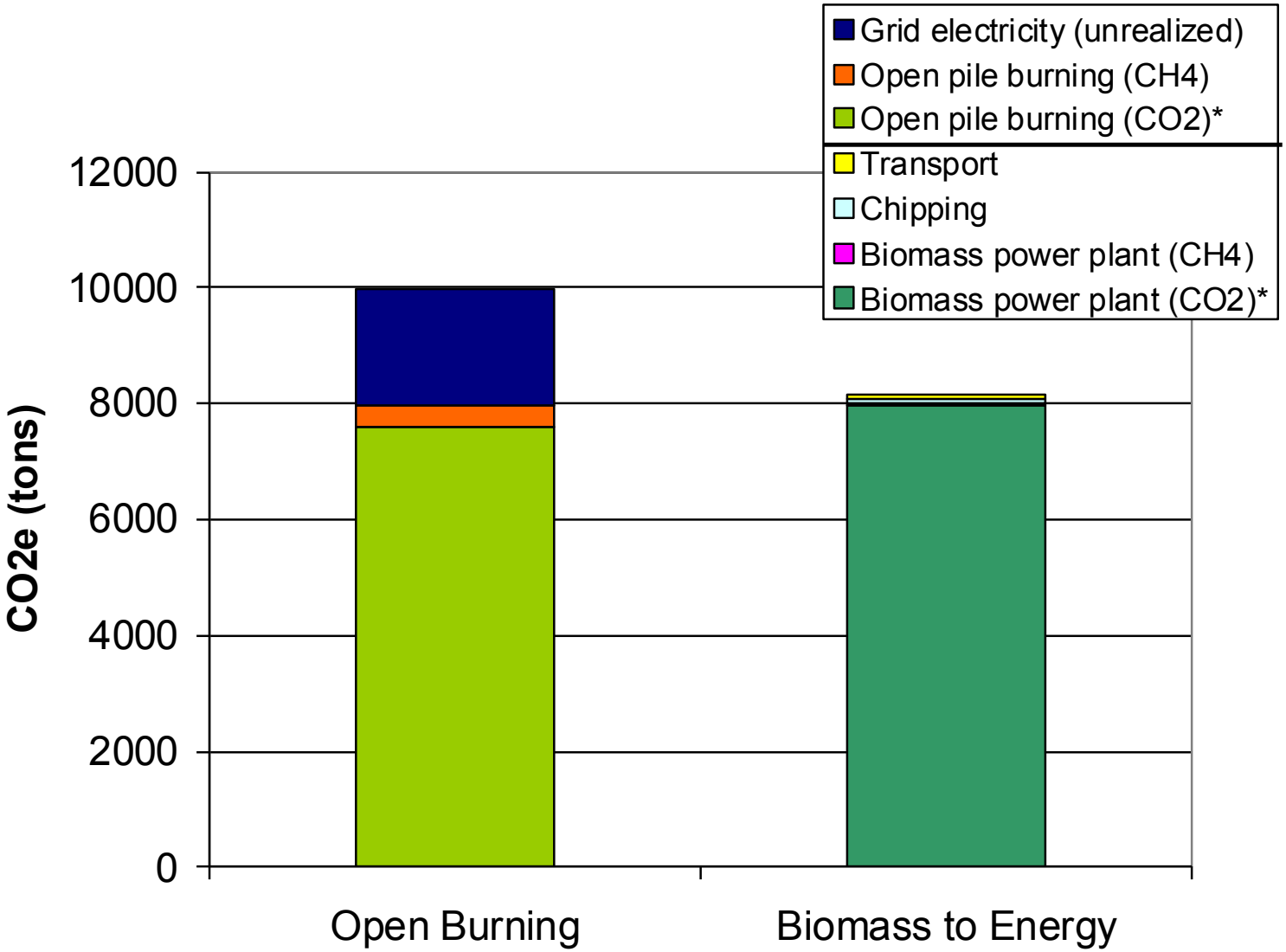


Forest Waste for Energy Project Calculations Example

Biomass Waste for Energy GHG Offset Credit Project Calculations					
Project Title	Utilization of Forest Slash From Forest Fuel Treatment Thinning Projects on the United States Forest Service Tahoe National Forest American River Ranger District for Energy at Sierra Pacific Industries Lincoln Biomass Cogeneration Boiler as an Alternative to Open Pile Burning				
Dates	April 14 - December 12, 2008				
Parameter	Value	Units	Symbol	Source	Item
Biomass production	10,503	green tons	$BM_{T,W}$	Energy facility weight tickets	1
Biomass moisture content	36.1	%	M	Lab analysis of representative samples	2
Biomass production	6,714	bone dry ton (BDT)	$BM_{T,D}$	$BM_{T,W}*(1-M)$	3
Biomass heating value	9,000	Btu/dry lb	HHV_{BM}	Lab analysis of representative samples	4
Biomass boiler CO_2 emission factor	1.8	ton CO_2/BDT	EF_{BM}	Protocol default	5
Biomass boiler CO_2 emissions	12,085	ton CO2	GHG_{boil}	$BM_{T,D}*EF_{BM}$	6
Biomass boiler heat rate	16,145	Btu/kWh_e	f	Boiler measurements	7
Biomass boiler electricity production	7,485	MWh_e	E_{BM}	$BM_{T,D}*HHV_{BM}/f/1000$	8
Displaced electricity grid CO_2 emission factor	800	lb CO_2/MWh_e	EF_E	Natural gas combined cycle	9
