Carbon sequestration in the built environment: Initial development of biochar wallboard (BWB)

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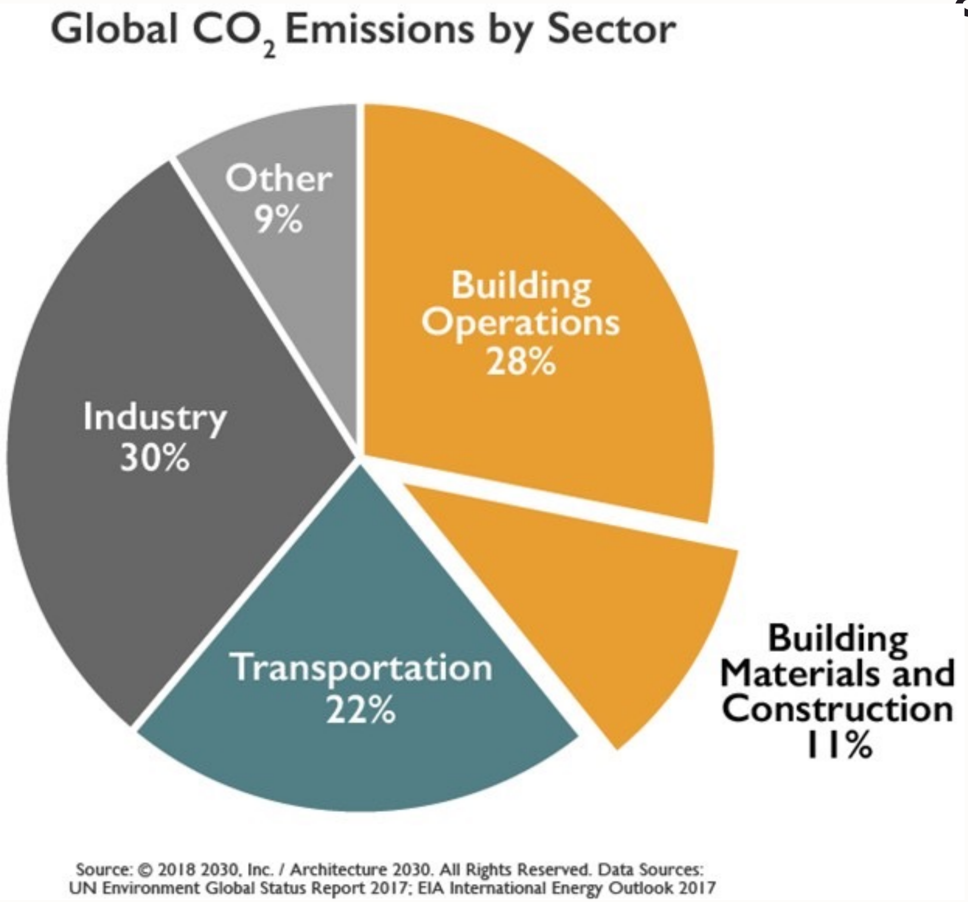
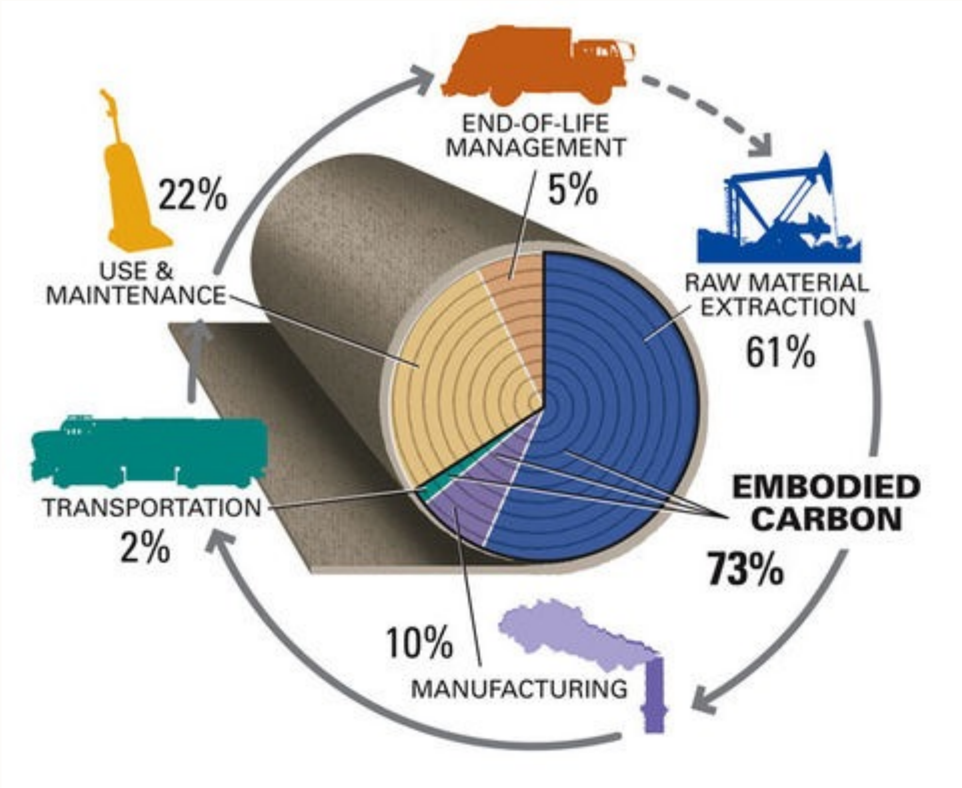
Problem

The built environment is responsible for nearly 40% of global emissions, with building materials and construction contributing 11%.





