Biochar in Concrete Applications: Challenges and Opportunities

Speaker and Principal Investigator:

Dr. Somayeh Nassiri, Associate Professor, UC Davis

Collaborators:

Souvik Roy, PhD Candidate, UC Davis

Dr. Vikram Yadama, Professor

Dr. Manuel Garcia Perez, Professor

Mohammad Mezbah Ul Hoque, PhD Student

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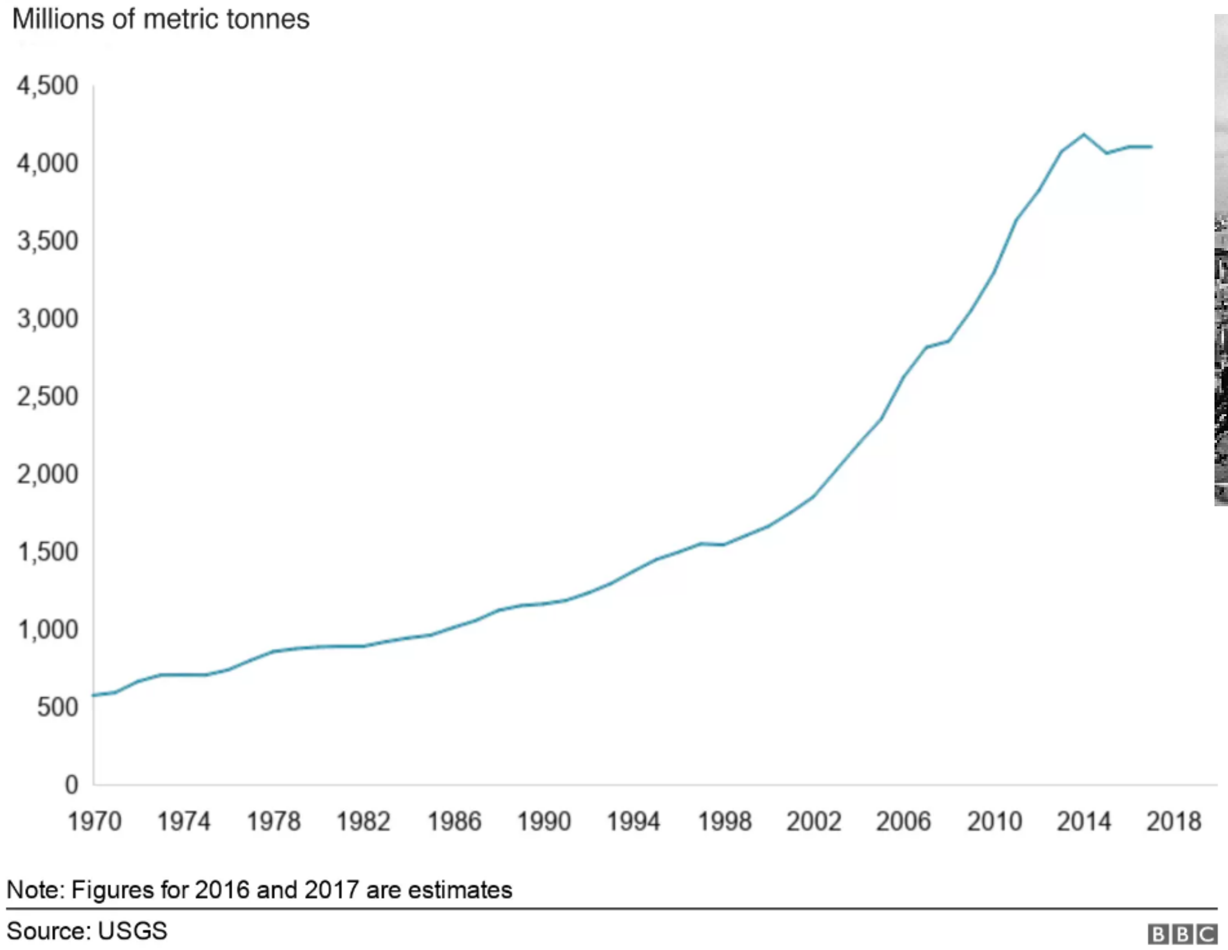
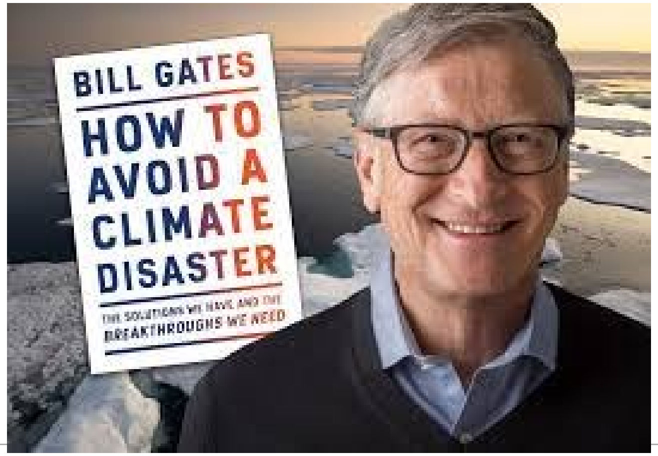
Global Cement Demand

