DEPARTMENT OF ECOLOGY
State of Washington

Clean Fuels Program AF-CCS Advisory Panel Meeting

October 27, 2022

Ecology Staff

- Abbey Brown – Technical Lead
- Debebe Dererie – Fuel Pathway Specialist
- Rebecca Sears – Project Manager & Partnership Specialist
- Janée Zakoren – Outreach & Engagement Specialist
- Joel Creswell – Climate Policy Section Manager

Agenda

- Opening & welcome
- Biochar basics & applications
- *Break*
- Biochar climate impact & LCA approach
- Plenary reflections
- Next steps & wrap-up

Opening & Welcome

Rebecca Sears

Keep in mind...

- Efficacy
- Quantifiable
- Verifiable
- Size of sequestration opportunity
- Reliability
- Durability
- Readiness
- Avoidance of negative impacts

For Today...

- Please leave your video on as much as possible
- Please keep your microphone muted unless speaking
- Actively participate in the group
- Demonstrate attentiveness when others are speaking
- Behave constructively and respectfully towards all participants
- Respect the role of the hosts to guide the group process

Biochar

Jim Amonette

Biochar: An Overview

J.E. Amonette

Pacific Northwest National Laboratory
and
Washington State University
Richland, WA

Washington Department of Ecology
Clean Fuel Standard: Agriculture and
Forestland Carbon Capture & Sequestration
Advisory Panel (AF-CCSAP)
27 October 2022

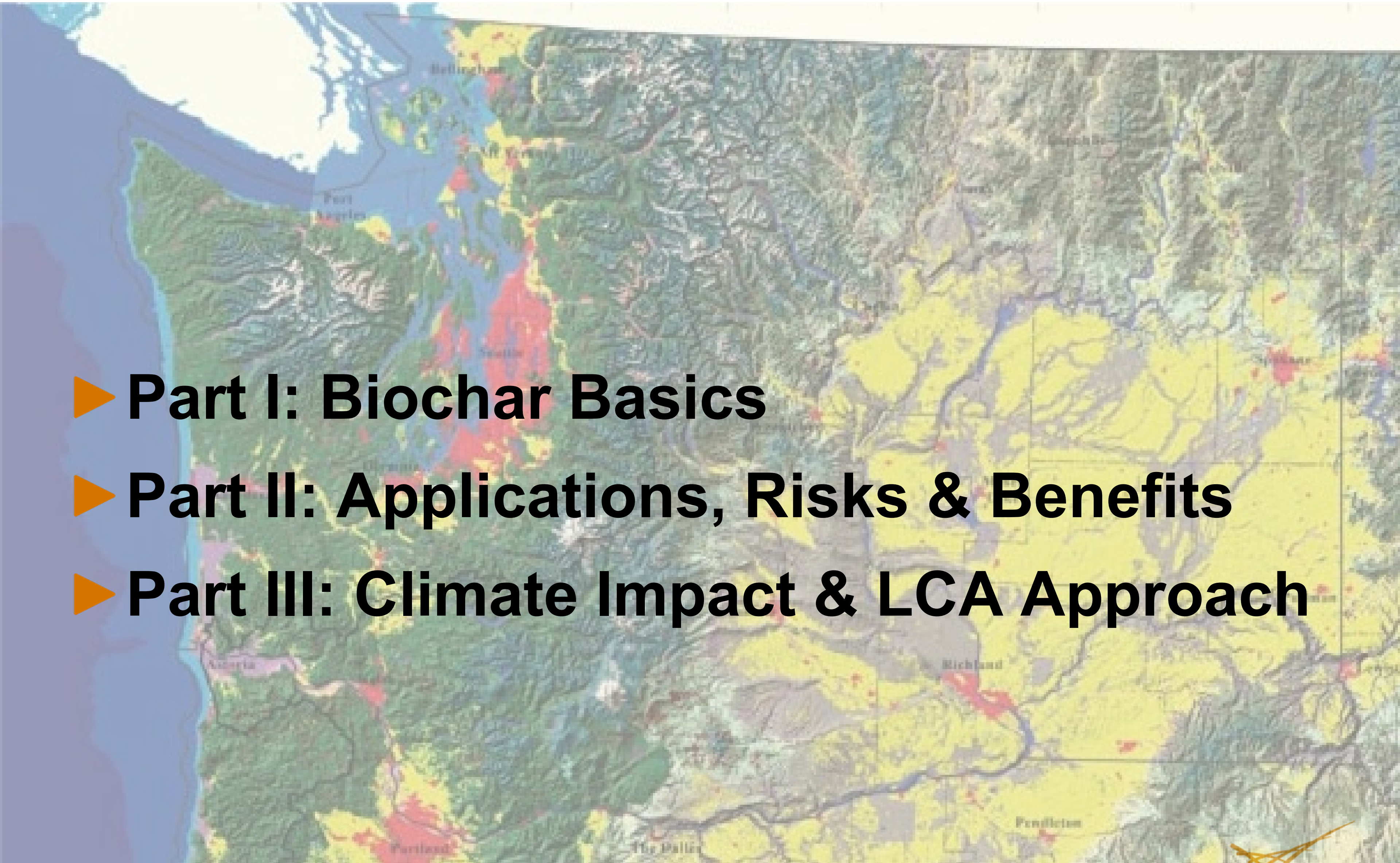
Center for Sustaining Agriculture & Natural Resources
Washington State University

PNNL-SA-179341

Pacific Northwest NATIONAL LABORATORY

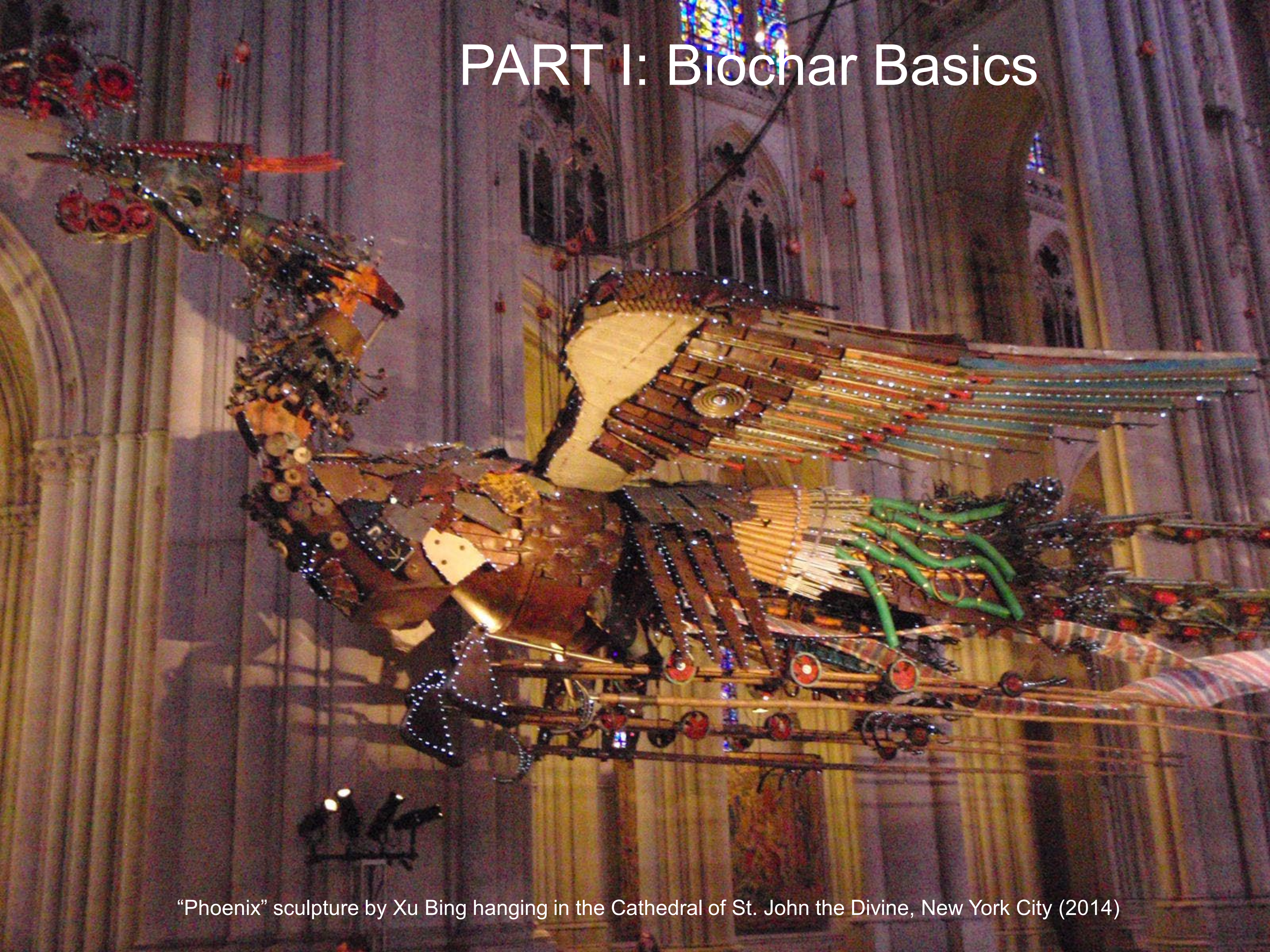
jim.amonette@pnnl.gov

Outline



- Part I: Biochar Basics
- Part II: Applications, Risks & Benefits
- Part III: Climate Impact & LCA Approach

PART I: Biochar Basics



“Phoenix” sculpture by Xu Bing hanging in the Cathedral of St. John the Divine, New York City (2014)

Biochar Basics

Biochar is, most simply, *charcoal* made from *biomass*

Feedstocks include *residues* from forestry and agriculture such as wood, straw, and manure

Biochar is produced by *pyrolysis* (anoxic 600-1200 °F) or *gasification* (low oxygen, 1200-1700 °F)

UC Davis Biochar Database

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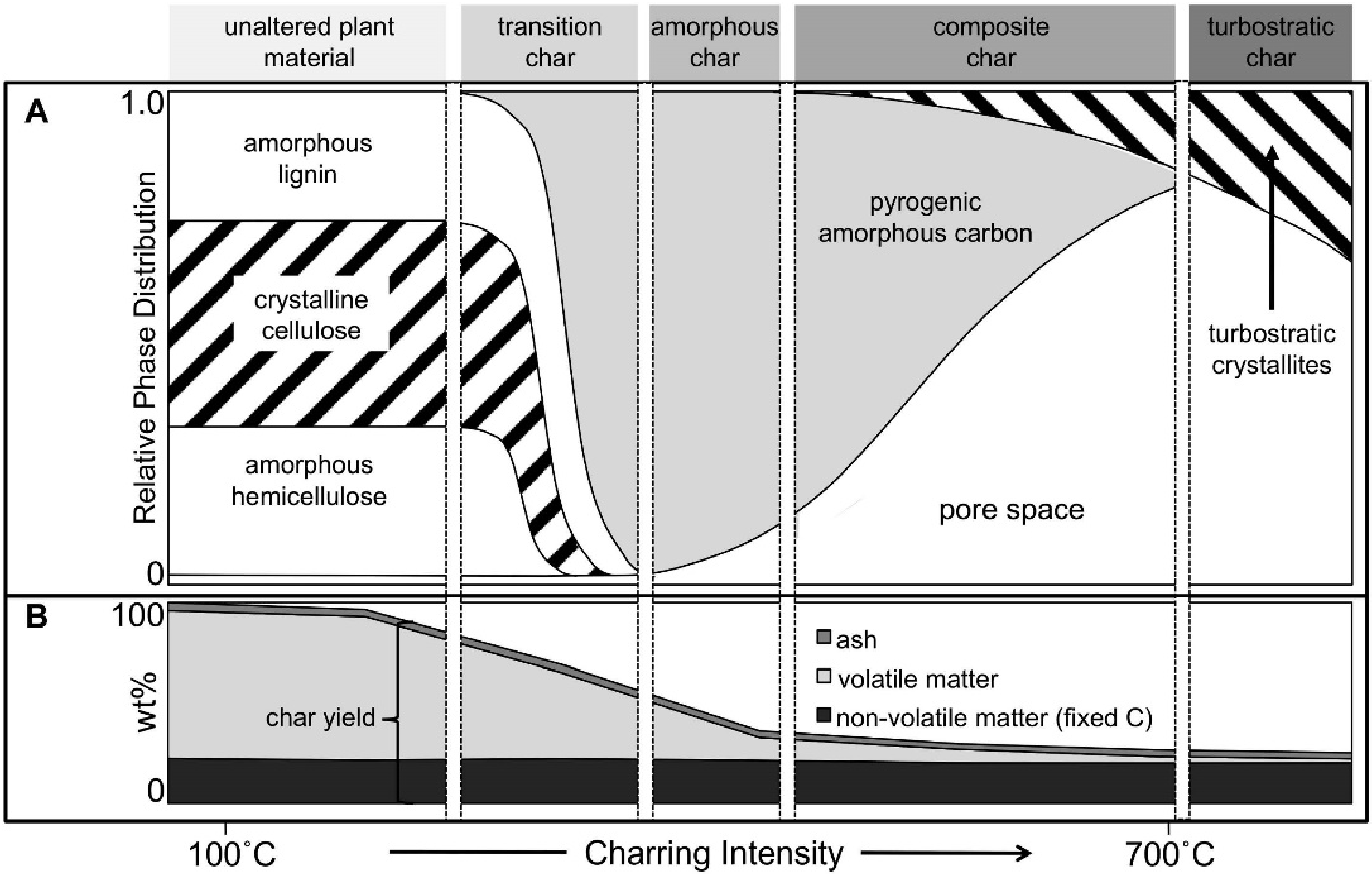
Biomass Conversion to Biochar