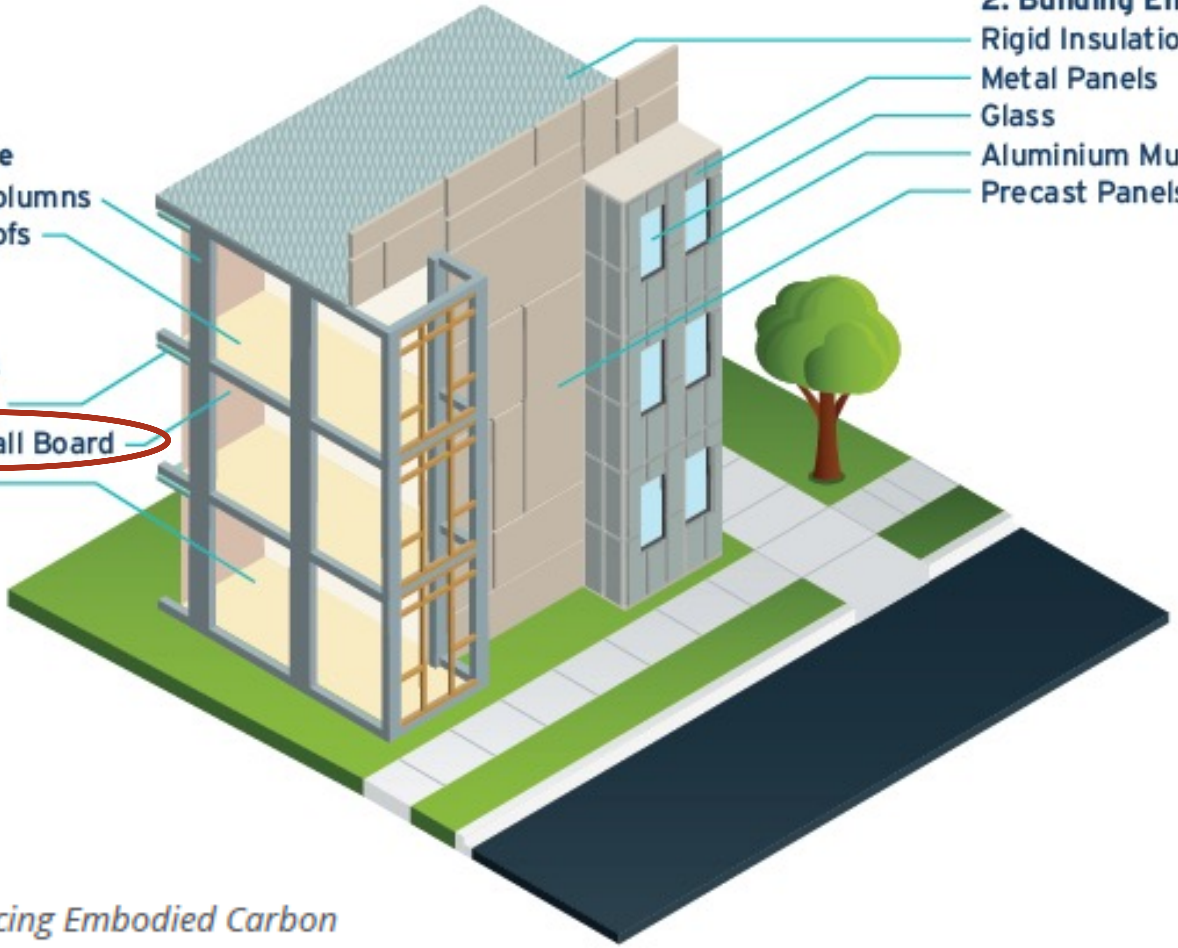
BuildingGreen (2018)

Solution

Use biochar (BC) to decarbonize gypsum wallboard, currently produced at over 20 billion ft²/year in North America.

~5.5 million t CO_2e/year

Exhibit 2 Typical high-embodied-carbon structural elements, building envelope materials, and finish materials



Matt Jungclaus, Rebecca Esau, Victor Olgyay, and Audrey Rempher, *Reducing Embodied Carbon in Buildings: Low-Cost, High-Value Opportunities*, RMI, 2021, http://www.rmi.org/insight/reducing-embodied-carbon-in-buildings.

Technical tasks

1. **Develop functional BWB specification**
2. **Screen biochar materials and mass loadings**
3. **Assess fillers that may enhance properties**
4. **Fabricate laboratory BWB prototypes**

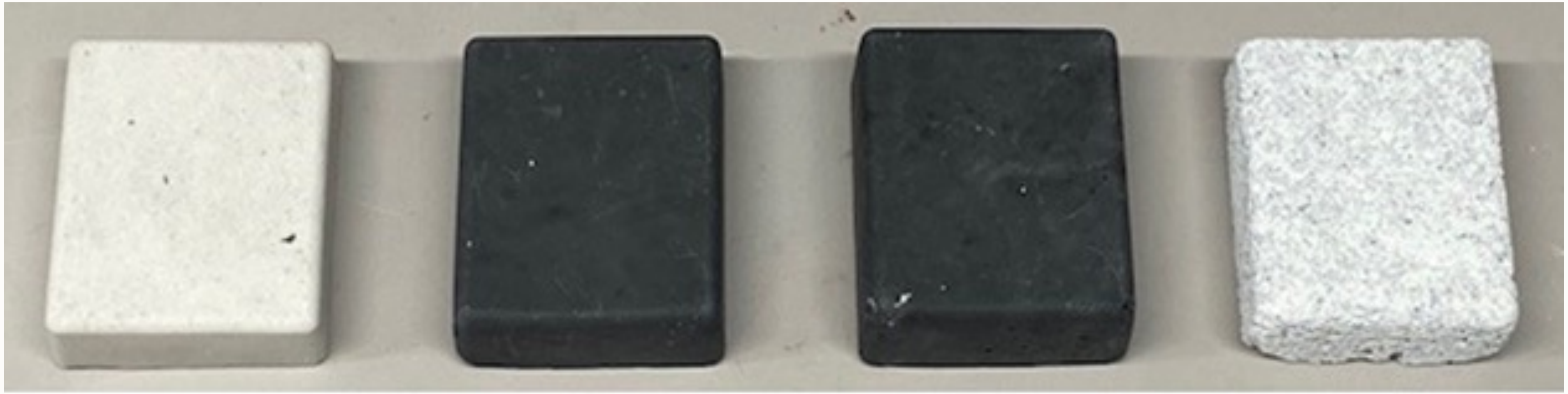
Task 1 – Develop BWB specification

Functional specification for biochar wallboard (BWB) development (assumed ½" thick)

Parameter	Value	Source
Density	0.772 g/cm^3	Gypsum Association (2019)
Water uptake	10% dry mass	Gypsum Association (2019)
Edge Hardness	49 N	Gypsum Association (2019)
Nail pull resistance	343 N	ASTM C473 (2019) Gypsum Association (2019)
Flexural strength [€]	160 N	ASTM C473 (2019) Gypsum Association (2019)
Thermal conductivity	0.160 W/(m K)	Gypsum Association (2019)

[€] For Method B with bearing edges parallel to length.

Task 2 – Screen biochar materials and mass loadings



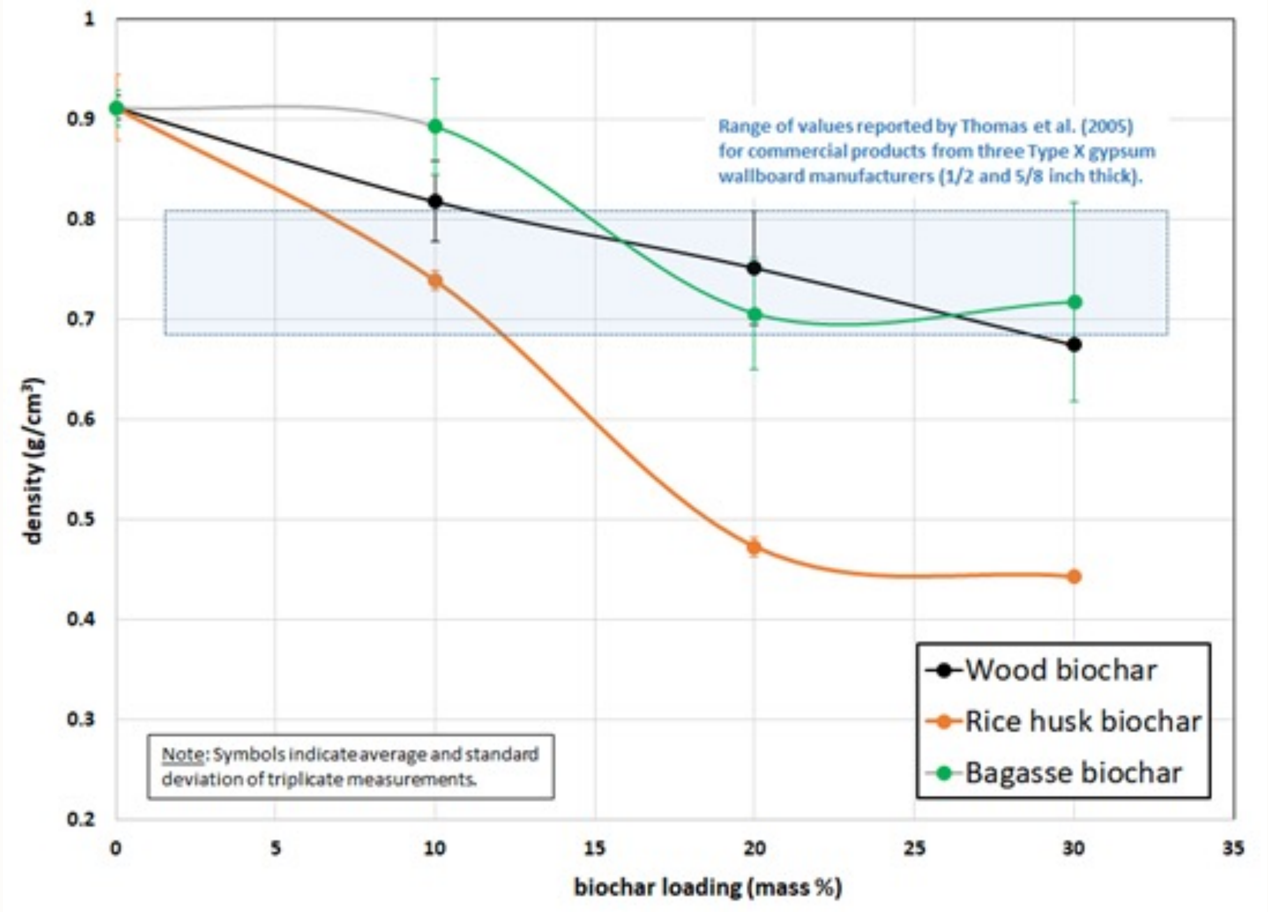
100% gypsum	90% gypsum 10% wood BC	80% gypsum 20% wood BC	90% gypsum 10% rice husk BC