Displaced electricity grid CO_2 emissions	2,994	ton CO_2	GHG_E	$E_{BM}*E_{FE}/2000$	10
Grinder fuel usage	7,704	gallons	F_{gr}	Fuel dispenser	11
Grinder fuel CO_2 emission factor	22.23	lb CO_2/gal	EF_{dies}	Default for diesel fuel	12
Grinder CO_2 emissions	85.6	ton CO_2	GHG_{gr}	$F_{gr}*EF_{dies}$	13
Loader fuel usage	2,010	gallons	F_{lo}	Fuel dispenser	14
Loader fuel CO_2 emission factor	22.23	lb CO_2/gal	EF_{dies}	Default for diesel fuel	15
Loader CO_2 emissions	22.3	ton CO_2	GHG_{lo}	$F_{lo}*EF_{dies}$	16
Chip van fuel usage	11,840	gallons	F_{van}	Fuel dispenser	17
Chip van CO_2 emission factor	22.23	lb CO_2/gal	EF_{dies}	Default for diesel fuel	18
Chip van CO_2 emissions	131.6	ton CO_2	GHG_{van}	$F_{van}*EF_{dies}$	19
Open pile burn fraction	100	%	X_{ob}	Disposal plan for biomass wastes	20
Open pile burn consumption factor	95	%	BF	Protocol default	21
Open pile burn CO_2 emission factor	1.73	ton CO_2/BDT	EF_{obCO2}	Protocol default	22
Open pile burn CH_4 emission factor	0.005	ton CH_4/BDT	EF_{obCH4}	Protocol default	23
Open pile burn CO_{2e} emissions	11,704	ton CO_{2e}	GHG_{ob}	$BM_{T,D}*X_{ob}*BF*(ER_{obCO2}+EF_{obCH4}*21)$	24
Net project CO_{2e} reduction	2,374	ton CO_{2e}	GHG_{Net}	$(GHG_{ob}+GHG_E)-(GHG_{boil}+GHG_{gr}+GHG_{lo}+GHG_{van})$	25