Keiluweit et al. 2010 ES&T 44:1247

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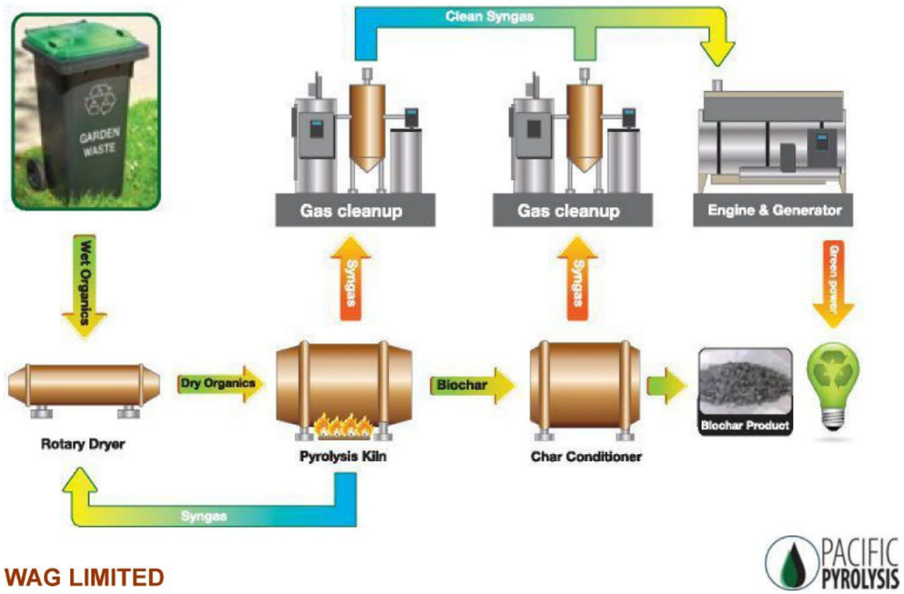
Biochar Pyrolyzers



FarmBio3 Mobile Fast Pyrolysis Unit
Source: USDA-ARS Fast Pyrolysis Team

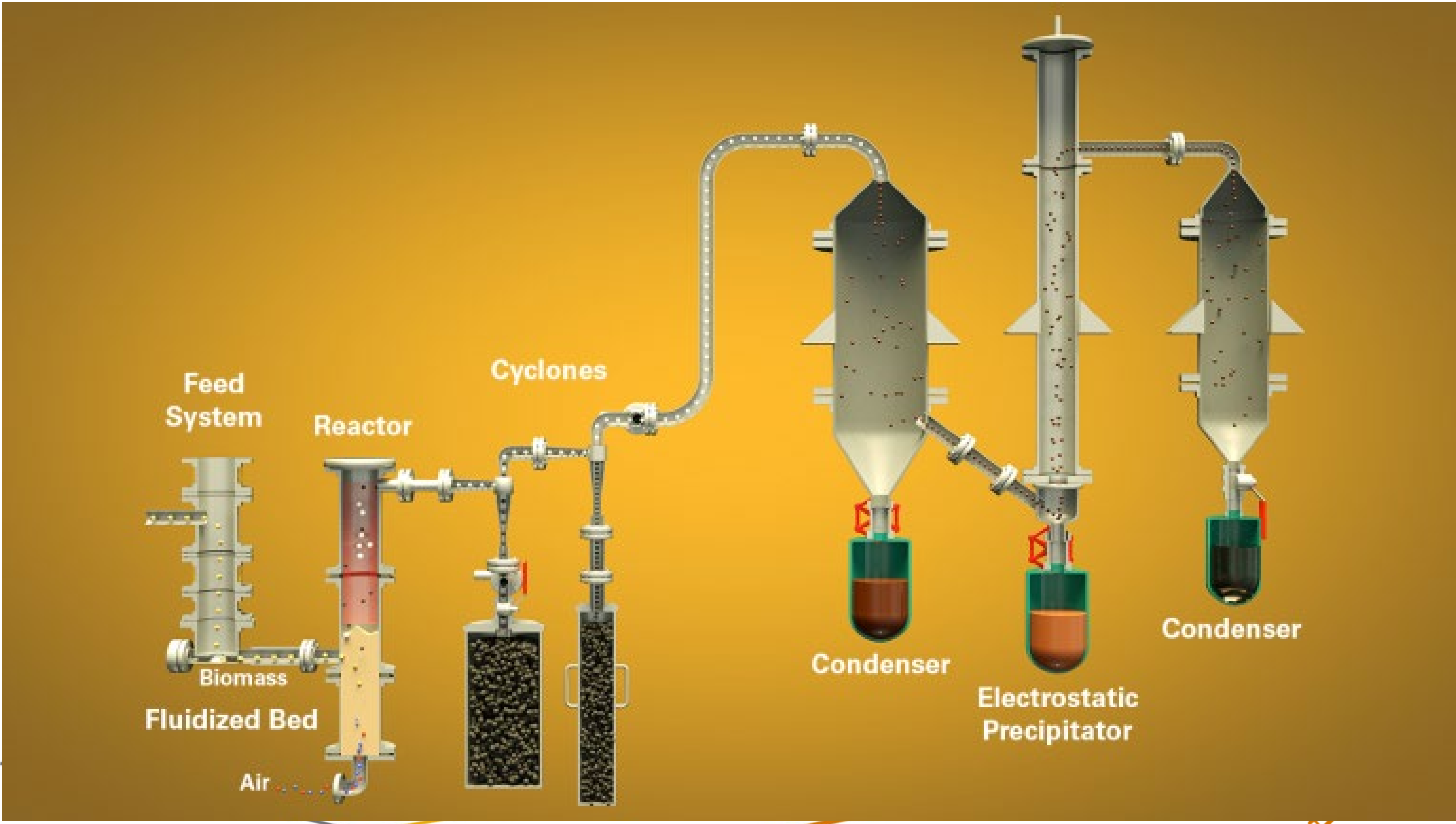
Slow Pyrolysis

Fast Pyrolysis

High-Temperature Slow Pyrolysis Kiln

https://biocharnow.com/kiln-based-technology/

Autothermal Fast Pyrolysis



https://www.biorenew.iastate.edu/research/thermochemical/autothermal

Autothermal Fast Pyrolysis Facility (50 TPD)

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Flame Cap Kilns

Cornelissen et al. 2016 PlosOne 11:e01546

“Ring of Fire Kiln” https://wilsonbiochar.com

Biochar Gasifiers

Homebuilt (photo courtesy of Wilson Biochar Associates)

Air curtain burner (photo courtesy of Wilson Biochar Associates)

Phoenix Energy, 500 KWe, Merced, CA

Containerized Gasifiers

https://www.qualterraag.com

https://www.arti.com/reactors/

Biochar from Conventional Boilers

- Boiler Conversion (alteration to reduce the residence time of biochar inside the boiler)
  - Simpler and more economical than some competing options
  - Alter feedstock moisture content and particle size, oxygen ratio, and biomass residence time
  - Biochar yields potentially comparable to other options
  - Flexible, so can maximize energy or biochar production as needed.

Biomass One, White City, OR

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Bichar Properties

- Depend on feedstock and pyrolysis conditions
- Typically include:
  - 60-80% C content
    - Stable for centuries
  - High porosity
  - Basic, alkaline, high-pH
    - Can be adjusted to lower pH during manufacture
  - Stores water and nutrients for plant use
  - Surface chemistry is similar to activated carbon
  - Binds metals and organic contaminants

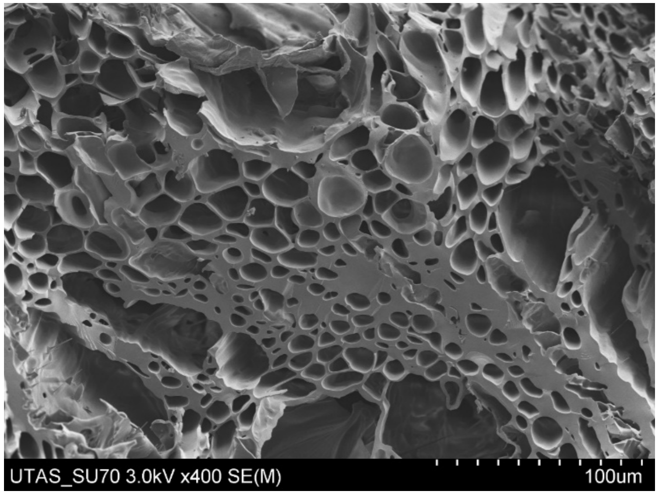

Photo: Biochar project http://biocharproject.org/

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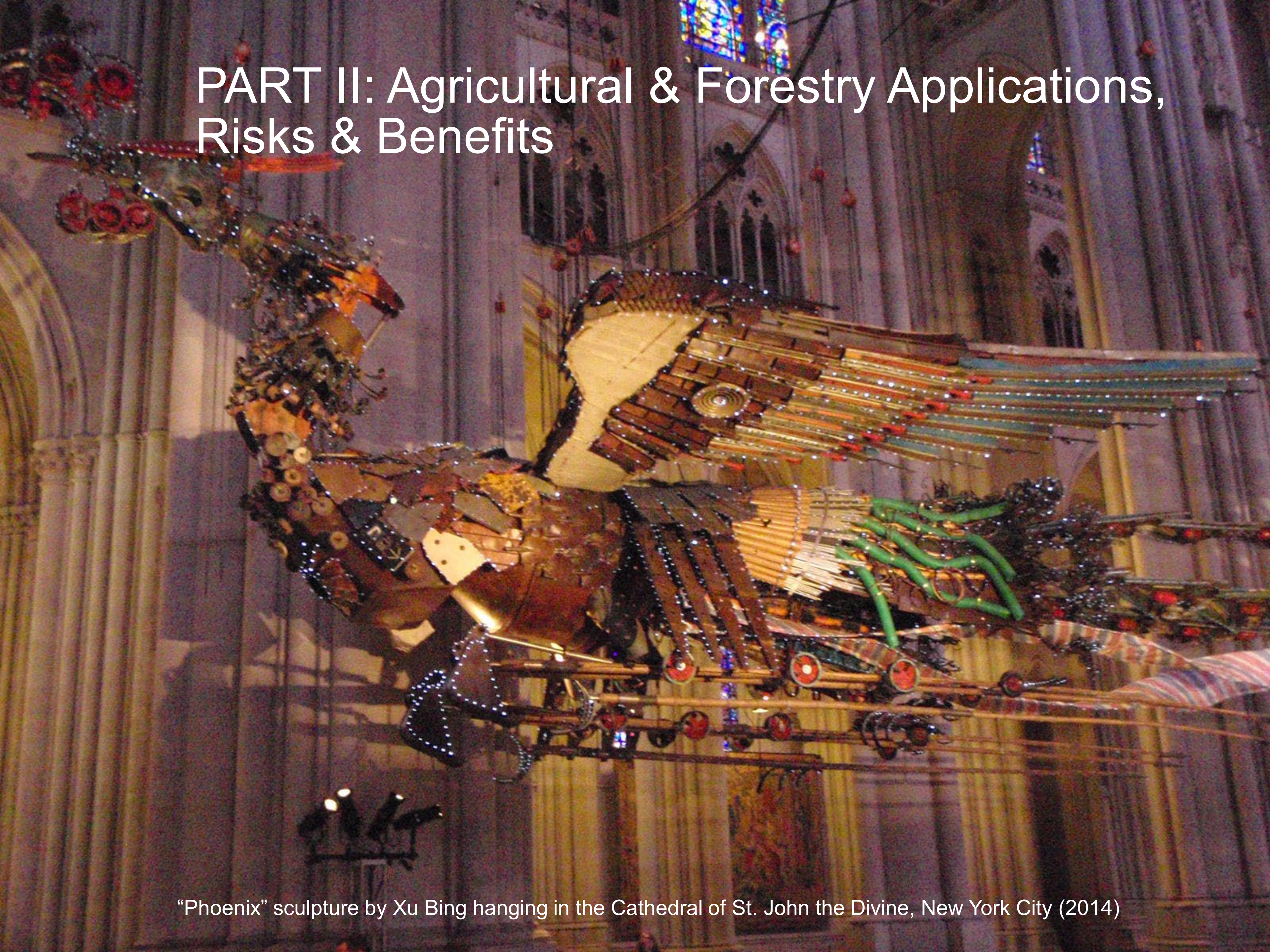
Q&A on biochar basics (15 min)

- Individually write down questions in Zoom chat. (4 min)
- Hosts will verbally pose questions from chat to Jim. (11 min)

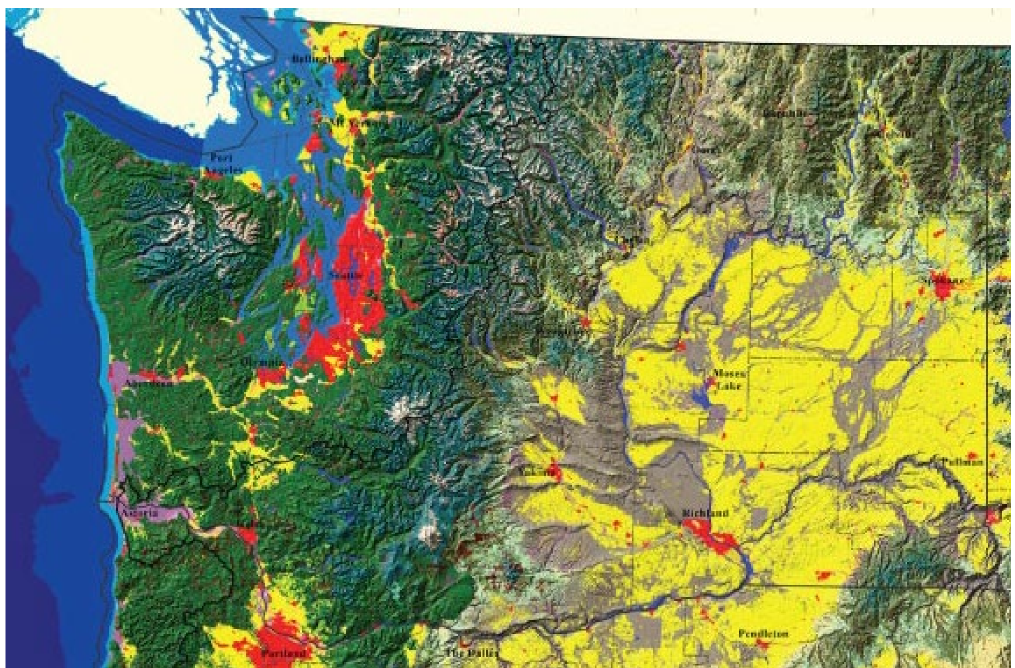
PART II: Agricultural & Forestry Applications, Risks & Benefits