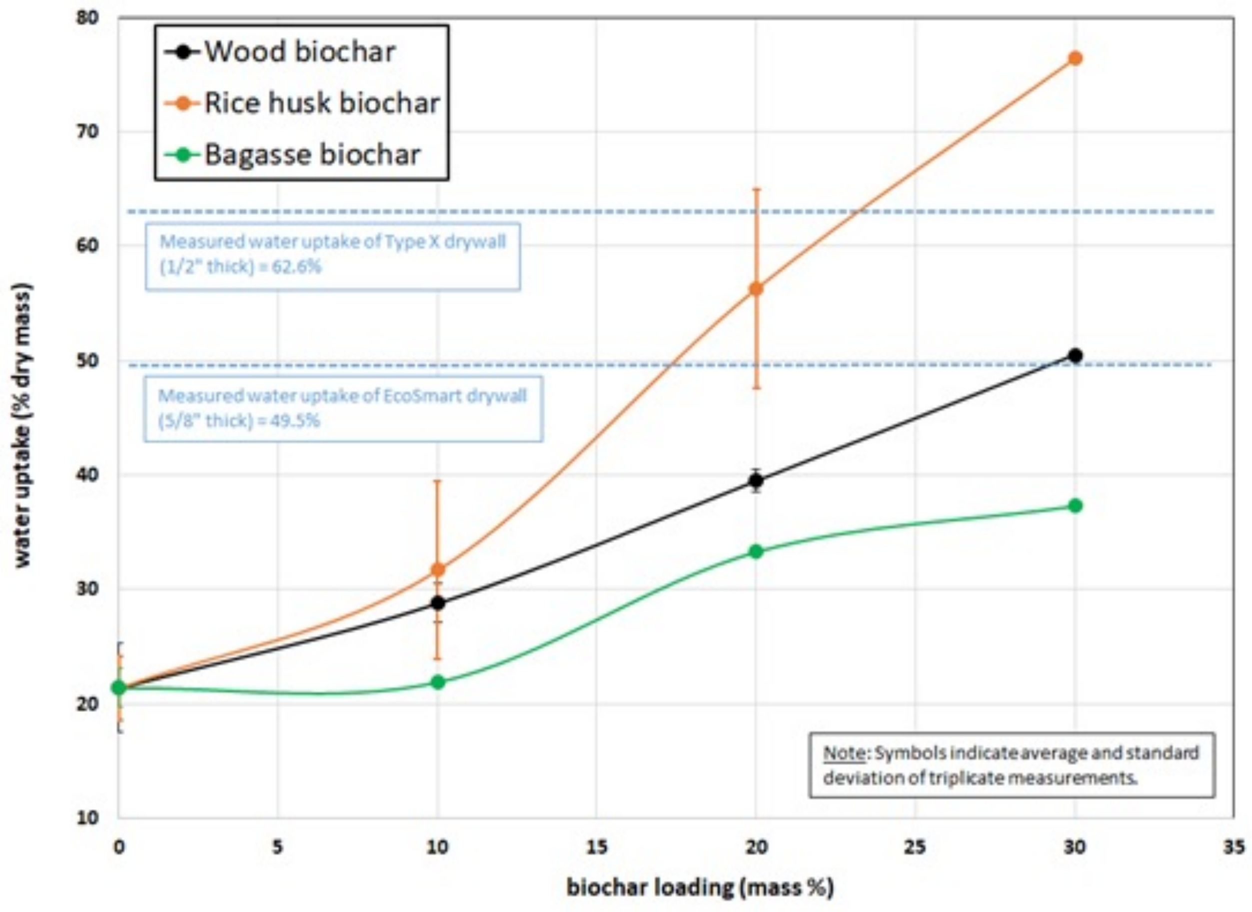
Initial BWB test samples (approximately 5 × 6.4 cm)

Evaluated 3 commercial biochar materials:

- ➢ **Wood** (Aries Clean Technologies, Franklin, TN)
- ➢ **Rice husk** (Glanris, Olive Branch, MS)
- ➢ **Sugar cane bagasse** (American Biocarbon, White Castle, LA)