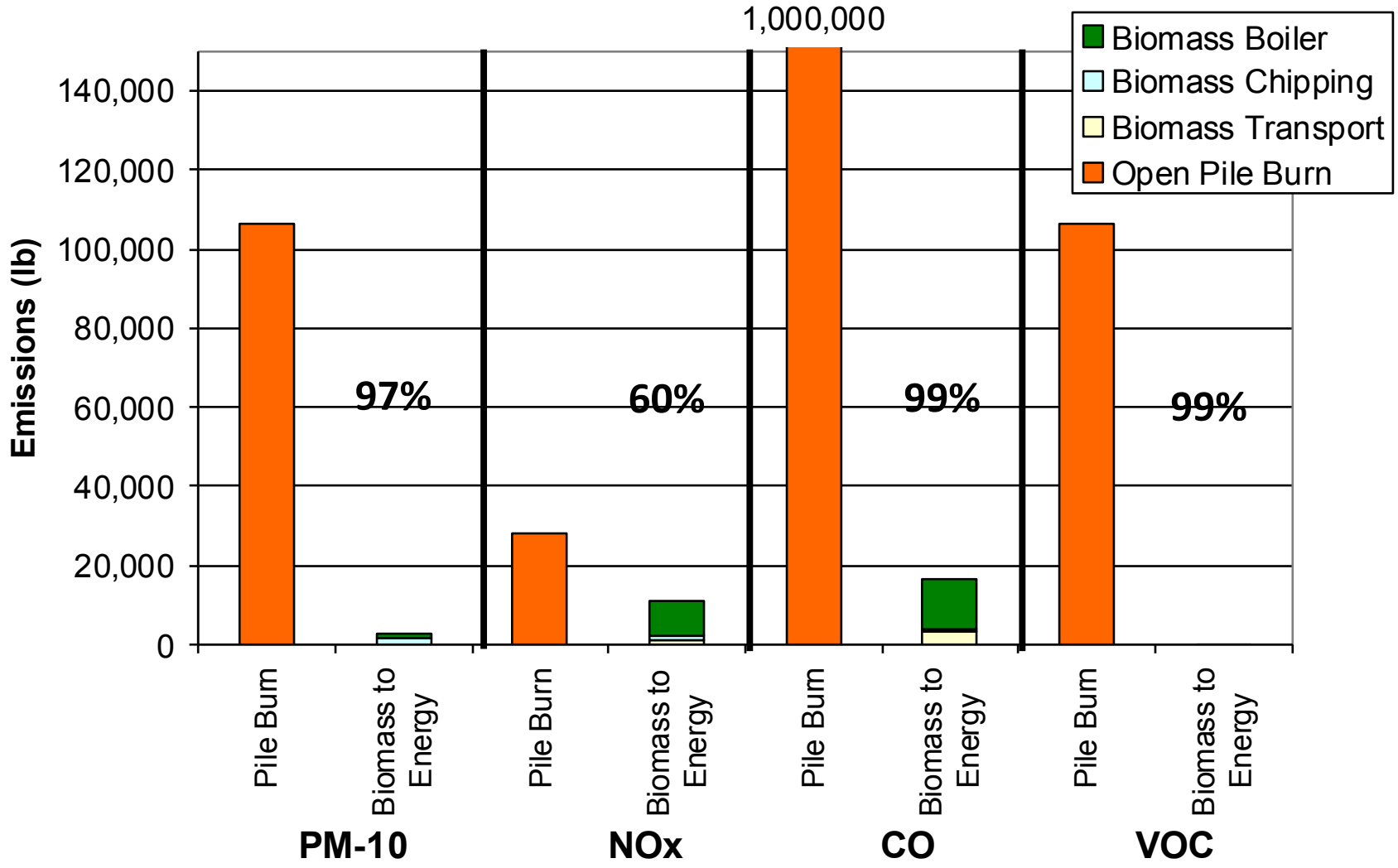
Forest Waste for Energy
Greenhouse Gases

Results from SSO biomass energy project (6,800 BDT forest slash)