“Phoenix” sculpture by Xu Bing hanging in the Cathedral of St. John the Divine, New York City (2014)

Biochar and Washington: A Good Match

- Large agricultural land area for incorporation
- Moderate soil fertility
- Adequate feedstock supply
- Need for more efficient irrigation methods
- Low carbon intensity of energy supply



Sustainably Procured Biomass Supply in Washington State

		Millions od tonnes
▶ Harvested Crop Residues		1.81
▶ Wood from Municipal Solid Waste		0.26
▶ Green Waste		0.03
▶ Forestry residues	(low)	4.91
	(high)	17.73
	TOTAL:	7-20 M odt

- Forestry residues account for 70% to ~90% of total

Amonette 2021 WA-ECY 22-07-002

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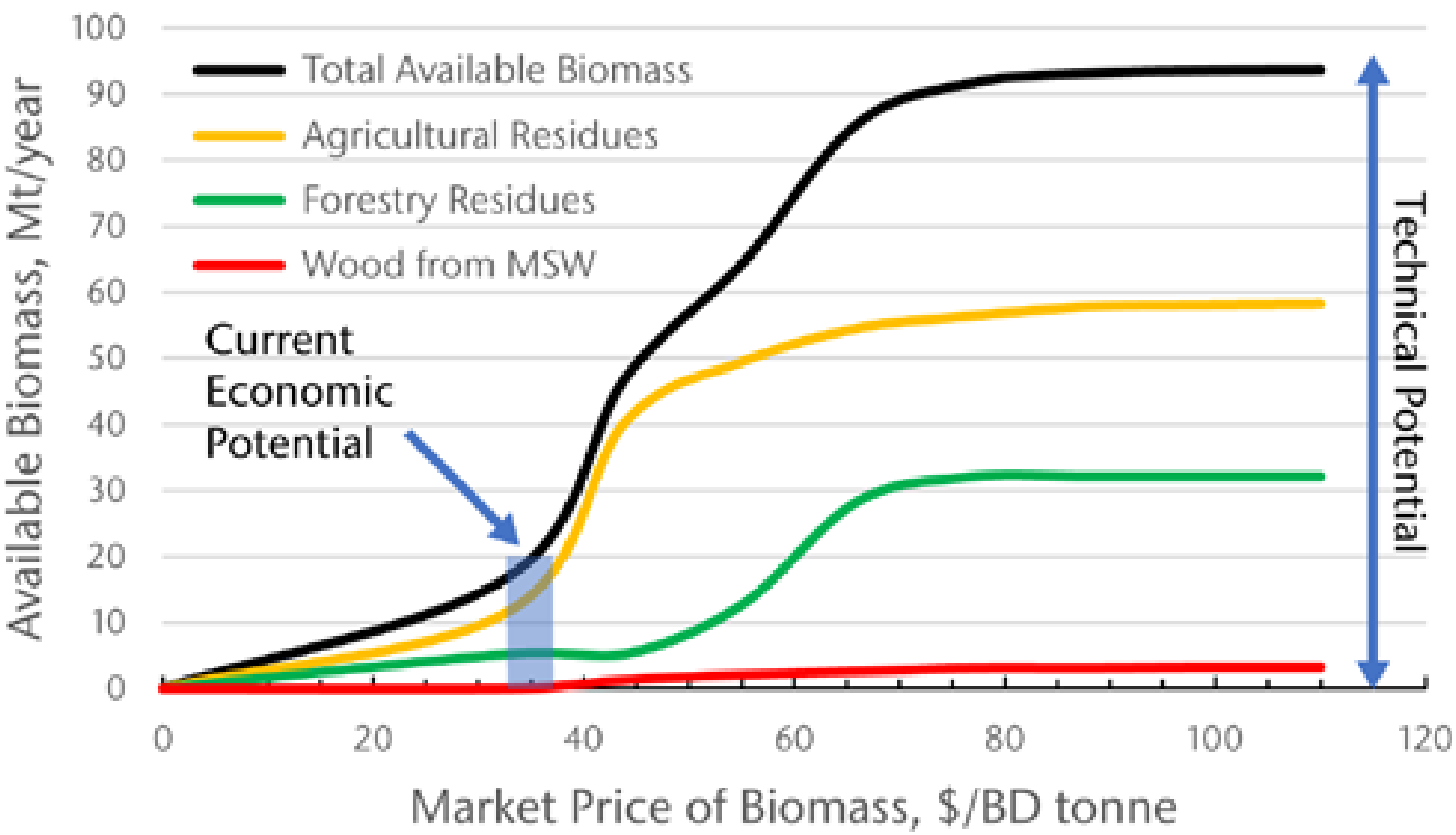
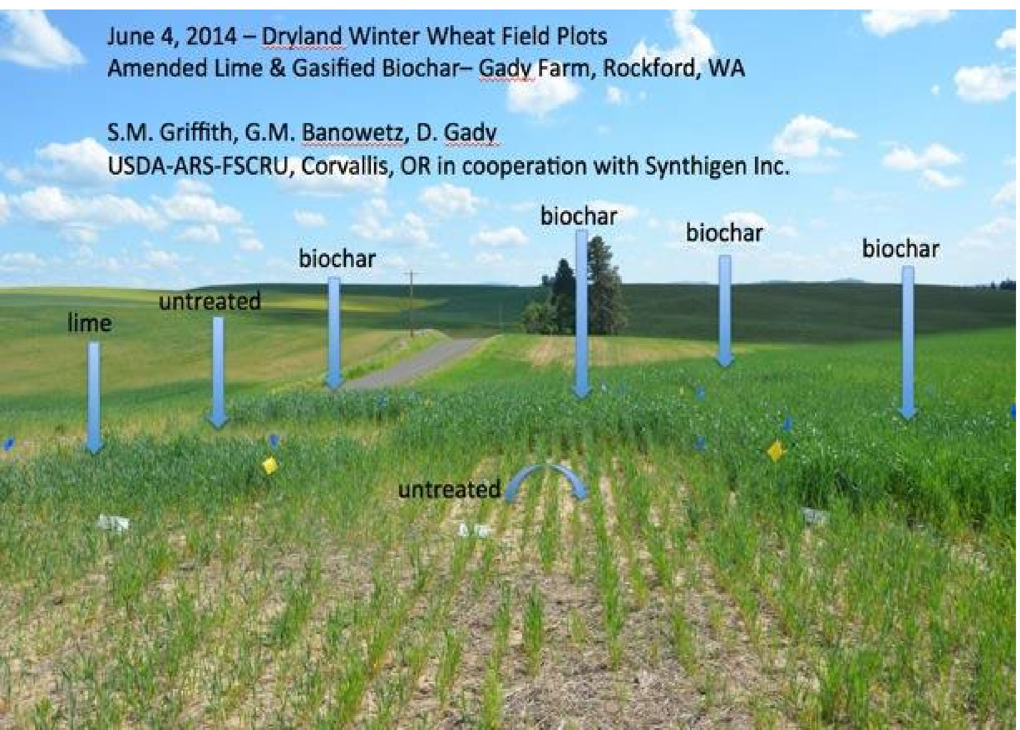
Biomass Availability Depends on Market Price (17 Western States)

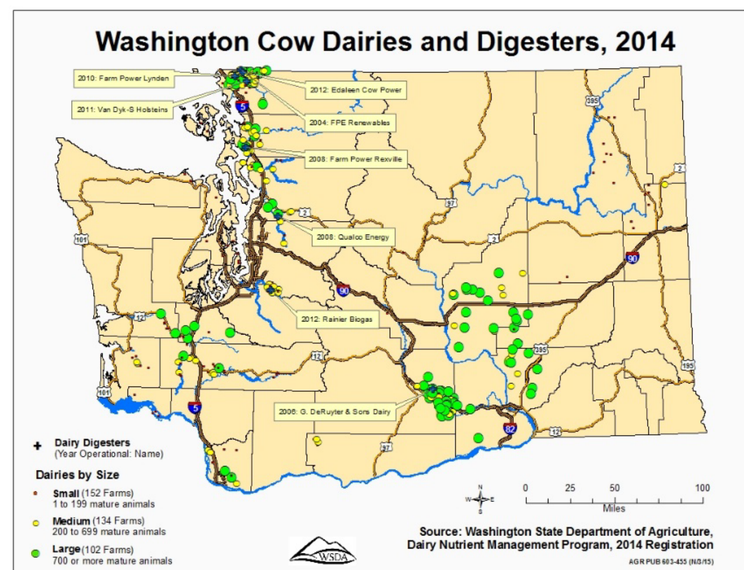


Amonette et al. 2021; https://csanr.wsu.edu/biomass2biochar/
Data from USDOE Billion Ton Report (2016)

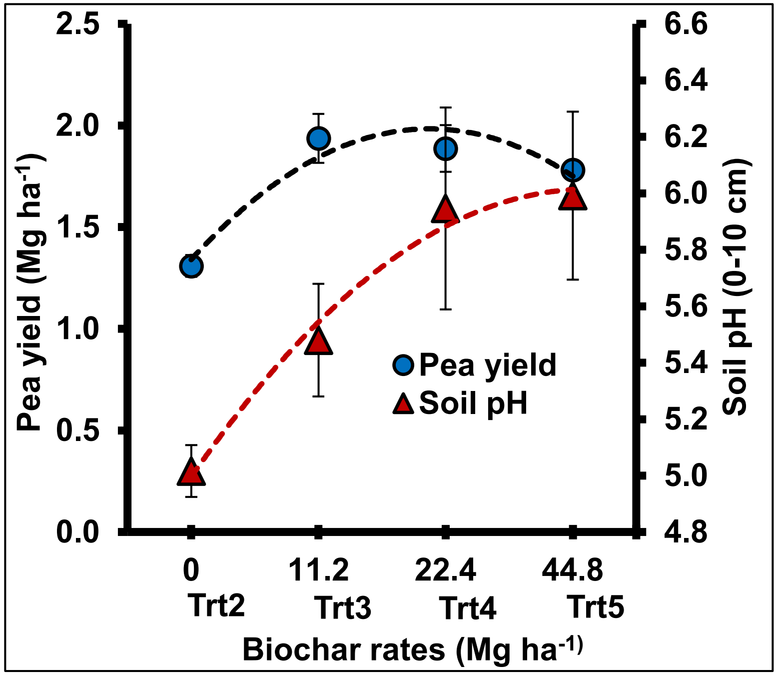
Agricultural Applications

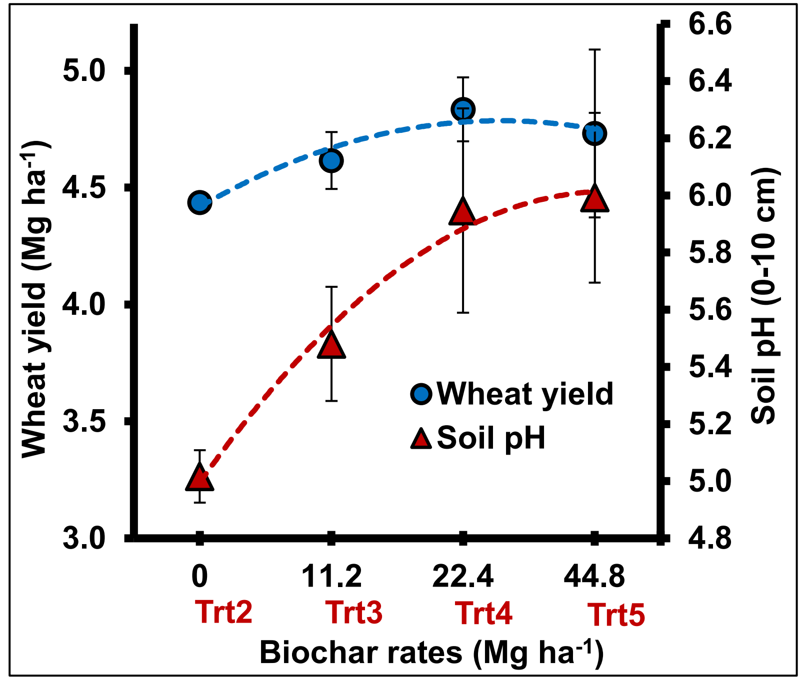
- Soil Amendment
  - Liming agent
  - Increases porosity and water holding capacity
  - Stores carbon
  - Promotes soil organic matter formation
  - May improve crop yields
- Livestock Feed Additive
  - Improved health
  - Lower methane emissions by ruminants
- Manure Disposal
  - Feedlots
  - Dairies
  - Methane digester solids