Task 2 results

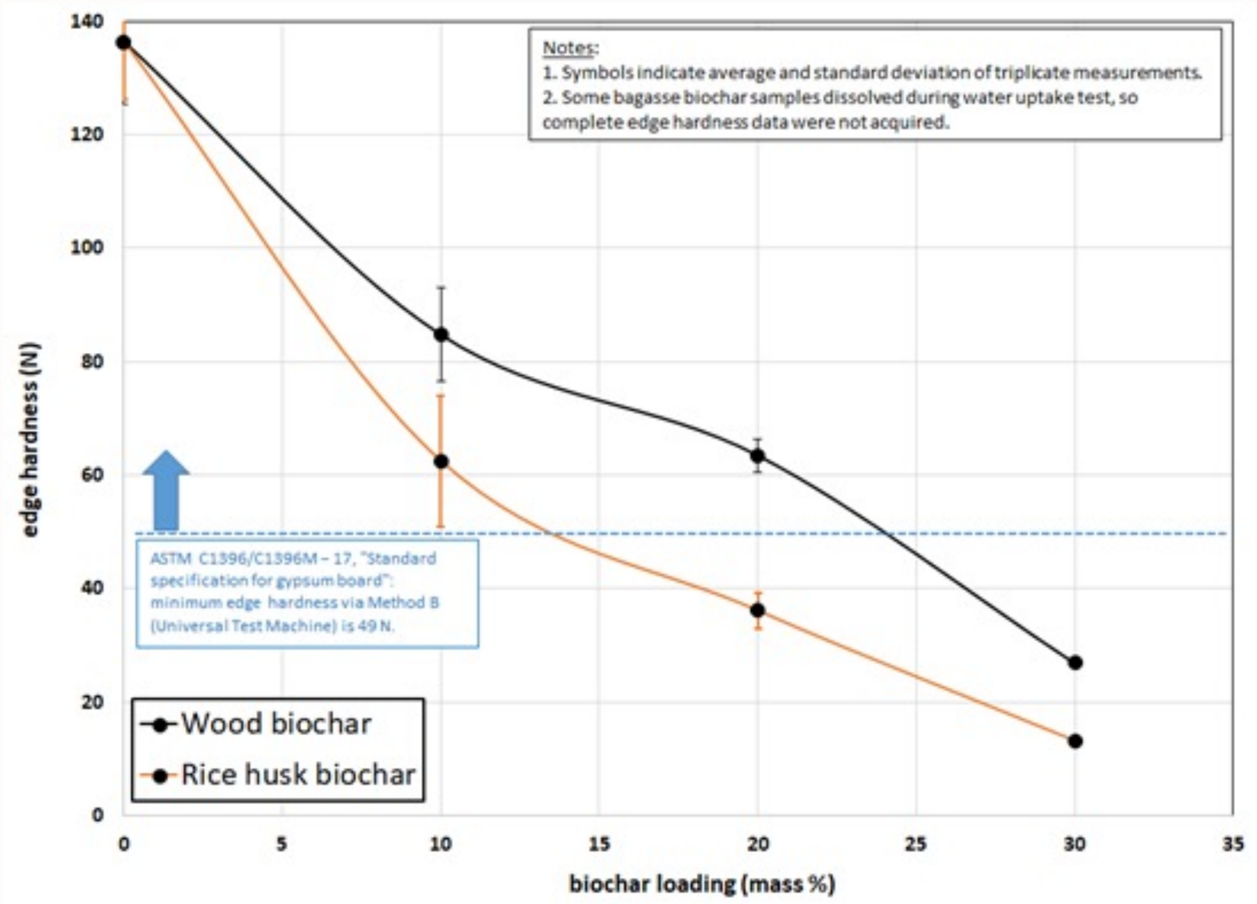




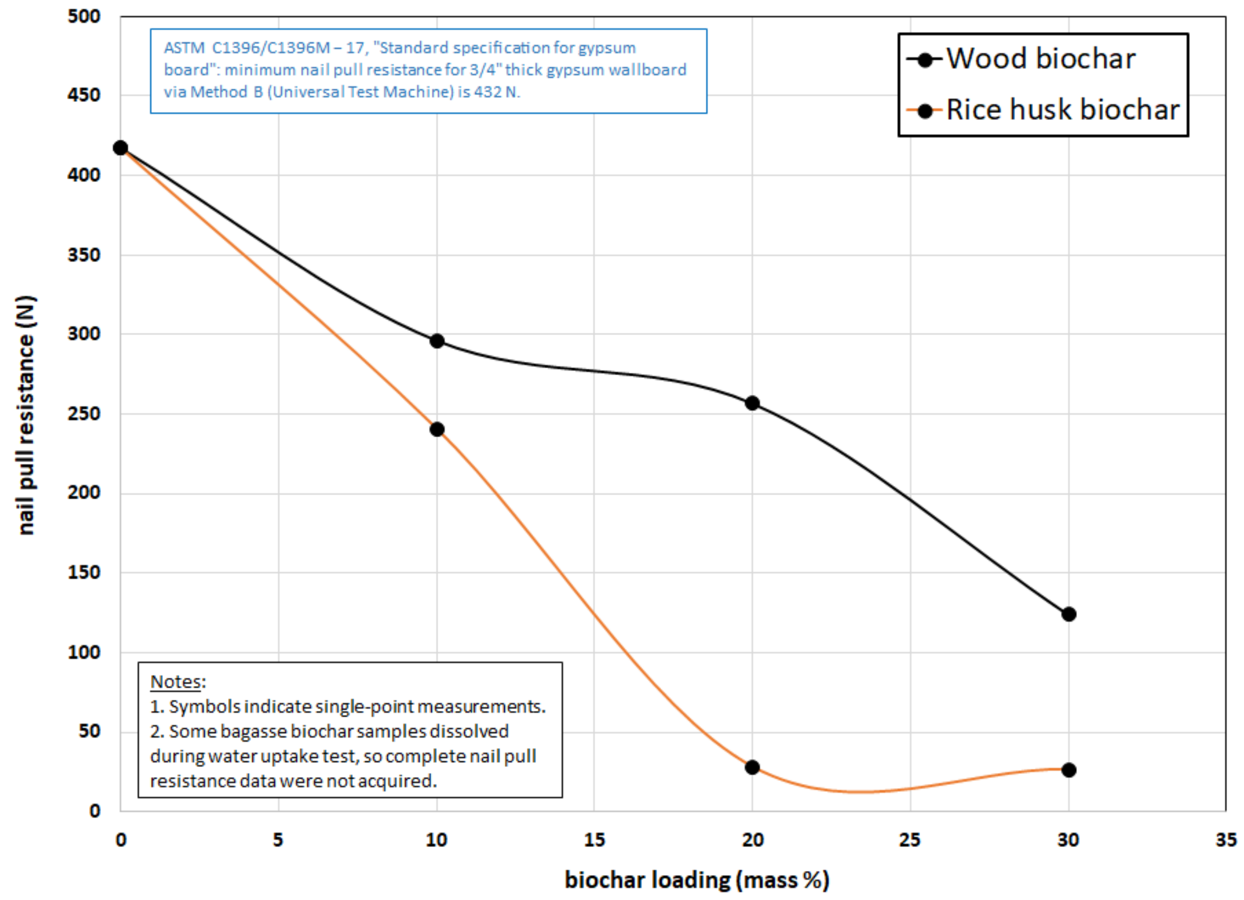
Densit
y

Water
uptake

Task 2 results

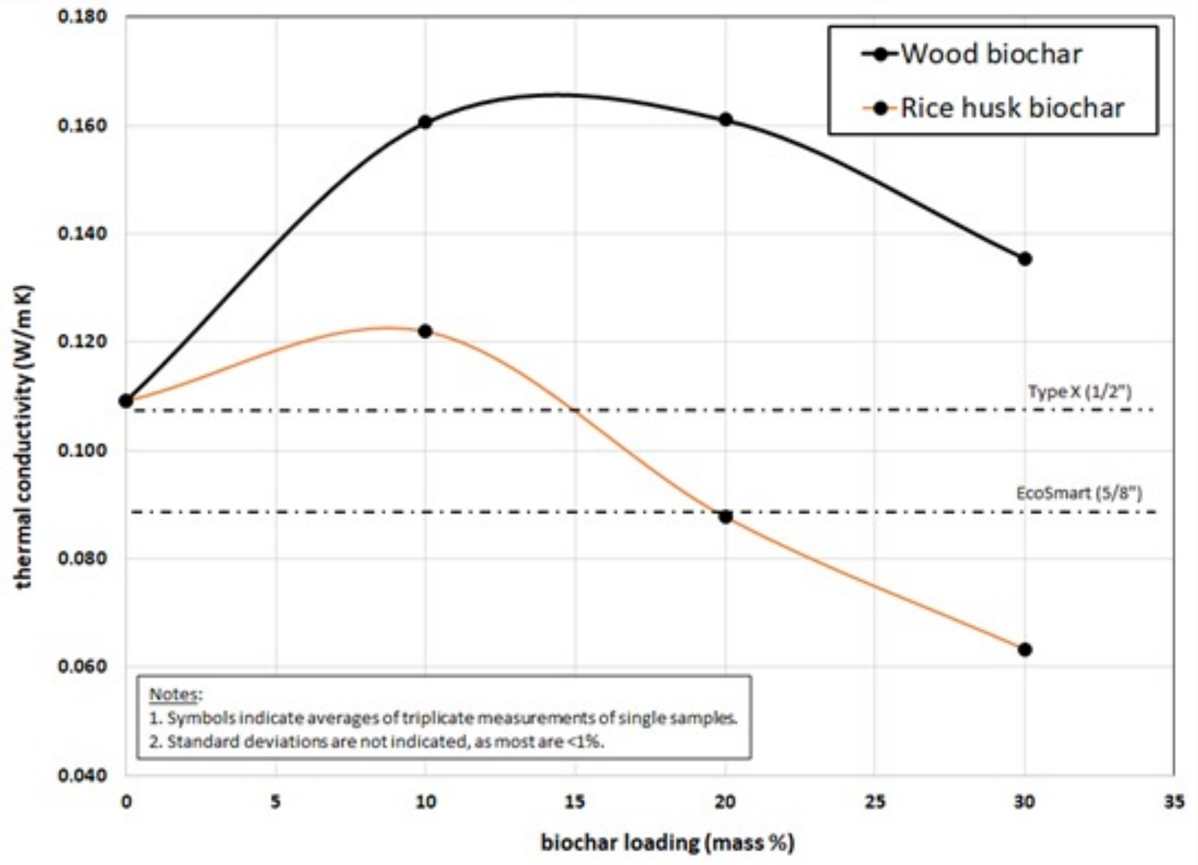


Edge hardness



Nail pull resistance

Task 2 results

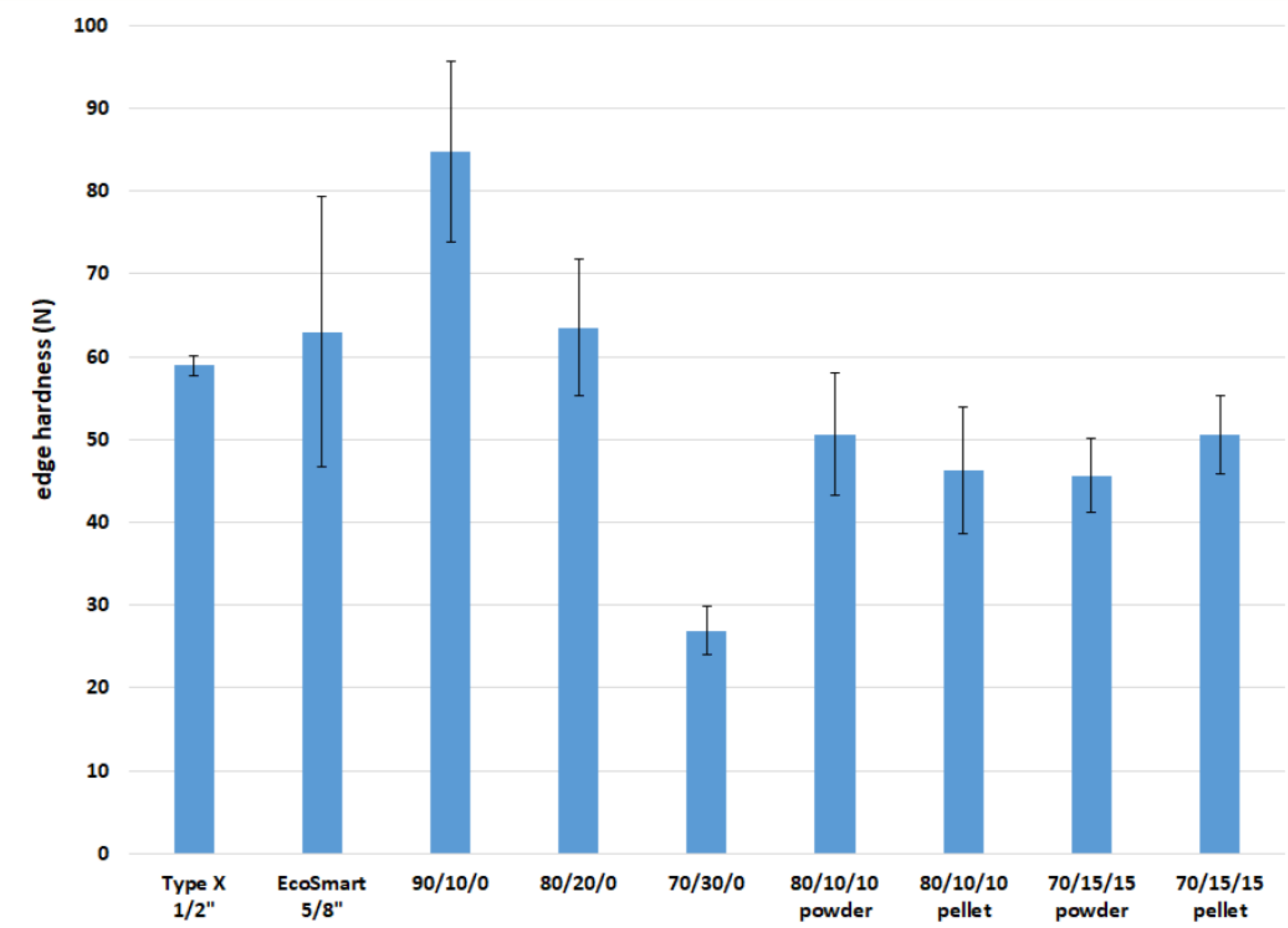


Thermal conductivity

Task 2 summary