Forest Waste for Energy
Criteria Air Pollutants

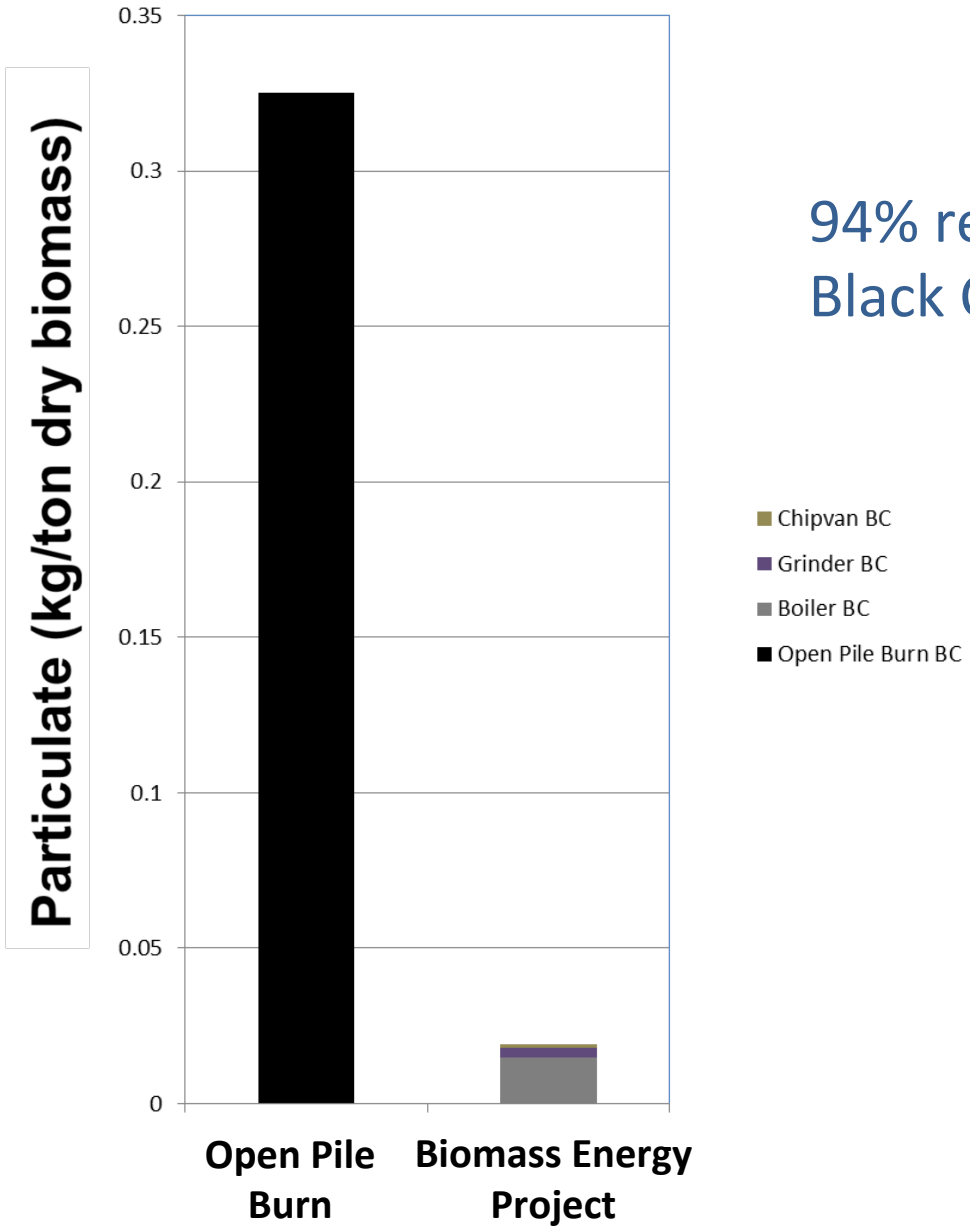
Results from SSO biomass energy project (6,800 BDT forest slash)



Black Carbon

- Product of incomplete combustion – pile burns, prescribed burns, wildfire
- "Short-lived climate forcing" – 900 times by weight more potent than CO_2

Black Carbon



94% reduction in Black Carbon

Black Carbon Open Pile Burn Field Study

- Quantify Black Carbon emissions from open pile burns
- Study related parameters
  - Woody biomass type
    - Mixed conifer
    - Brush
    - Ag fruit and nut wood
  - Moisture/seasoning
  - Pile stacking
    - Hand
    - Machine
  - Combustion efficiency
  - Carbon content
- Create a user-friendly matrix to quantify avoided Black Carbon emissions from open pile burn

Resources

- SSO Project
  - "Emissions reduction from the use of woody biomass for energy as an alternative to open burning", Journal of the Air and Waste Management Association, Volume 61, pages 63-68, January 2011
    - http://www.placer.ca.gov/~/media/apc/documents/APCDBiomass/EmissionReductionsFromWoodyBiomassAWMA.pdf
- Blodgett Project
  - "Air pollutant measurements from a forest slash open pile burn"
    - http://www.placer.ca.gov/~/media/apc/documents/APCDBiomass/BFPileReport.pdf
  - "Forest biomass diversion in the Sierra Nevada – energy, economics, and emissions"
    - Undergoing review for upcoming publication in the California Agriculture Journal