Agricultural Applications





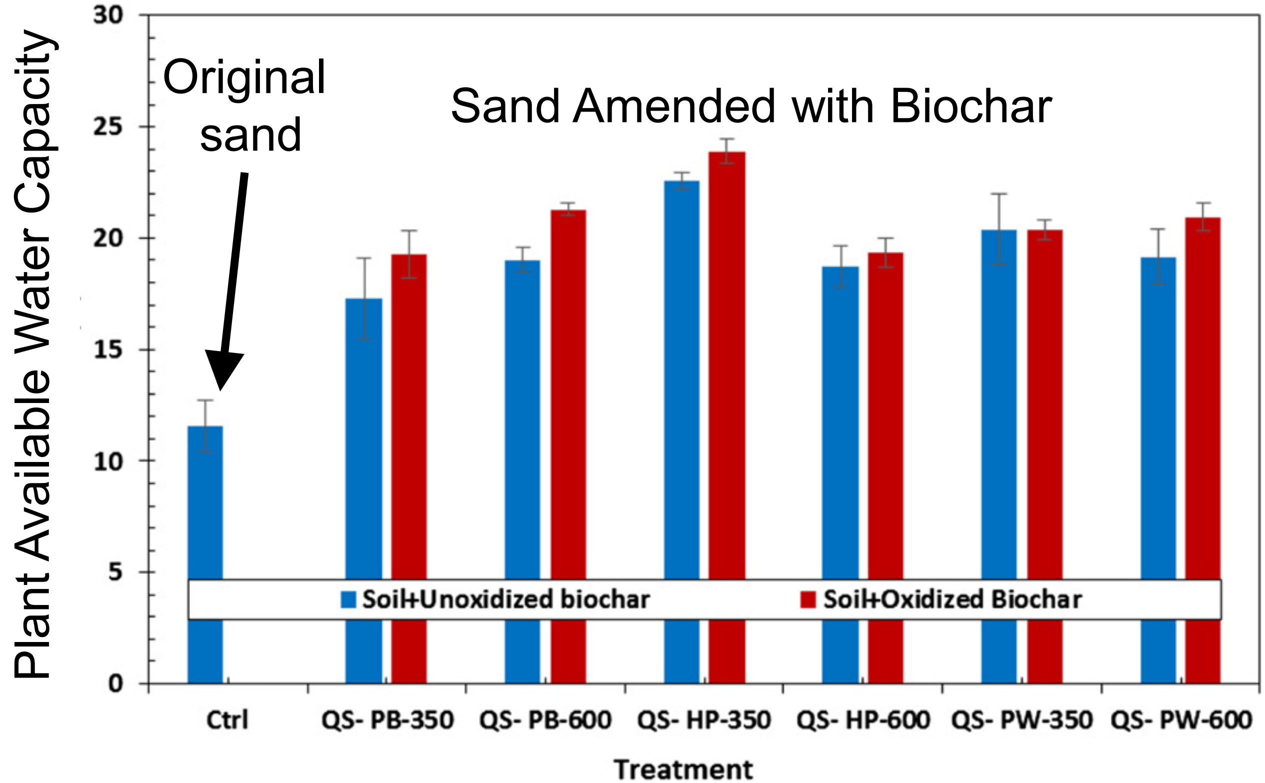
Treatments	Biochar rate (Mg ha^{-1})	Fertilizer-N rate (kg ha^{-1})	
		Wheat	Pea
Trt2	0	94	18
Trt3	11.2	94	18
Trt4	22.4	94	18
Trt5	44.8	94	18

Soil pH & Mean Yields for Dryland Wheat & Peas, 2014, 2016, 2017
Columbia Basin Agricultural Research Center
Adams, OR

Machado et al., 2017, Oregon State University

Agricultural Applications

- Doubling of plant-available water holding capacity in a Quincy sand



Suliman et al., 2017, Sci.Tot. Environ. 574:139

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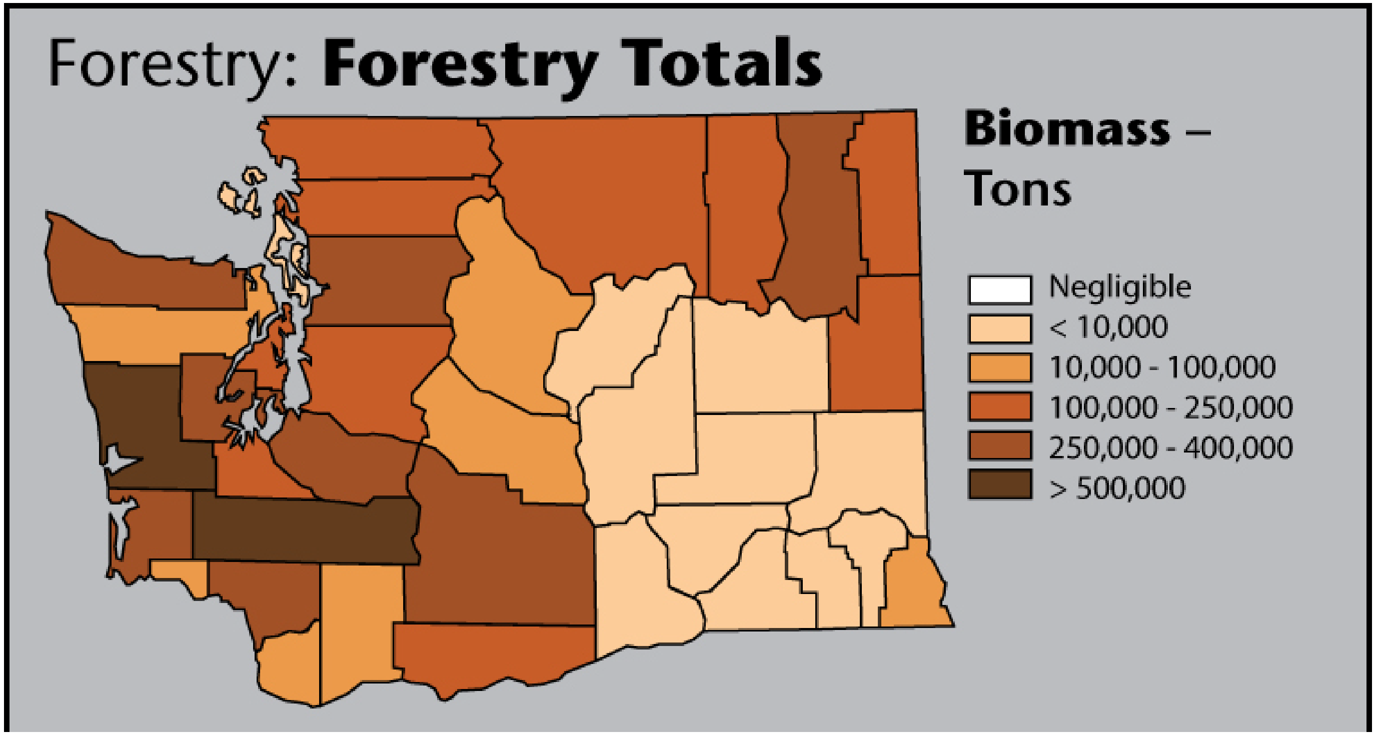
Forestry Applications

- Location of Forestry Biomass in Washington State



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Forestry Applications

- Thinning for fire hazard reduction
- Slash during timber harvest
- Key is to avoid open slash pile burns, which are the worst alternative from a climate perspective

Logs and slash piled near Flagstaff, Arizona covering four acres at a depth of approximately 20 feet. This pile was assembled but never taken off-site due to the lack of forest products manufacturing facilities nearby and was subsequently consumed in the 2019 Museum Fire. (Photo: Markit! Forestry)

Amonette et al. 2021
https://csanr.wsu.edu/biomass2biochar/

Forestry Applications

- Mobile air curtain burners can function as gasifiers with minimal smoke production and *high throughput* but are not efficient biochar producers
- Containerized gasifiers, slow-pyrolysis kilns, and large bioenergy facilities have *best climate impacts*
- Flame cap kilns work for *small wood lots, rough terrains*, and where biochar is returned to forest lands, but climate impacts are not as robust

Air curtain burner, Clean Air Combust, LLC

https://www.qualterraag.com

Biomass One, White City, OR

https://wilsonbiochar.com

https://biocharnow.com

Linking Forestry and Agriculture

- Thinning of forests to reduce fire risk can supply woody biomass
- Mobile biochar units can convert biomass to high quality biochar
- Application of biochar to acid croplands can improve crop yields and water management
- A potential win-win

https://www.arti.com/reactors/

Control Lime Biochar (10 t/ac)

Griffith et al. 2015

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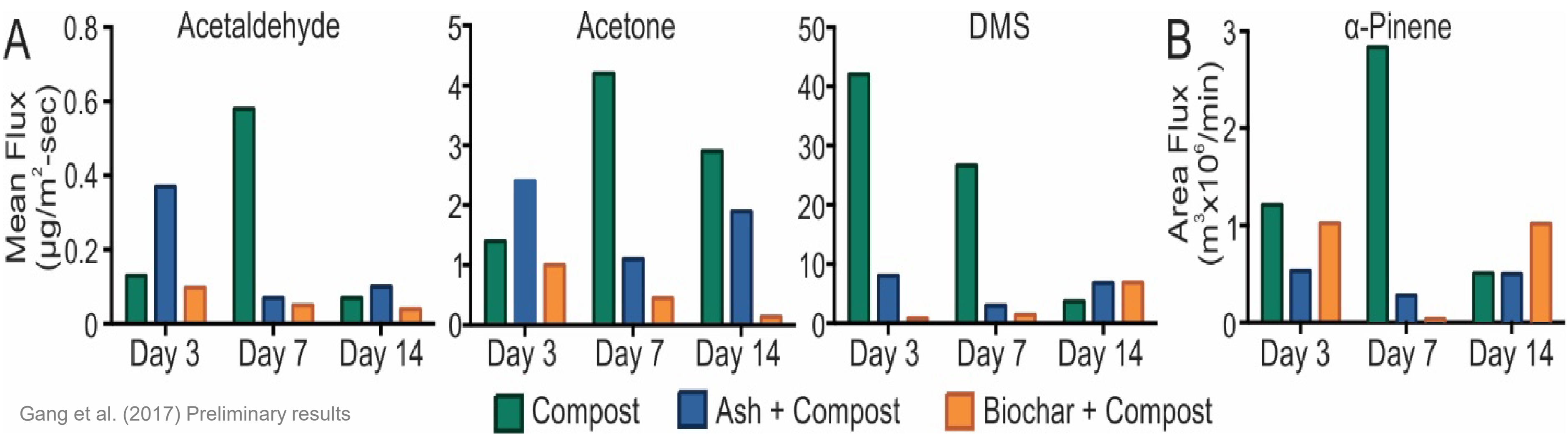
Organic Waste Management Applications

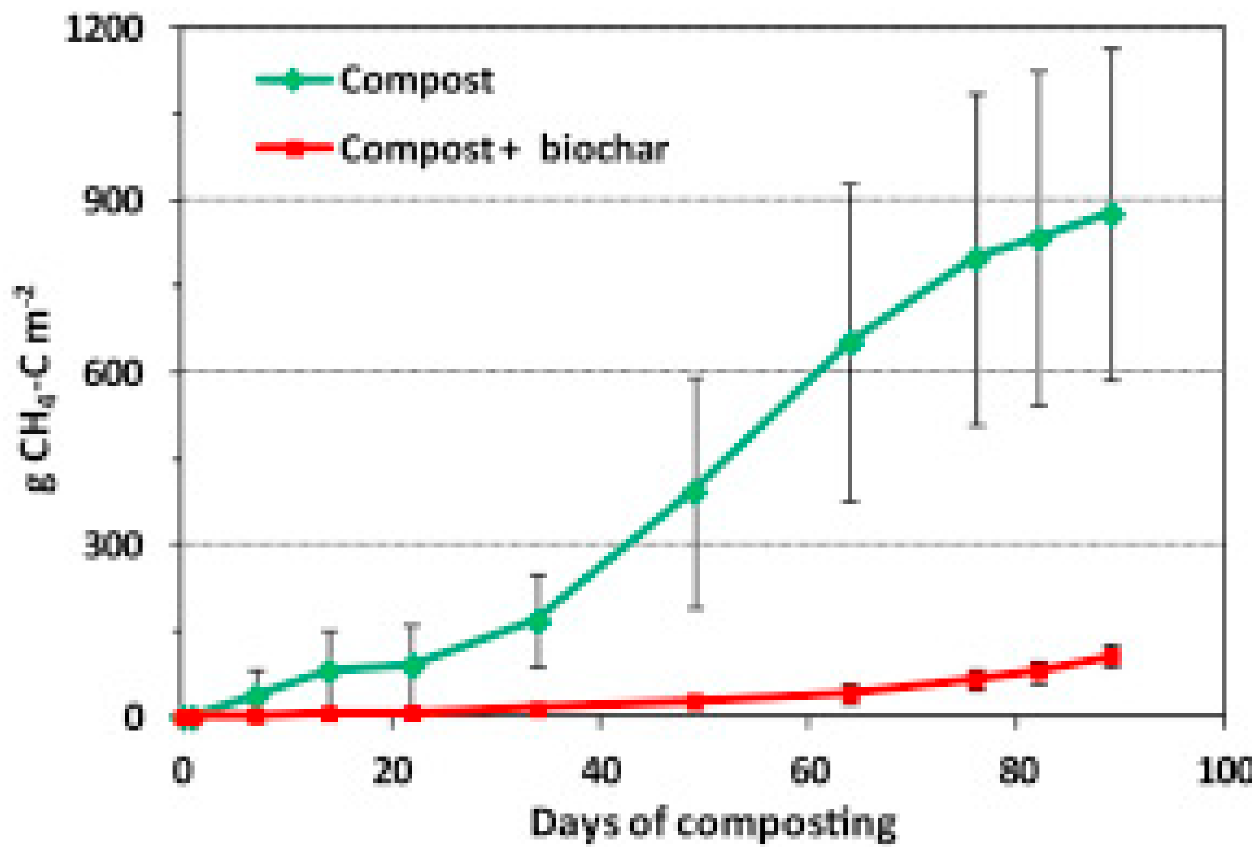
- Clean woody biomass in municipal waste streams
- Composting operations
  - Lowers odors
  - Speeds process
  - Decreases methane emissions