- Main challenge facing the cement industry is to reduce CO_2 emissions while meeting global demand

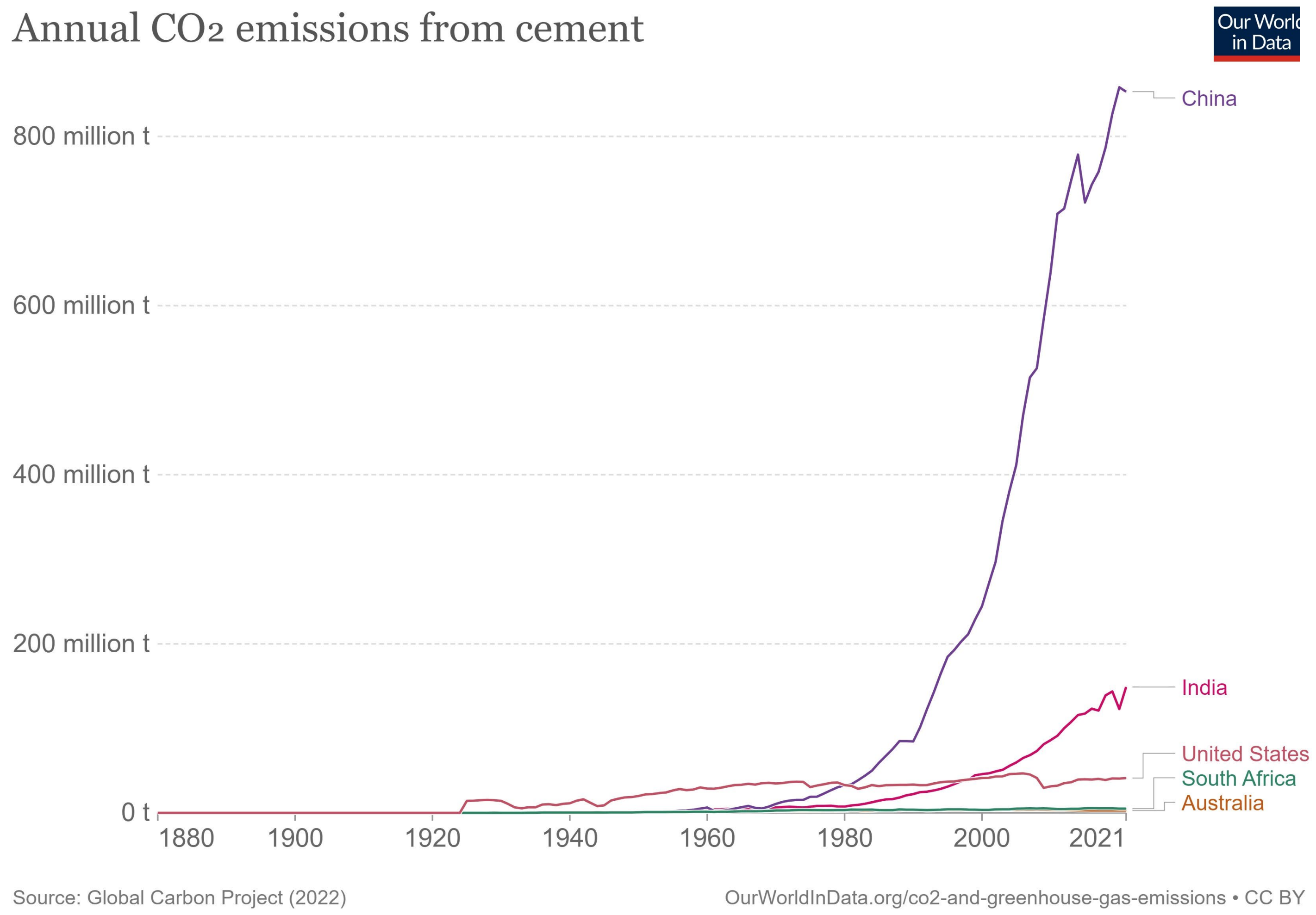


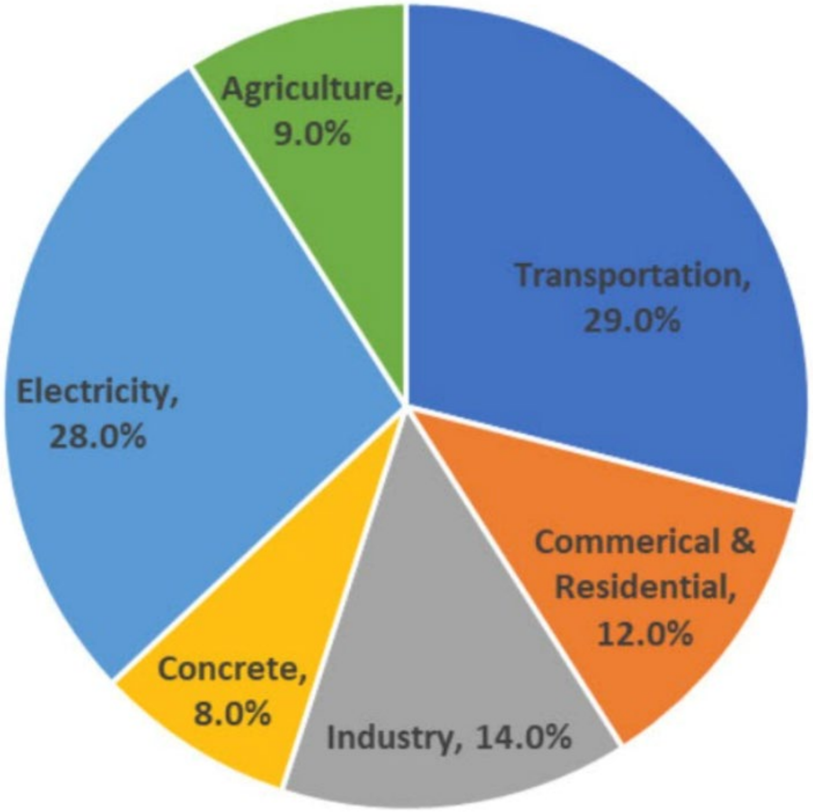
1987 (left) and 2013 (right).