Biochar

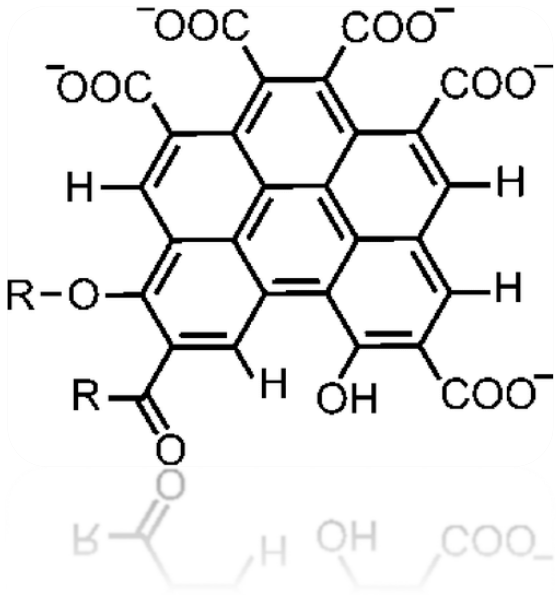
- Biochar -- porous, carbon-rich, charcoal -like solid
- Formed from the thermal pyrolysis / gasification of biomass
- Use as soil amendment:
  - Sequesters carbon -- highly stable and resistant to decomposition
  - Enhances soil fertility -- increases water and nutrient holding capacity
  - Reduces soil emissions, enhances biomass growth
  - Displaces fertilizer manufacturing
- Also produces renewable energy

Biochar GHG Project Accounting Protocol

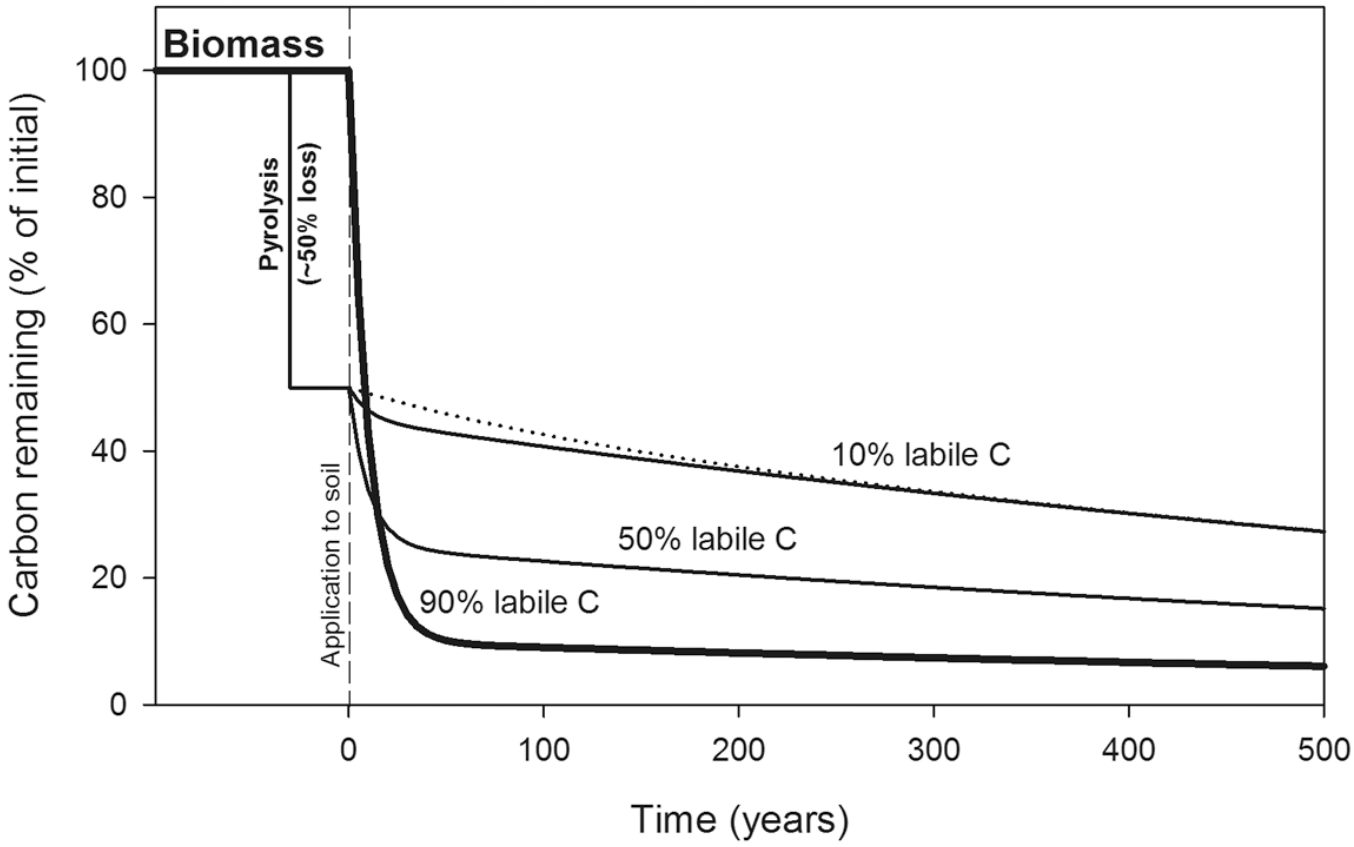
- Biochar GHG Offset Protocol developed through contract with Prasino Group, International Biochar Initiative, and The Climate Trust
  - Extension of concurrent effort that is currently under review with the American Carbon Registry
- Protocol currently under review for approval in the CAPCOA GHG Rx
  - Focused on California woody biomass forest and ag wastes that would have otherwise been open pile burned or used for energy
  - Biochar hydrogen/organic carbon ratio used to determine long-term stability
  - Biochar application to legitimate agricultural use
  - Draft protocol available at http://www.placer.ca.gov/~/media/apc/documents/APCDBiomass/BiocharProductionforProjectReportingProtocol.pdf