Gang et al. (2017) Preliminary results

Organic Waste Management Applications

- Decreased Methane Emissions



Vandecasteele et al. 2016, J Environ. Manag. 168:200

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Environmental Filtration Applications

- Roadway Strips
- Storm Water Runoff
- Road Salt
- Remediation of Spills
- Mine Reclamation

Myles Gray, Oregon State University

Pacific Northwest Pollution Prevention Resource Center

Risks

- Polyaromatic hydrocarbons (PAHs)
  - Generally not a problem, each biochar needs testing to confirm
  - In many instances biochar *removes* PAHs from water
- Decreased efficacy of pesticide/herbicides
  - Sorption of organics works both ways . . .
- Uncontrolled Preparation
  - Clean, efficient methods need to be used
  - Byproducts from fast pyrolysis often a problem
  - Spontaneous combustion if product not handled correctly
- Uncontrolled Application
  - Need to match specific biochars to specific soils and crops
  - Dust and runoff if not injected or tilled
- Quality Control
  - Very diverse range of biochar properties possible
  - Certification programs

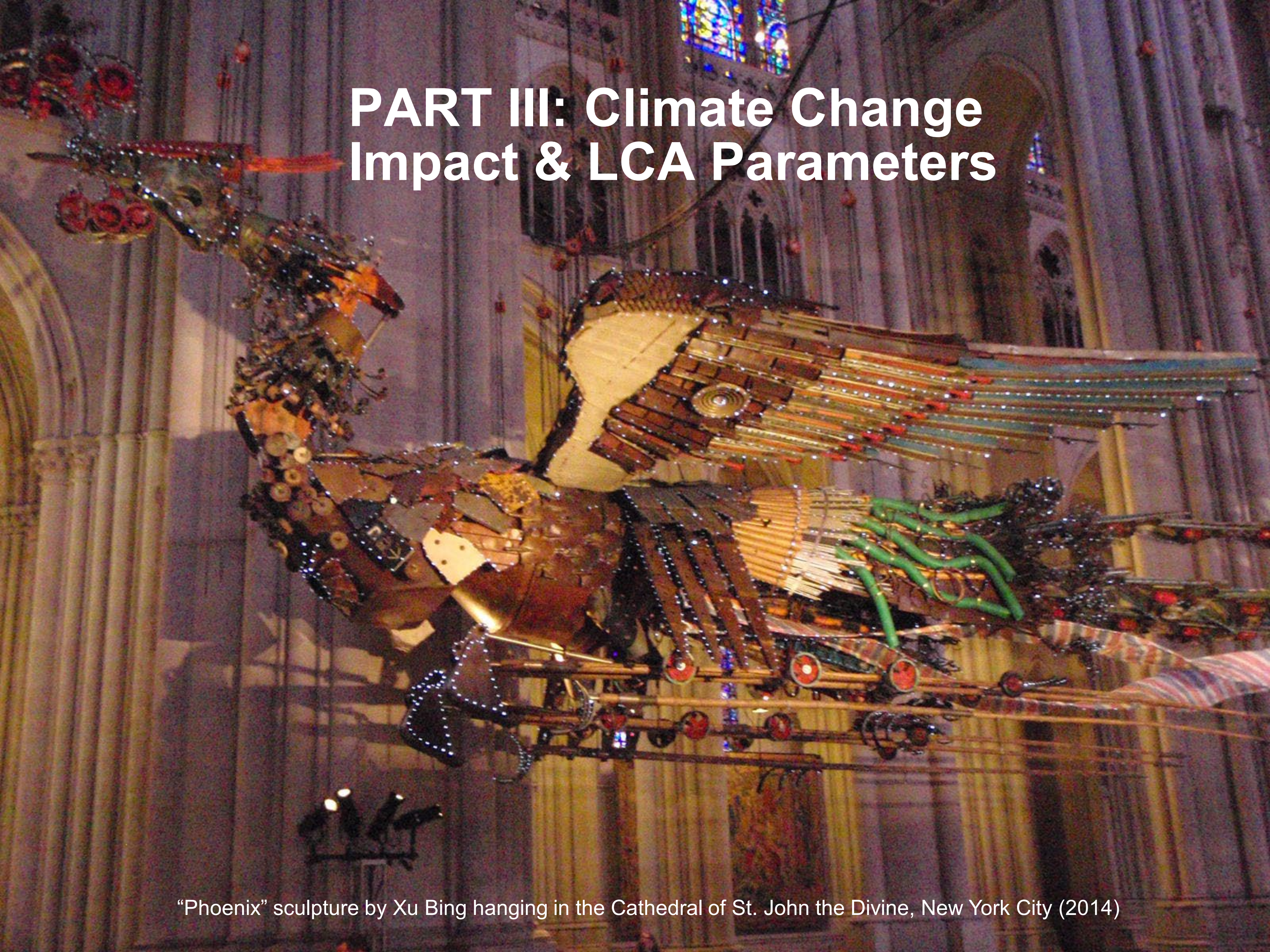
Benefits

- Development of new industry
  - Boost to rural and urban economies
  - New equipment/technological development
- Improve soil health and crop yields
  - Catalyze formation and retention of soil organic matter
  - Increase yields in acid soils
  - Already finding use with high-value cropping systems
- Fire risk mitigation and cost
  - Shift equation away from fighting fires to managing forests
- Water management
  - Improve water holding capacities of sandy soils
- Climate change mitigation
  - Store carbon in easily verifiable form

Q&A on biochar applications (15 min)

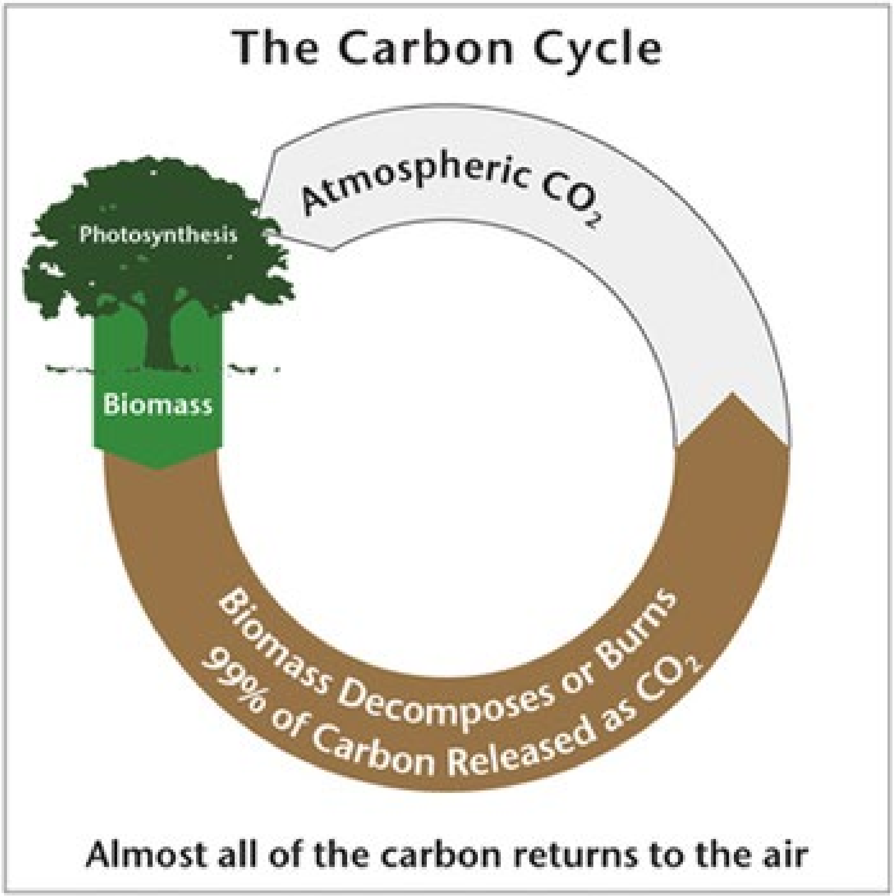
- Individually write down questions in Zoom chat. (4 min)
- Hosts will verbally pose questions from chat to Jim. (11 min)

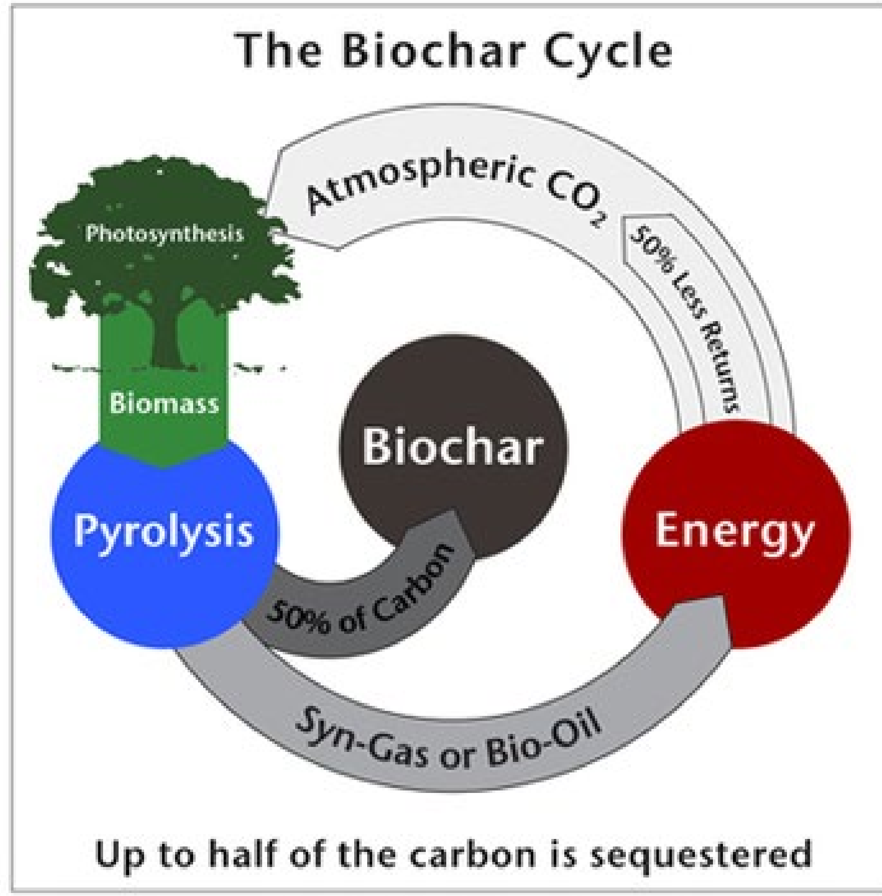
PART III: Climate Change Impact & LCA Parameters



“Phoenix” sculpture by Xu Bing hanging in the Cathedral of St. John the Divine, New York City (2014)