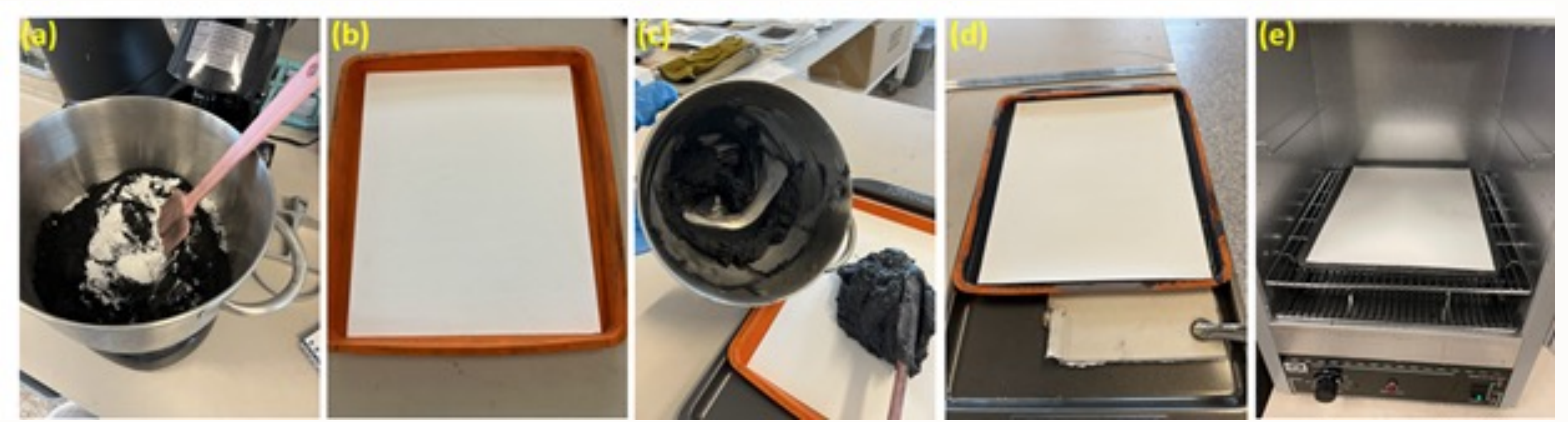
- Sugarcane bagasse biochar samples had poor mechanical properties and durability.
- Wood and rice husk biochar samples in 10-20% mass loading range were close to properties of conventional materials.
- Wood biochar provided better mechanical properties, rice husk biochar better density and thermal conductivity.