Biochar Stability

- **Fused aromatic carbon rings →** material property most likely responsible for biochar



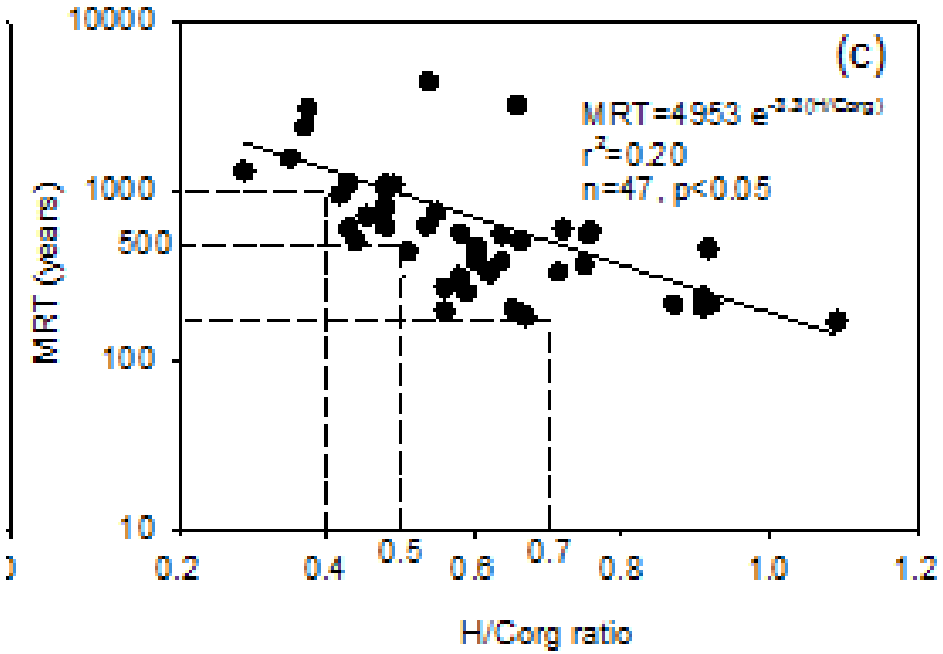
Biochar Stability



Biochar Stability

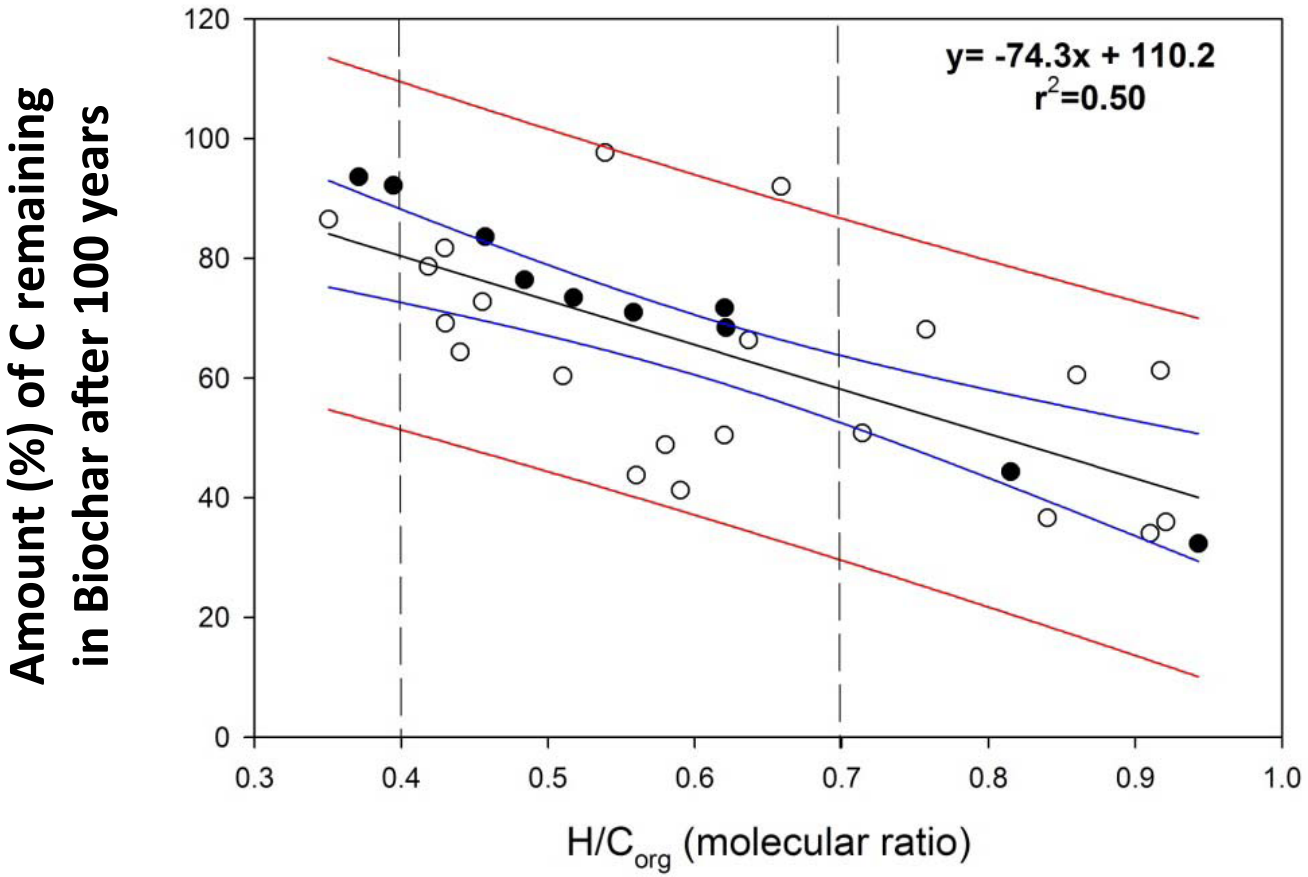
Hydrogen/Organic Carbon (H/C_{org})

At H/C_{org} <0.7 all biochars have mean residence time (MRT) of >100 years



J. Lehmann, S. Abiven, M. Kleber, G. Pan, B.P. Singh, S. Sohi, A. Zimmerman. Persistence of biochar in soil. In: Biochar for Environmental Management - Science and Technology, 2nd edition. Johannes Lehmann and Stephen Joseph (eds.). Earthscan, and references therein

Biochar Stability



Biochar Stability

H/C_{org} and BC_{+100} equivalences at 95% confidence

Chosen values represent **conservative estimates** of biochar C expected to remain based on experimental data

Two levels identified:

1. **$H/C_{org} < 0.4$** → at least 70% biochar C expected to remain after 100 years
2. **$H/C_{org} < 0.7$** → at least 50% biochar C expected to remain after 100 years

	BC_{+100} (%)			
H/C_{org}	Mean	Lower Limit	Upper Limit	Chosen Value
0.4	**80.5**	**72.6**	**88.2**	**70**
0.5	73.1	67.1	78.9	50
0.6	65.6	60.5	70.6	50
0.7	**58.2**	**52.5**	**63.8**	**50**

Biochar Potential

- Biochar production rate – 0.10 lb biochar/ lb biomass
- Carbon content of biochar – 0.75 lb C/lb biochar
- CO_2 sequestered in biochar – 0.28 MT CO_2/ BDT biomass