CO_2 Emissions from Cement Production-Global

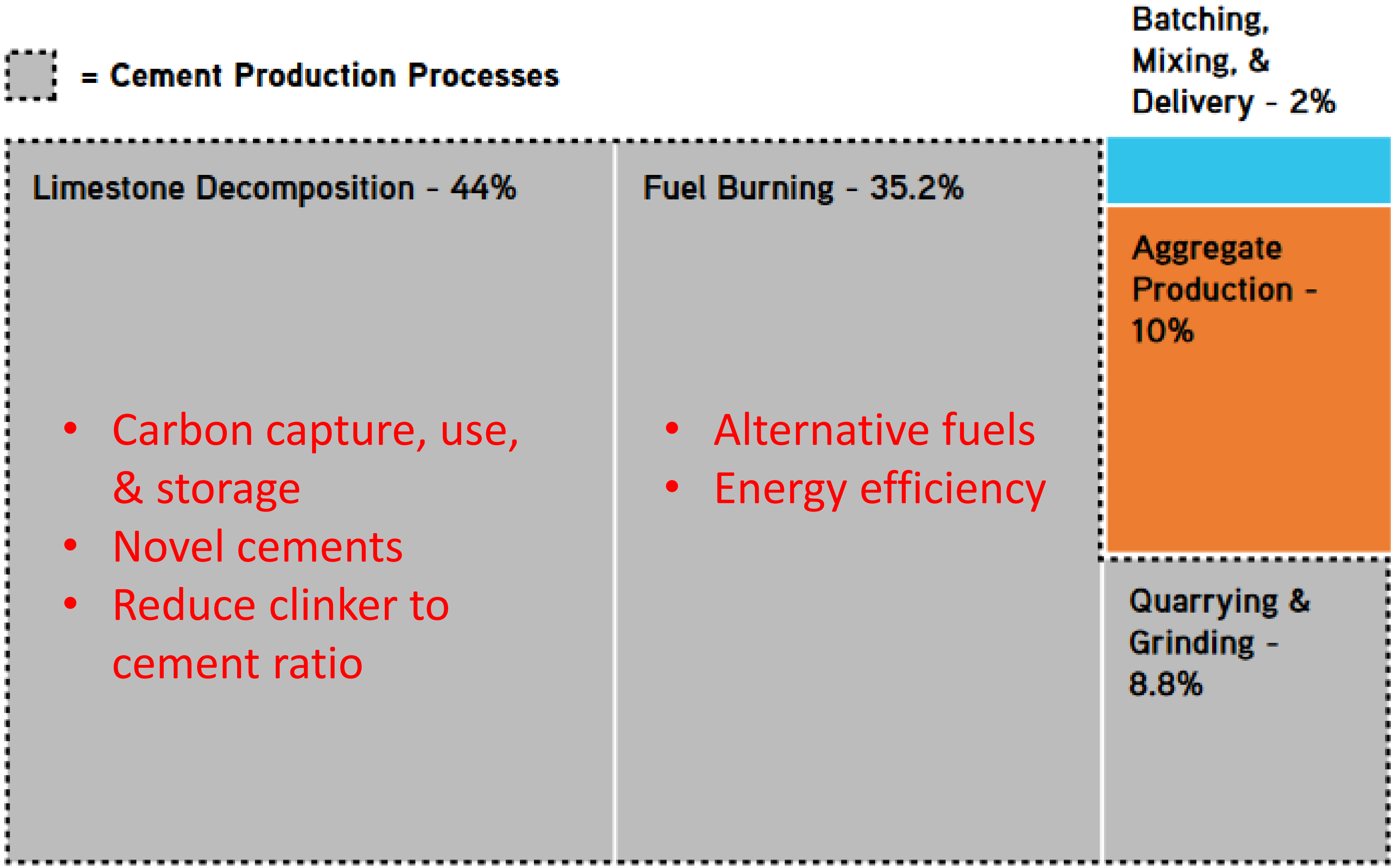
- Concrete responsible for 8% of global anthropogenic CO_2 emissions





Princeton Student Climate Initiative

Decarbonization Opportunities



Carbon Reeducations by Avoidance

- Calcareous or siliceous-aluminous materials in fine particles chemically react with calcium hydroxide in the concrete (water requried) …to form compounds with cementitious properties (ASTM C125)

- SCMs from industrial sector:
  - Coal Fly ash (most common)
    - Domestic supplies of fly ash diminishing
    - Sources of fly ash in UT, AZ, CO, NM and foreign countries
  - Steel slag (GGBFS)
    - Little steel making in the US, GGBFS mainly imported
  - Natural materials: diatomaceous earths,…, tuffs and volcanic ashes or pumicites,…, and some clays and shales (AASHTO M295)

Coal Fly Ash: The Rise, the Fall, and in Between

The Navajo Generating Station in Arizona, demolished in 2020. Source: the guardian