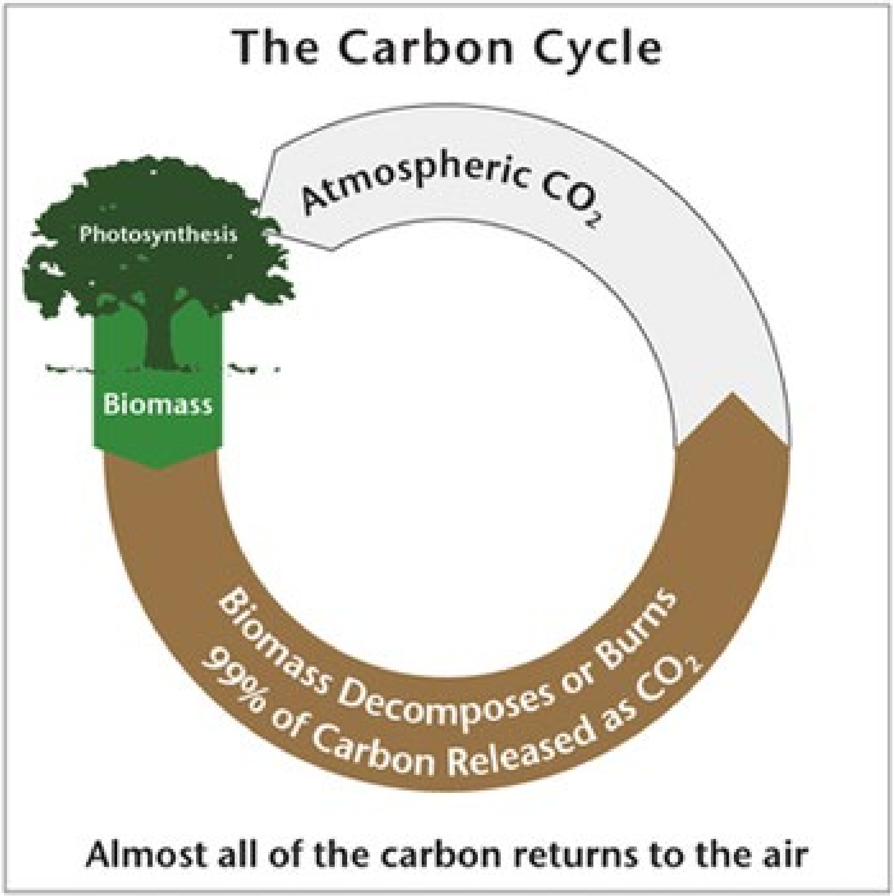
Climate Change Mitigation

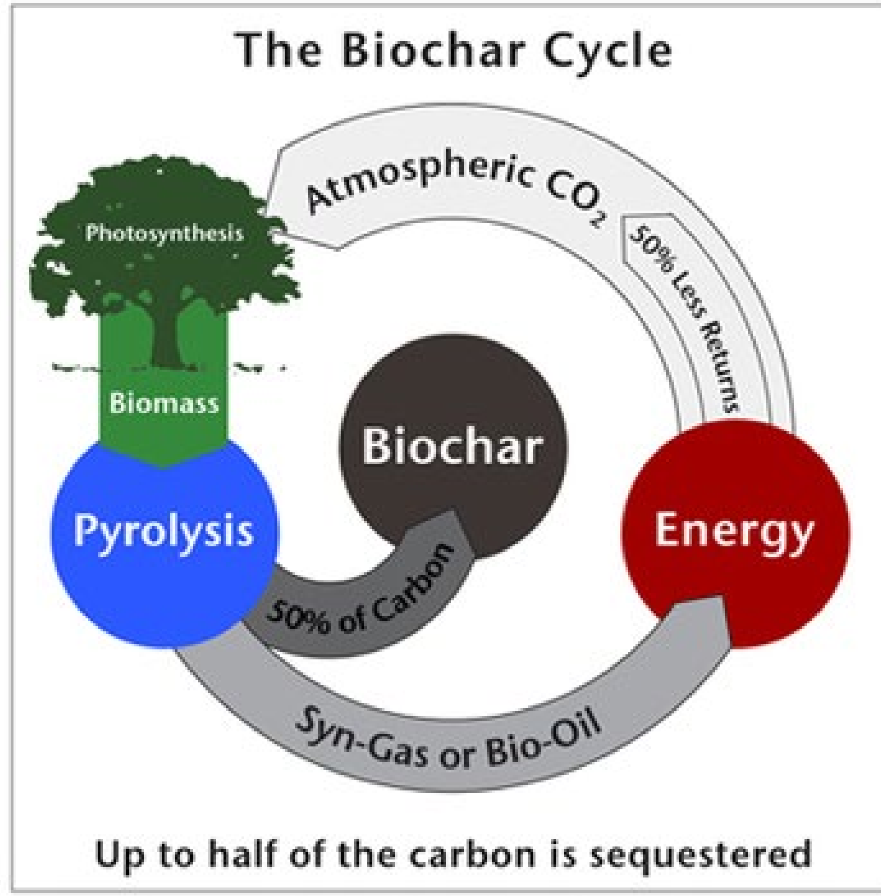




Biochar Solutions, Inc. 2011

Climate Change Mitigation

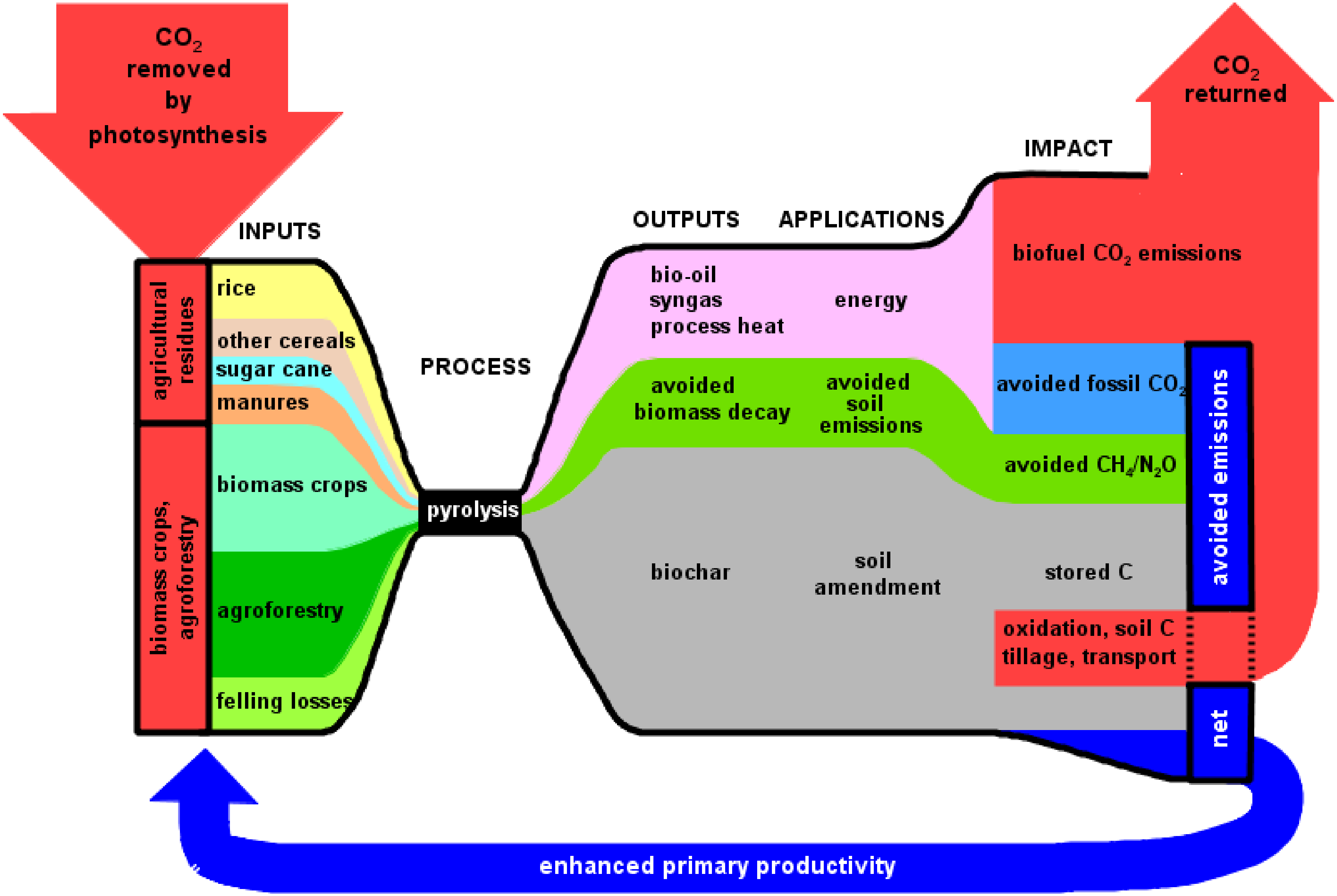




Biochar Solutions, Inc. 2011

- Lifetime of high-quality biochar is ~20x greater than wood and ~200-500x greater than straw
- Carbon efficiency and quality of man-made biochar exceed those of natural charcoal from wildfire

Concept for Sustainable Biochar/Bioenergy

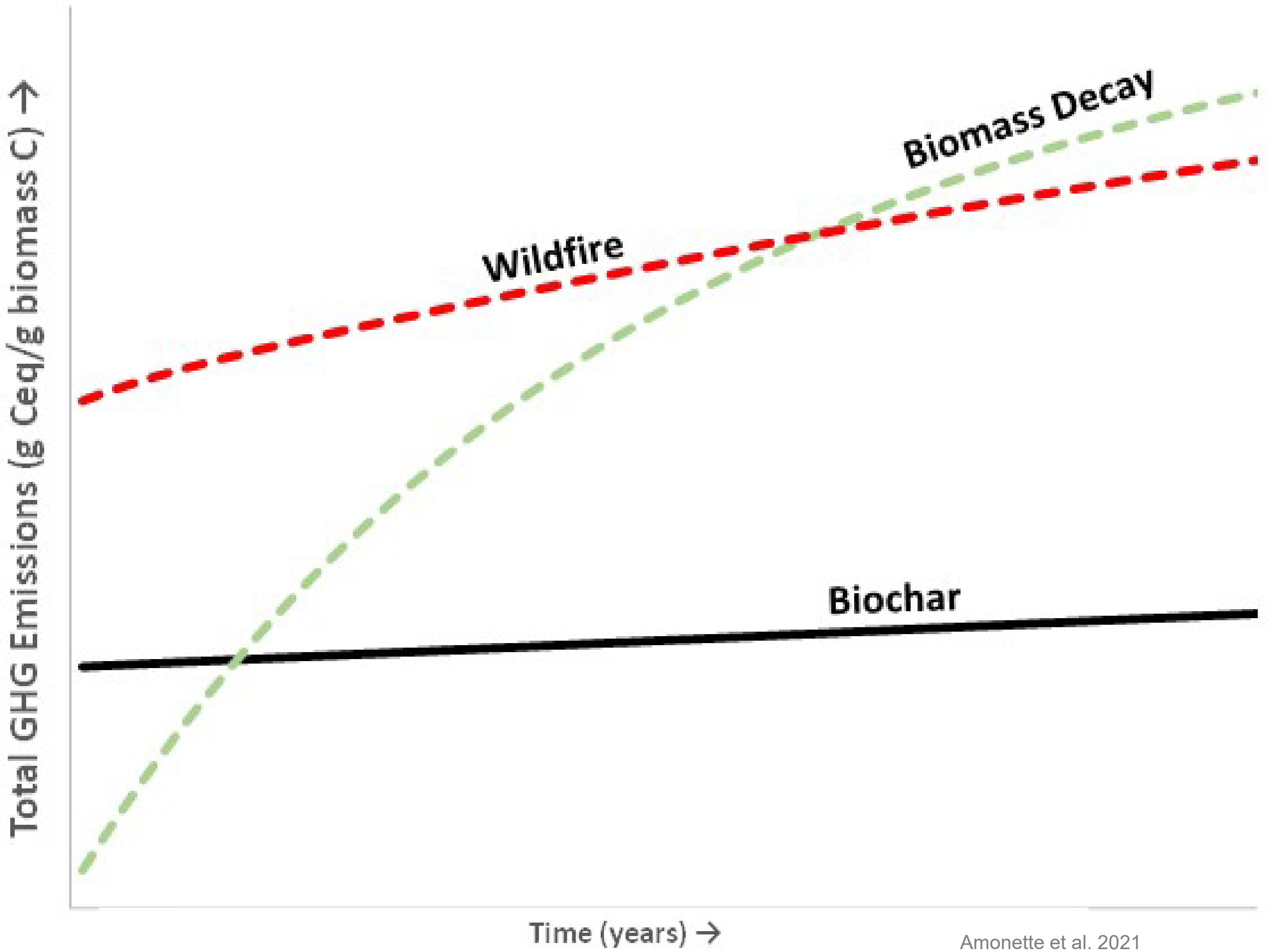


Woolf et al. 2010 Nature Comms 1:56

Key LCA Parameters

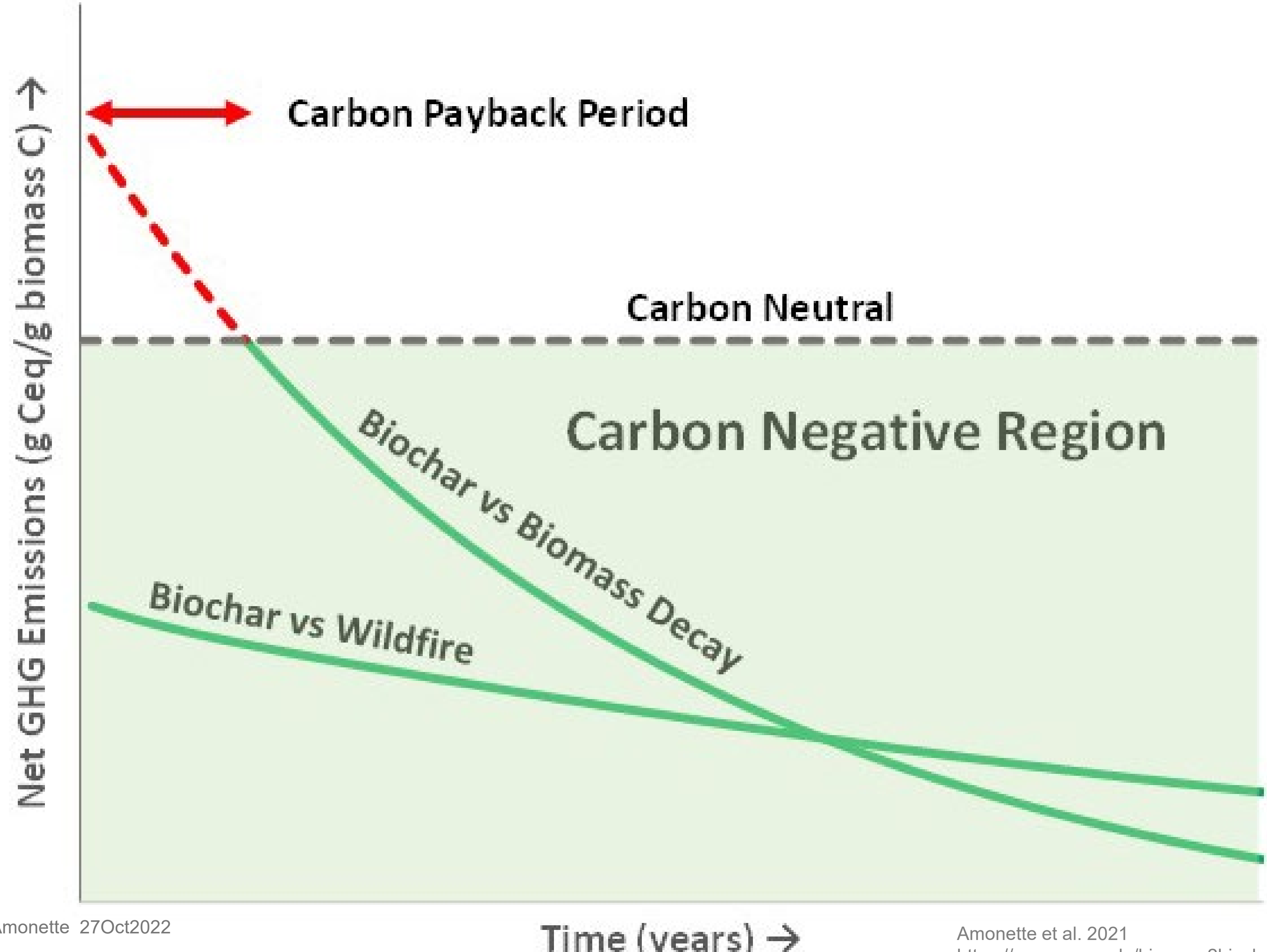
- Biomass Composition
  - C content
  - Lignin content
- Alternative Pathway(s) for Biomass
- Bioenergy Production
- Carbon Efficiency of Production
  - $C_{biochar}/C_{biomass}$
- Production GHG/A Emissions
  - Methane (GWP_{20} = 108)
  - Soot (GWP_{20} = 3300)
- Biochar Quality
  - C content
  - $H:C_{org}$ Ratio (Proxy for Chemical Stability to Oxidation)
- Impact on Soil Properties
  - C Stocks (Priming)
  - GHG Emissions
  - Plant Growth (Primary Productivity)