Task 3 – Assess fillers that may enhance properties



Adding glass in either pellet or powder form generally degraded performance vs. biochar addition only

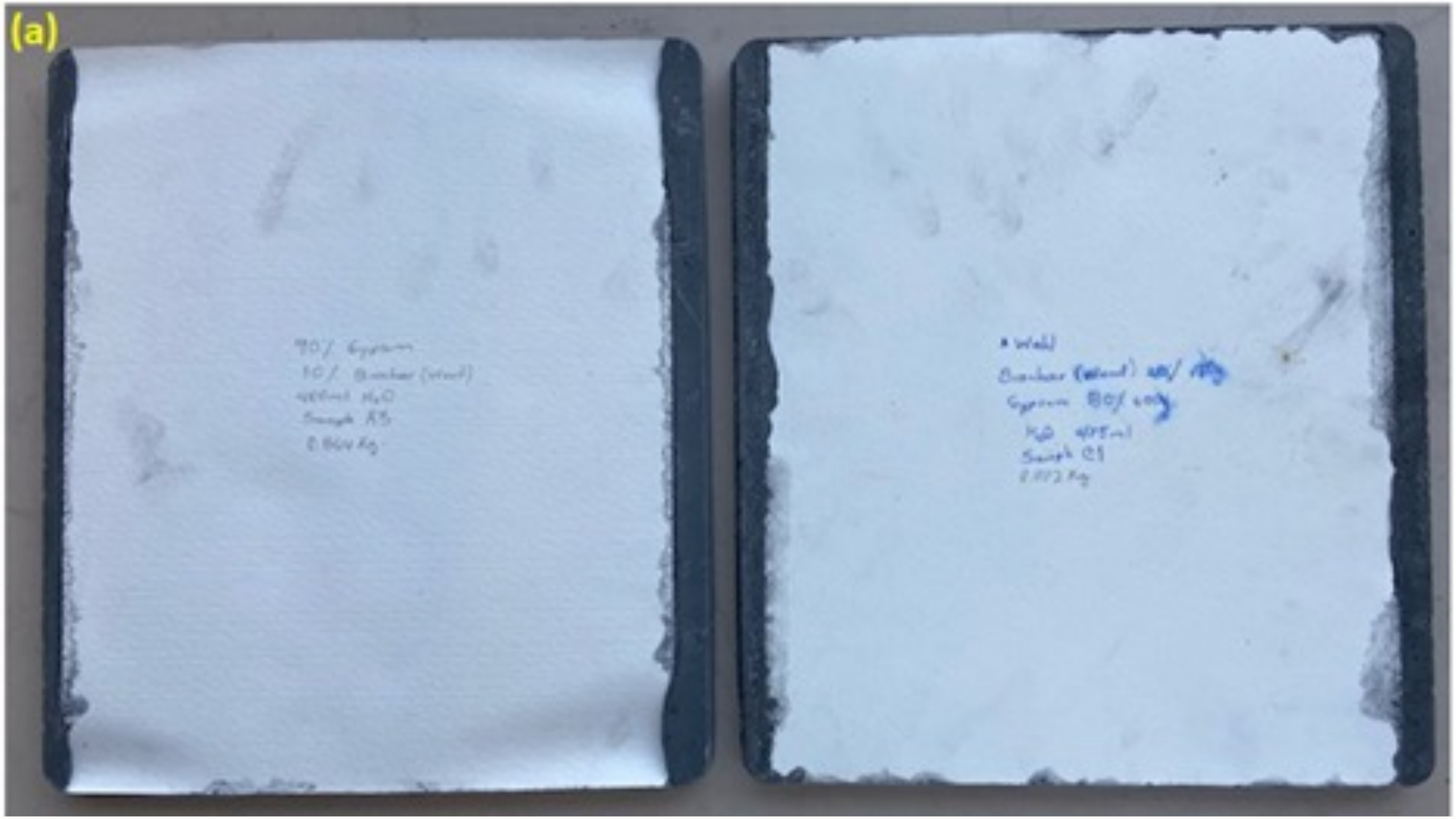
Task 4 – Fabricate laboratory BWB prototypes



Blend | *Bottom paper* | *Press* | *Top paper* | *Dry*

Larger format BWB prototype fabrication process (25.4 x 29.7 cm)