Climate Offsets Depend on Alternative Fate(s) of Biomass



Amonette et al. 2021
https://csanr.wsu.edu/biomass2biochar/

Climate Offsets Depend on Alternative Fate(s) of Biomass



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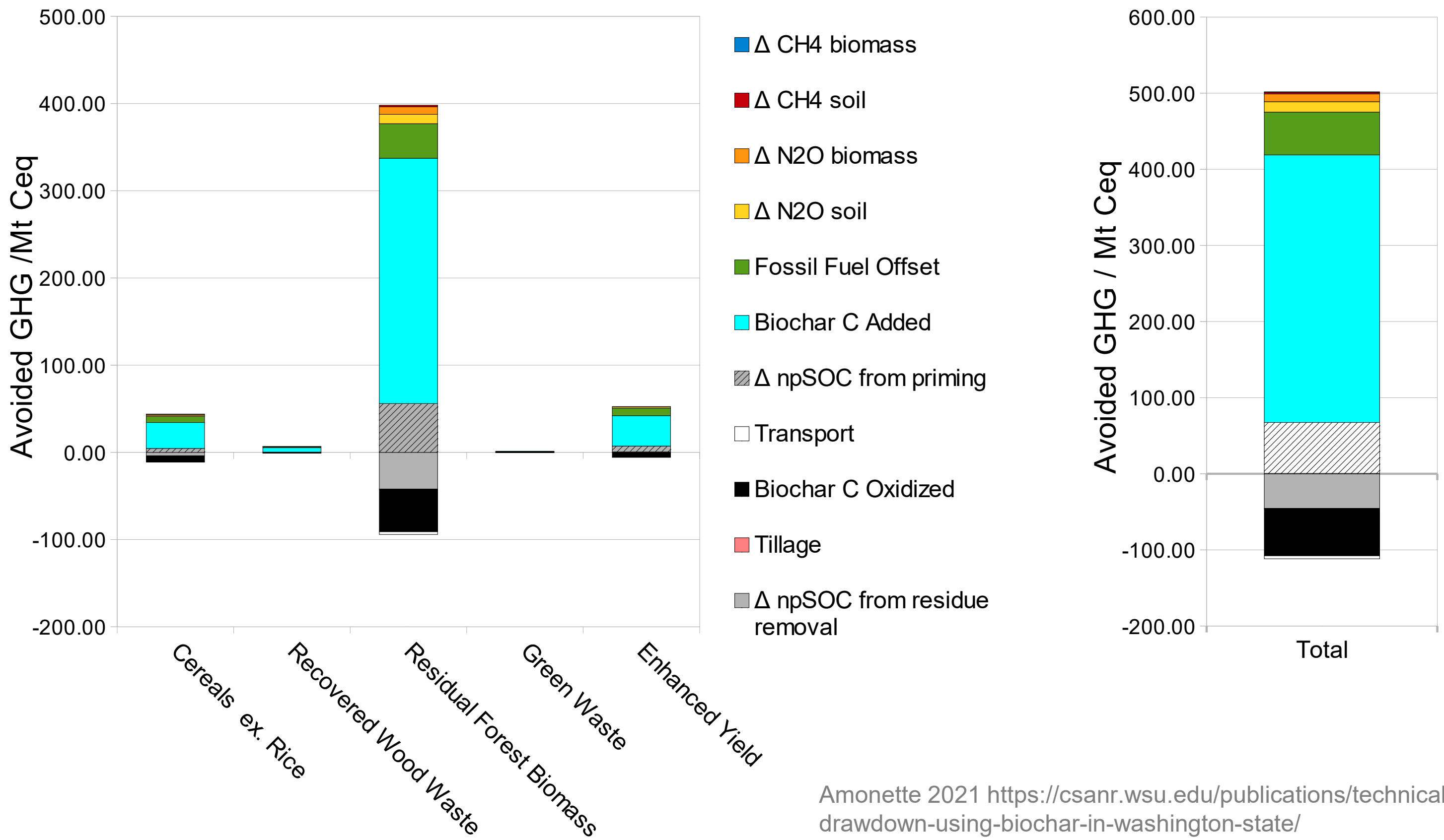
Amonette et al. 2021
https://csanr.wsu.edu/biomass2biochar/

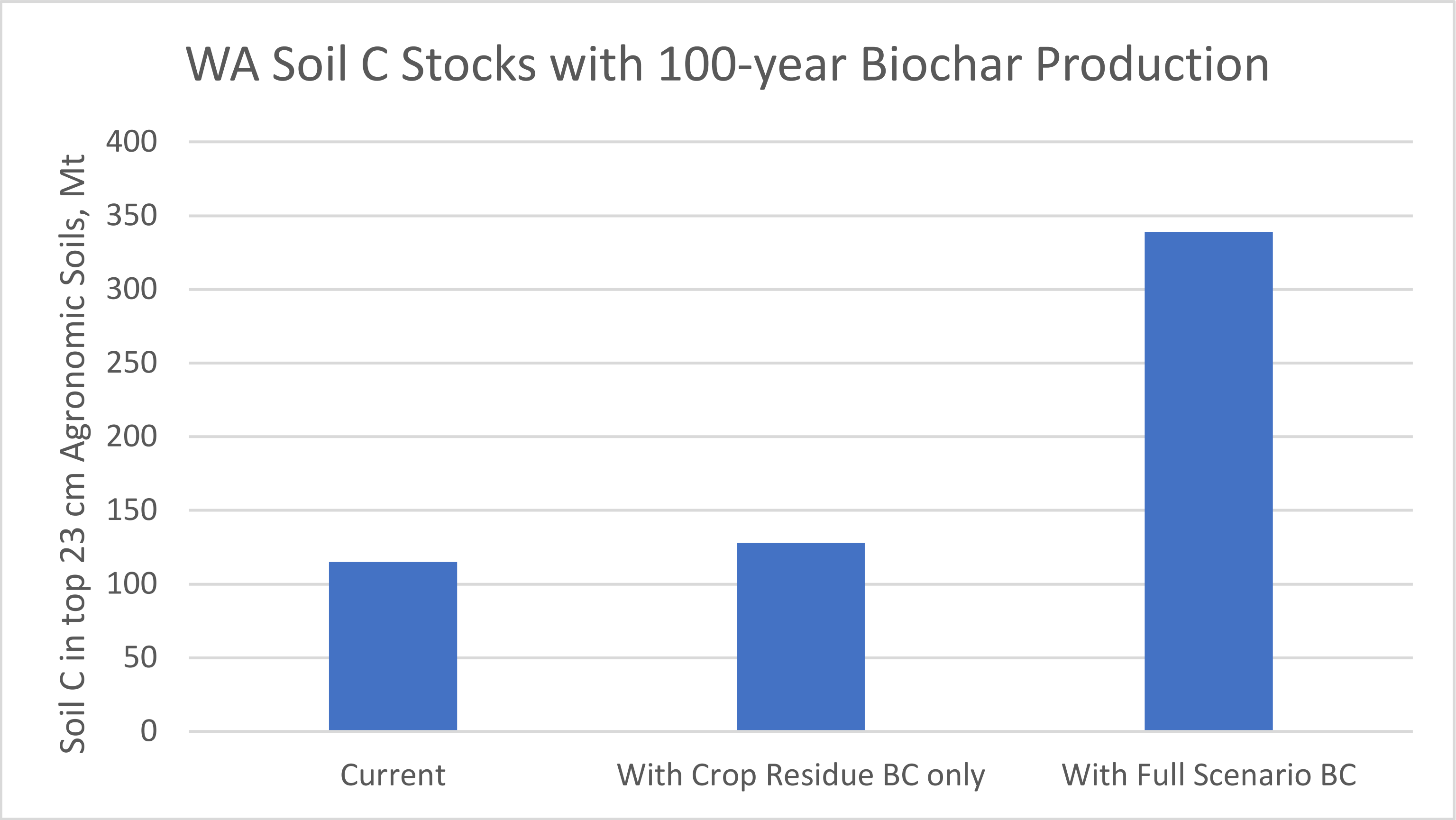
Climate Change Mitigation in WA State



Amonette 2021 https://csanr.wsu.edu/publications/technical-potential-for-co2-drawdown-using-biochar-in-washington-state/

- *Supply* of sustainably harvested feedstock, *C-efficiency* of biochar production, and *C-quality* of biochar determine impact
- Over a century, biochar can offset 8% to 19% of the GHG emissions in WA State (2018 levels, max. *technical* potential)
- 75-80% of this offset is net C storage/accumulation in soils

Predicted Soil C Stocks in WA Agronomic Soils with Biochar Production



Data from Amonette 2021 https://csanr.wsu.edu/publications/technical-potential-for-co2-drawdown-using-biochar-in-washington-state/

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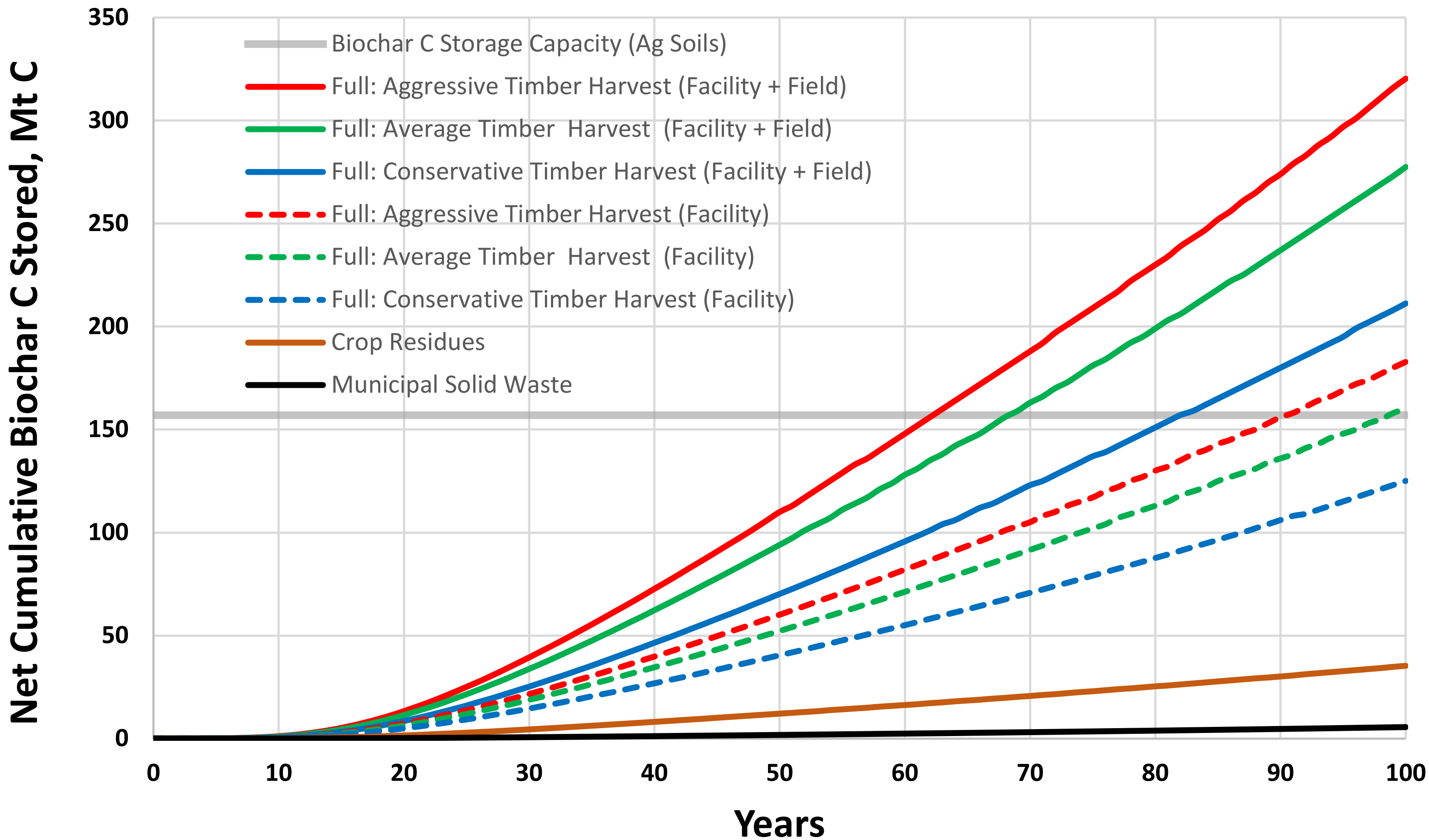
Biochar Storage Capacity in WA Soils



Amonette 2021 https://csanr.wsu.edu/publications/technical-potential-for-co2-drawdown-using-biochar-in-washington-state/

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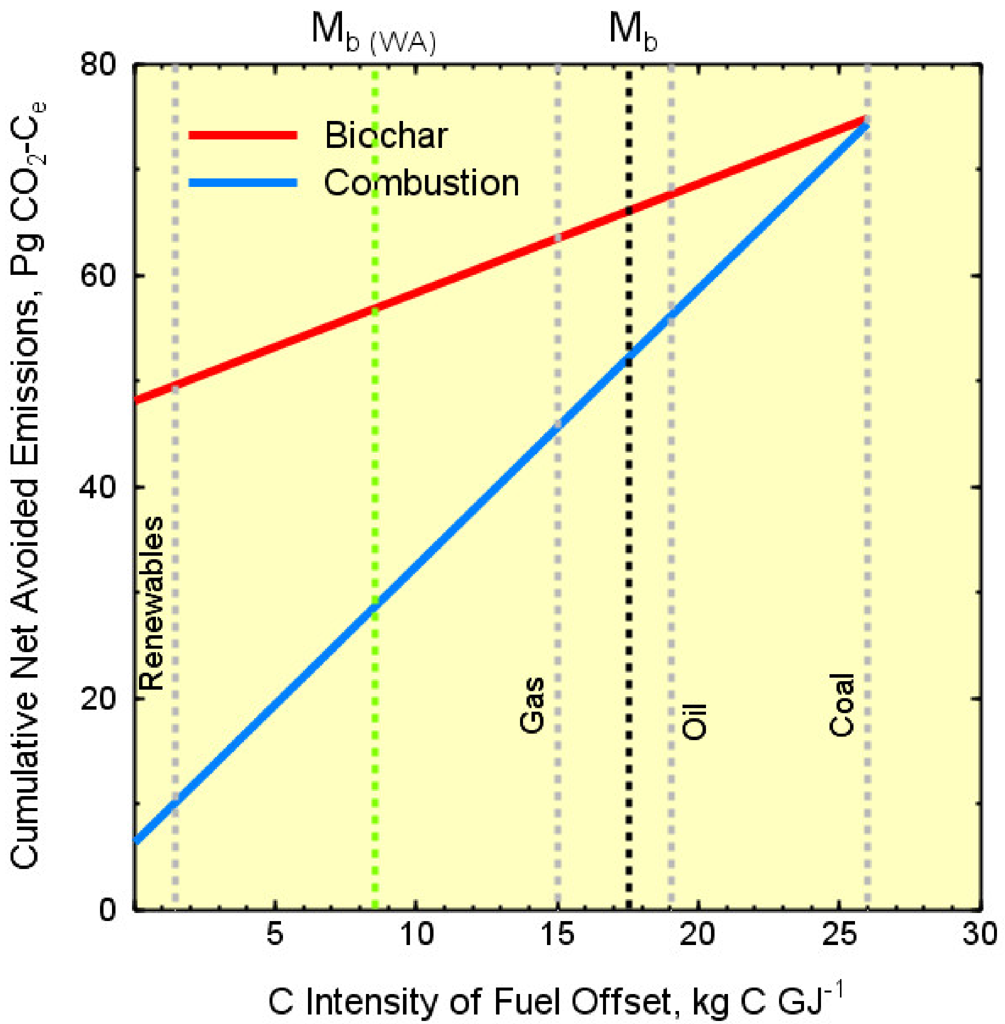
Biochar is twice as effective as bioenergy for climate change mitigation in Washington



after Woolf et al. (2010)

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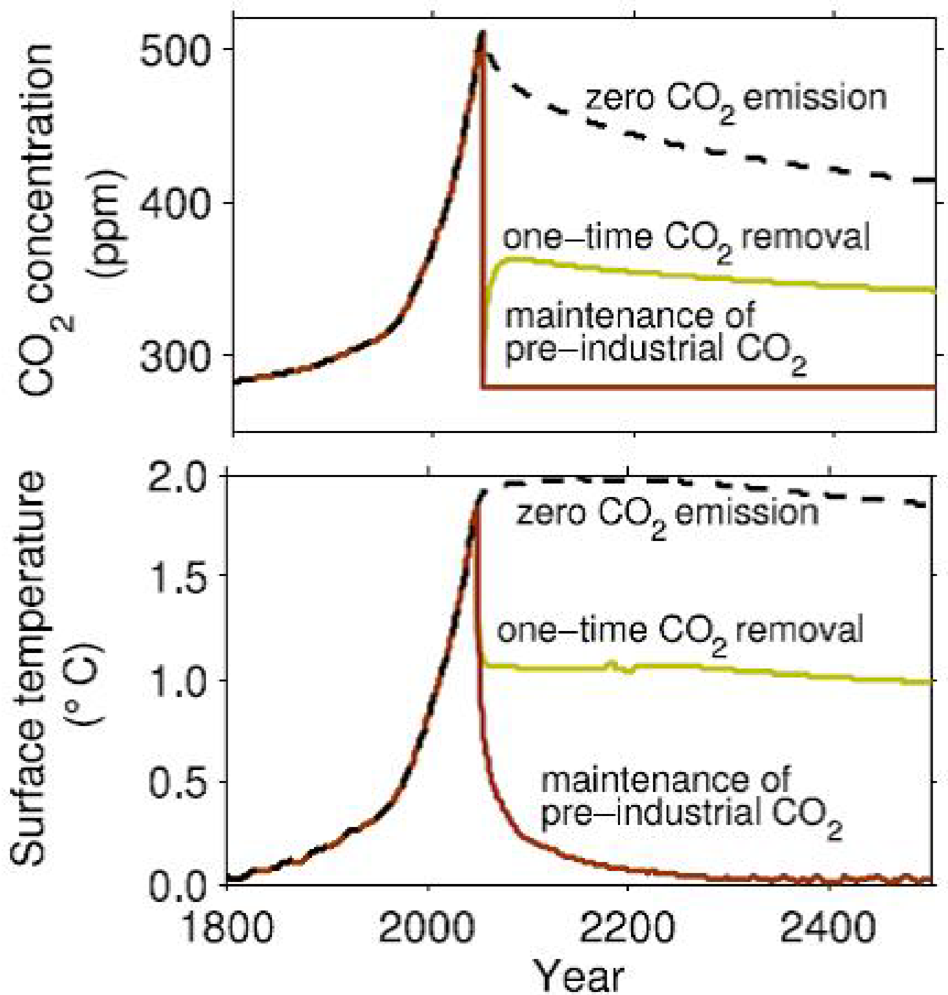
Immediate and Ultimate Drawdown Potentials



Cao & Caldeira (2010)

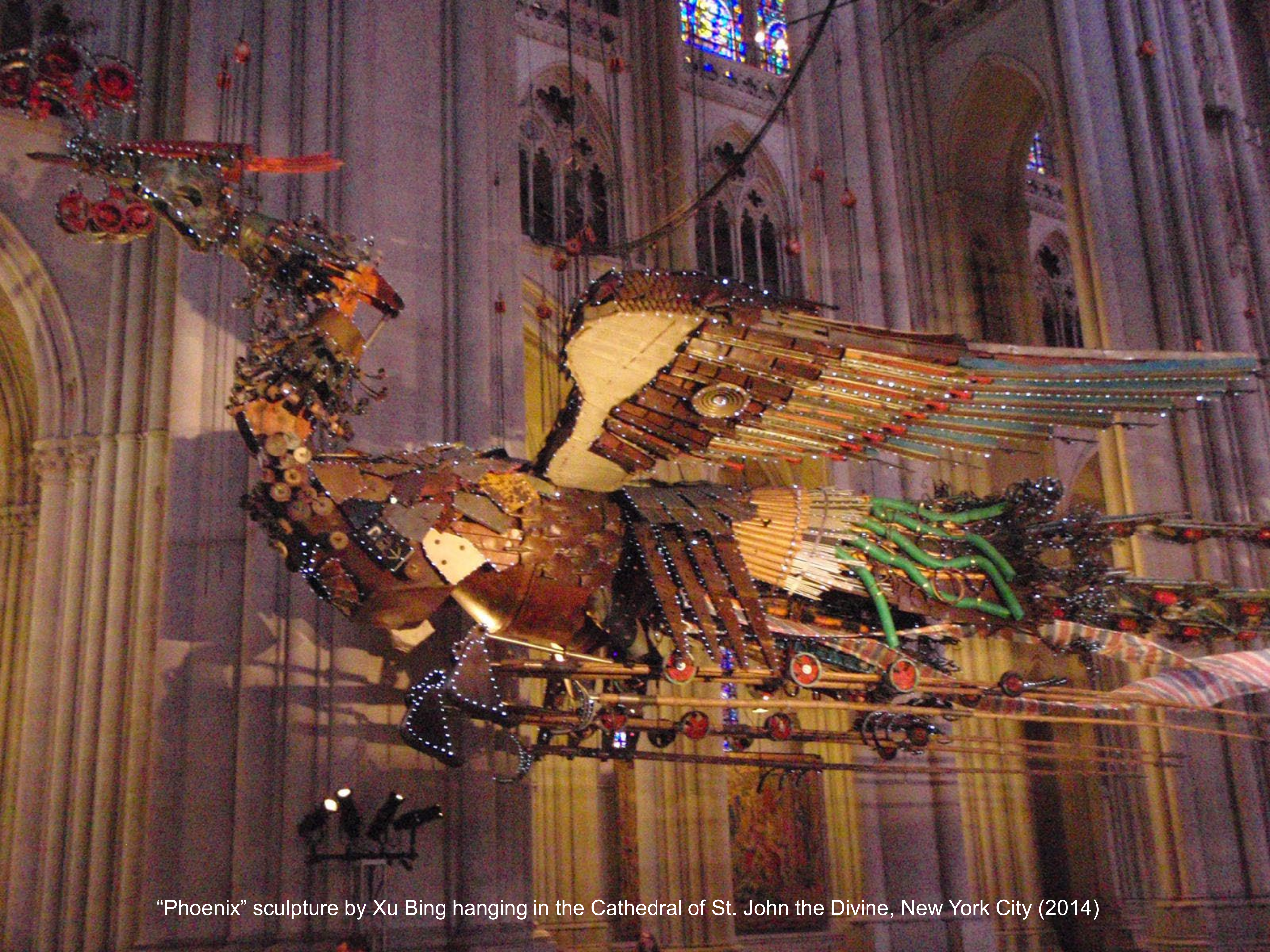
Due to climate system responses, primarily ocean degassing, the ultimate drawdown potential is 2.17 times smaller than the immediate drawdown potential

Back to the Future

- To return our climate to the “safe” zone (~350 ppm CO_2) we will need to draw down at least 1000 Gt of CO_2 over the next century or two
  - Half of this is in the atmosphere now
  - The other half is in the ocean and will be released as we draw down atmospheric CO_2
- Minimum cost for this effort is in the tens of trillions of $
- Biochar can sustainably draw down about a third of the amount needed (ca. 333 Gt CO_2)
- In concert with a build-up of native soil C stocks (regenerative ag) and enhanced weathering of calcium and magnesium silicates (think basalt) we can likely get to 500 Gt CO_2
- All C-drawdown technologies will likely be needed!
- An integrated biochar research program will guide the fastest pathway to C drawdown

Q&A on biochar climate impacts & LCA approaches (15 min)

- Individually write down questions in Zoom chat. (4 min)
- Hosts will verbally pose questions from chat to Jim. (11 min)



“Phoenix” sculpture by Xu Bing hanging in the Cathedral of St. John the Divine, New York City (2014)

For further information . . .

Lehmann J. and S. Joseph (eds.). 2015. *Biochar for Environmental Management: Science, Technology and Implementation, 2nd Edition*, Routledge, Abingdon, Oxon OK and New York, New York USA. https://www.routledge.com/Biochar-for-Environmental-Management-Science-Technology-and-Implementation/Lehmann-Joseph/p/book/9780415704151

International Biochar Initiative (www.biochar-international.org)

United States Biochar Initiative (www.biochar-us.org)

Pacific Northwest Biochar Atlas (www.pnwbiochar.org)

Acknowledgments

Staff from the following organizations contributed to this presentation:

United States Department of Agriculture Forest Service

Washington State Department of Ecology

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Oregon State University, Columbia Basin Agricultural Research Center

T. R. Miles Technical Consultants, Inc.

Sustainable Obtainable Solutions

Wilson Biochar Associates

JE Amonette holds a Joint Appointment with the Pacific Northwest National Laboratory (PNNL) and Washington State University as authorized and sponsored by the U.S. Department of Energy (USDOE). The PNNL is a multi-program national laboratory operated for the USDOE by Battelle Memorial Institute under contract DE-AC05-76RL01830.

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References and Links Cited—1

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ARTi (https://www.arti.com/reactors/)

Biochar Now LLC (https://biocharnow.com/kiln-based-technology/)

Biochar Project (http://biocharproject.org/understandingbiochar/)

Biochar Solutions, Inc. (http://www.biocharsolutions.com/overview.html)

Biomass One, White City, OR (https://biomassone.com/electricity/)

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Clean Air Combustion, LLC (http://www.roi-equipment.com/products/air-curtain-burners)

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Gray, M. G. 2015. Biochar for stormwater treatment: Technology overview & research update. Presentation given at 2015 Sustainable Stormwater Symposium, Portland, OR, 16 September 2015.

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Plenary Reflections

Rebecca Sears

DEPARTMENT OF ECOLOGY State of Washington

Round robin reflections

Share a **takeaway**

and

Share a biochar **question/topic** you're curious about

Advisory Panel Work Plan

Ecology

DEPARTMENT OF ECOLOGY
State of Washington

Future biochar exploration

- **IN THE NEAR TERM:** ENVISIONING 1-2 ADDITIONAL MEETINGS BUILDING ON BIOCHAR OVERVIEW.
- **QUESTION:** HOW MIGHT WE FOCUS FUTURE MEETINGS ON BIOCHAR TOPICS? PLEASE WRITE DOWN TOPIC IDEAS IN ZOOM CHAT.
- **EXAMPLES:** BEST FEEDSTOCKS, COMPARING PROCESSES, USES OF BIOCHAR, IMPACTS ON GHG REDUCTION, HEALTH AND SAFETY, ENVIRONMENTAL IMPACTS, ECONOMICS, LIFECYCLE ASSESSMENTS

Next Steps & Wrap Up

Ecology

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Thank you for attending