Task 4 results – wood biochar

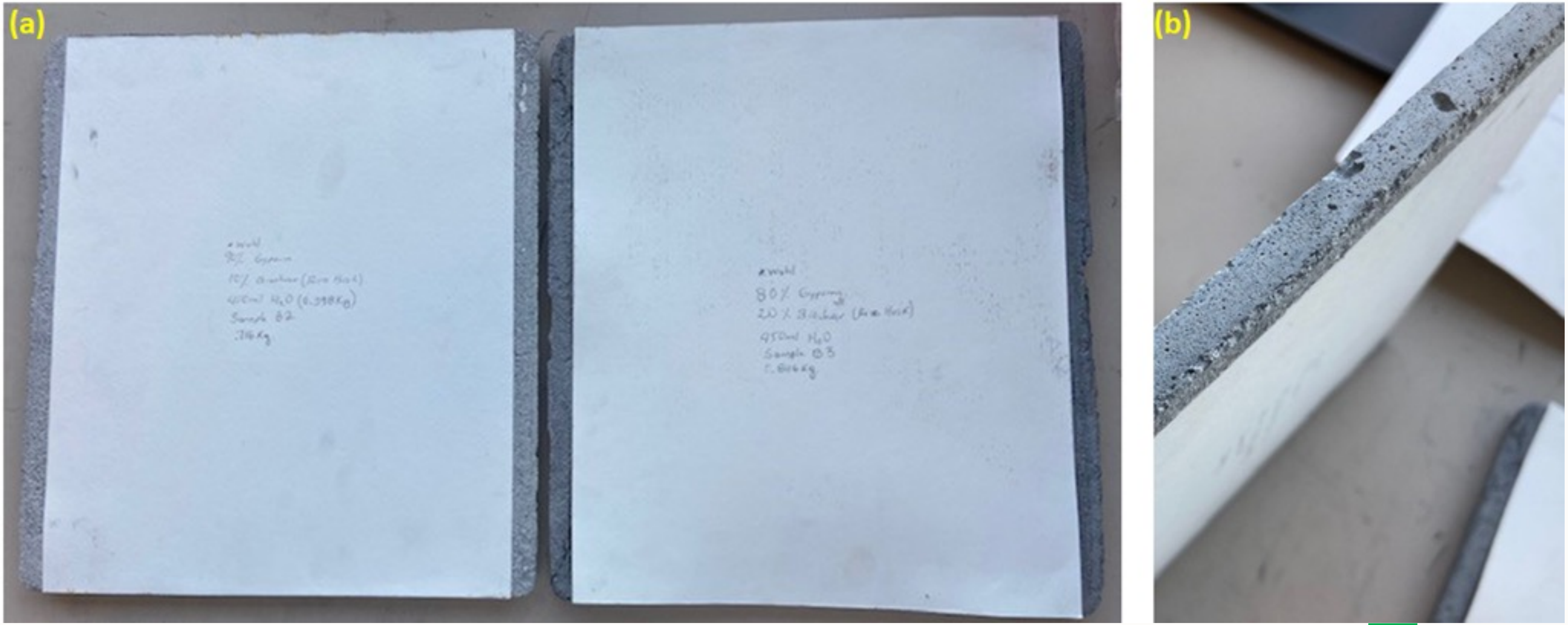


90% gypsum
10% wood BC

80% gypsum
20% wood BC

Excellent mechanical strength!

Task 4 results – rice husk biochar

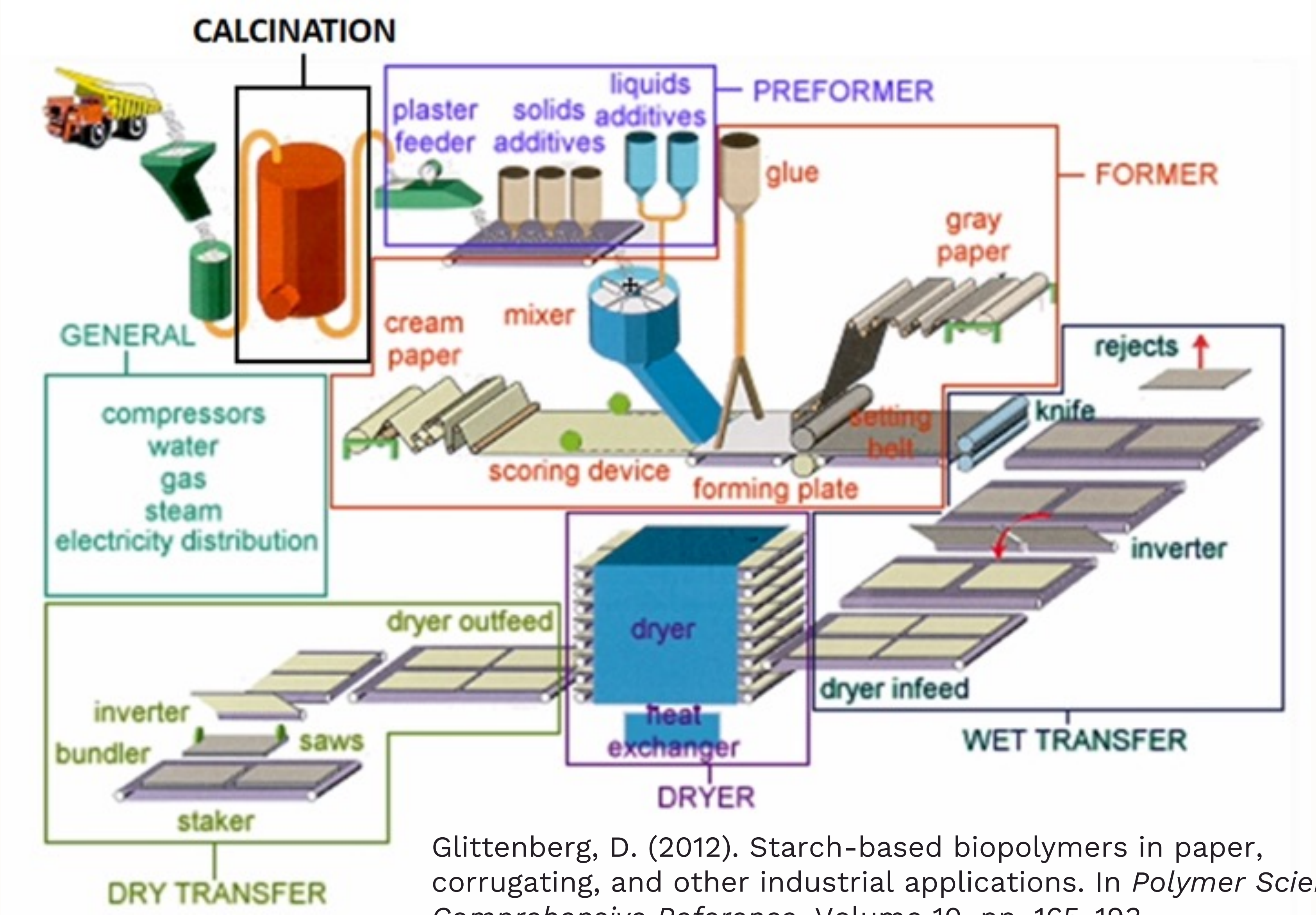


90% gypsum
10% wood
BC

80% gypsum
20% wood
BC

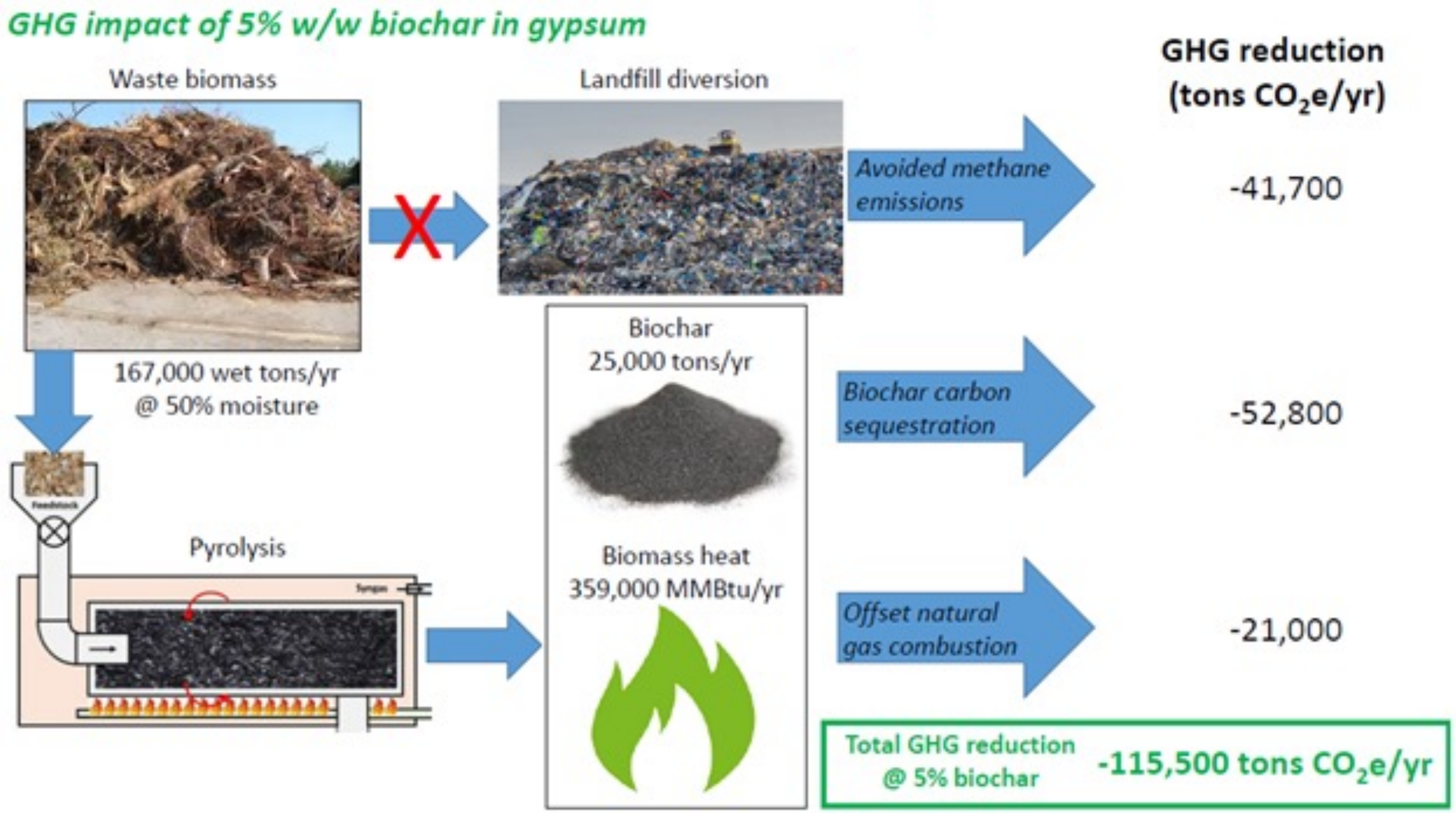
High porosity – low density and thermal conductivity!

Biochar wallboard at manufacturing scale



Glittenberg, D. (2012). Starch-based biopolymers in paper, corrugating, and other industrial applications. In *Polymer Science: A Comprehensive Reference*, Volume 10, pp. 165-193.

Potential GHG impact at medium-sized US plant



Carbon neutrality @ 10% biochar loading

GHG reduction source	Biochar loading (% mass)			
	5%		10%	
	Net GHG reduction [ton CO_2e/yr]	Conventional wallboard GWP reduction‡	Net GHG reduction [ton CO_2e/yr]	Conventional wallboard GWP reduction‡
Avoided methane from landfill diversion	-41,700		-83,300	
Biochar carbon sequestration	-52,800	40%	-105,600	80%
Displaced natural gas via pyrolysis waste heat	-21,000	16%	-42,000	32%
Totals	**-115,500**	**56%**	**-231,000**	**112%**

‡Reduction based on global warming potential (GWP) of conventional Type X gypsum wallboard, reported as 277 kg CO_2e per 1000 ft^2, equal to 611 lb CO_2e per 1000 ft^2 (NSF, 2020). Following the methodology in this same publication, avoided methane from landfill diversion of waste biomass feedstock is not included as contributing to GWP reduction, but is considered as a contribution to net GHG reduction.

Scale-up issues

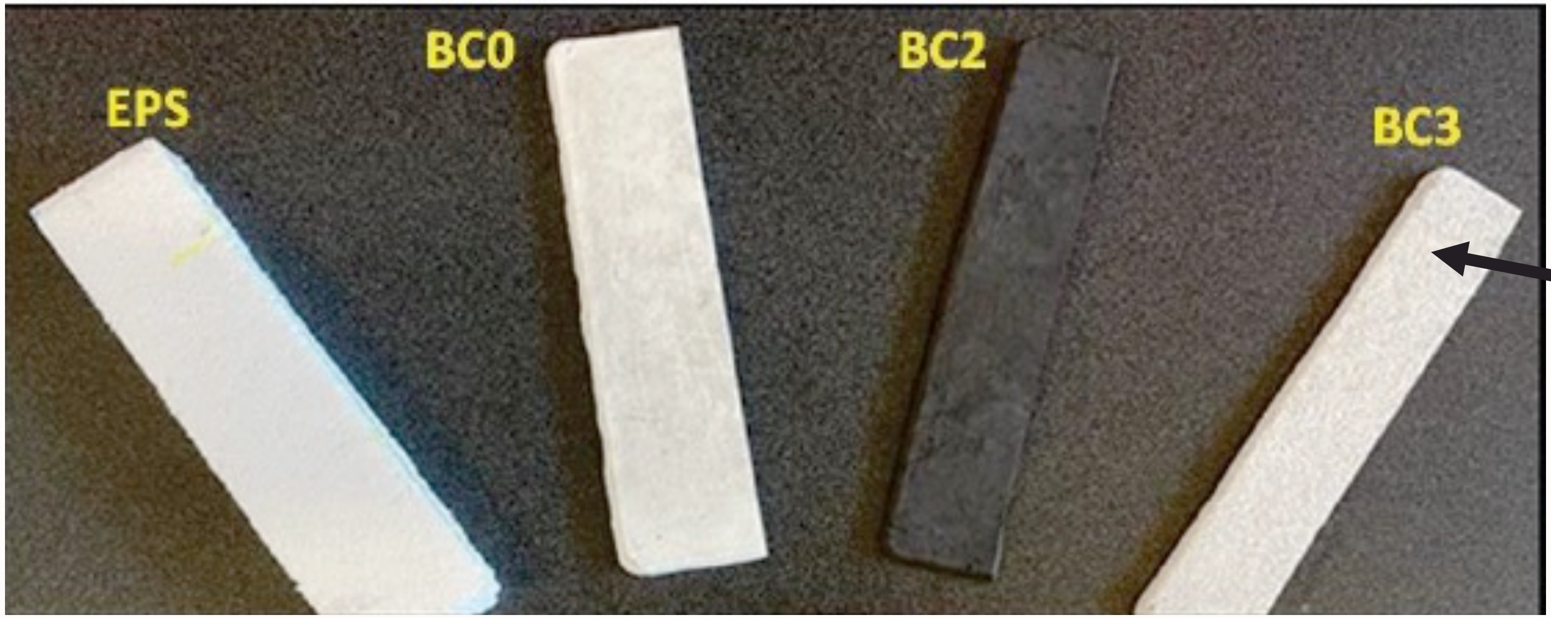
- ➢ Biochar feedstock availability
- ➢ Space at manufacturing site
- ➢ Slurry rheology and drying
- ➢ Waste heat
- ➢ Final product cost
- ➢ Additional biochar benefits

Technology transfer

Many potential applications of biochar blended in a continuous binder phase to create new low-carbon materials

Example: ***Thermal packaging***

Rice husk biochar + bio-binder can achieve thermal insulating properties of expanded polystyrene (EPS)



33% by mass Glanris rice husk Biochar

0.037 $Wm^{-1}K^{-1}$
vs.
0.039 $Wm^{-1}K^{-1}$
for EPS

M.M. Manipati, C.R. Draper, K.T. Draper, T.A Trabold and C.A. Diaz, "Biochar composites for sustainable thermal packaging applications," *Proceedings of the 31st IAPRI World Conference on Packaging,* Paper PM-GO01, Mumbai, India, May 22-25, 2023.

Thank you for your attention!

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https://www.rit.edu/sustainabilityinstitute/

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