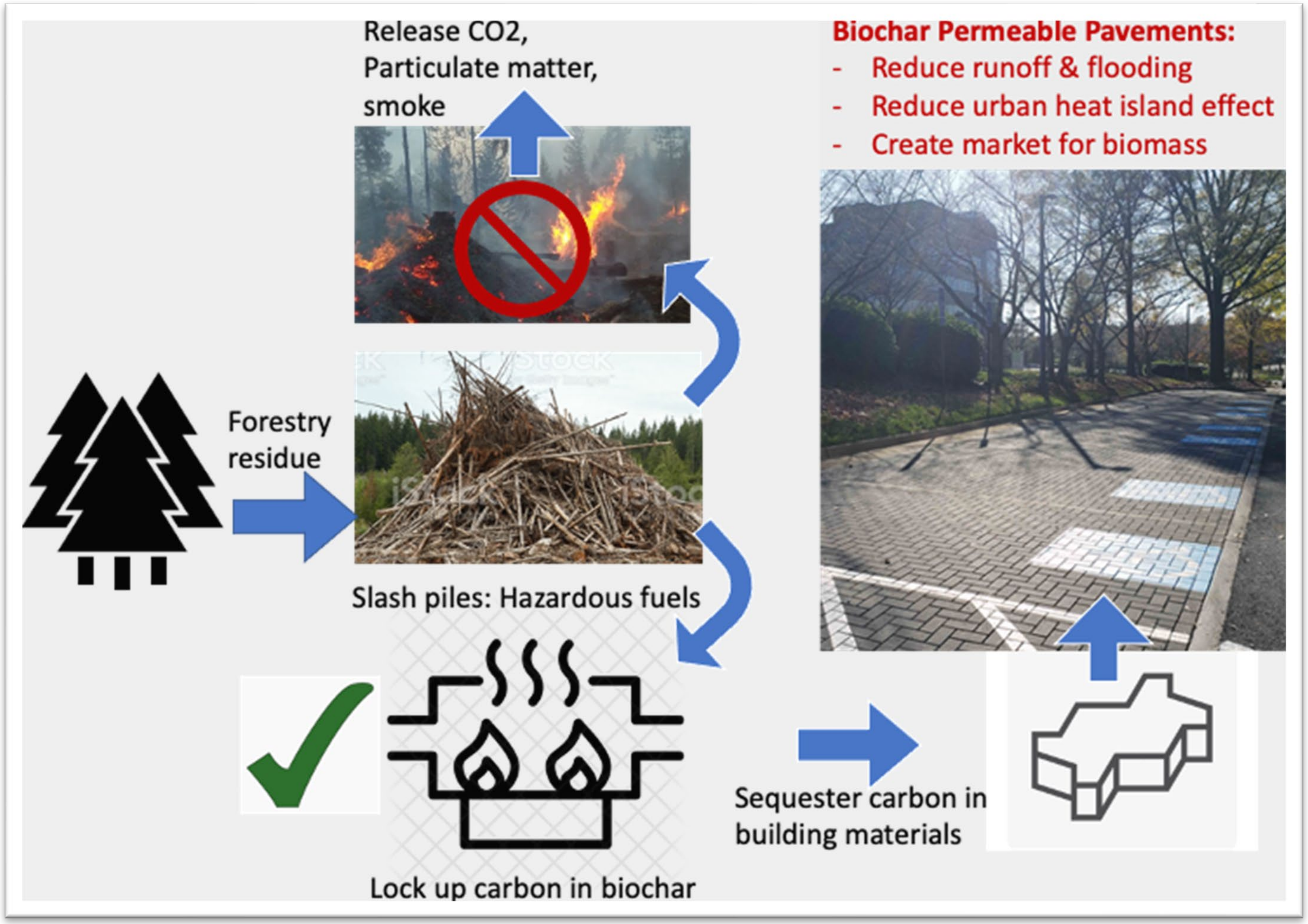
- Gradual shift from natural pozzolans to coal fly ash in 1960s to 1980s
- Coal fly ash presented as a cost-effective and easily accessible pozzolanic alternative
- Becoming increasingly unavailable as coal power plants phased out

Challenges Facing Cement and Concrete Sector

- Implementation of new materials needed at much faster pace
- To meet net zero 2045 (California): SB 596

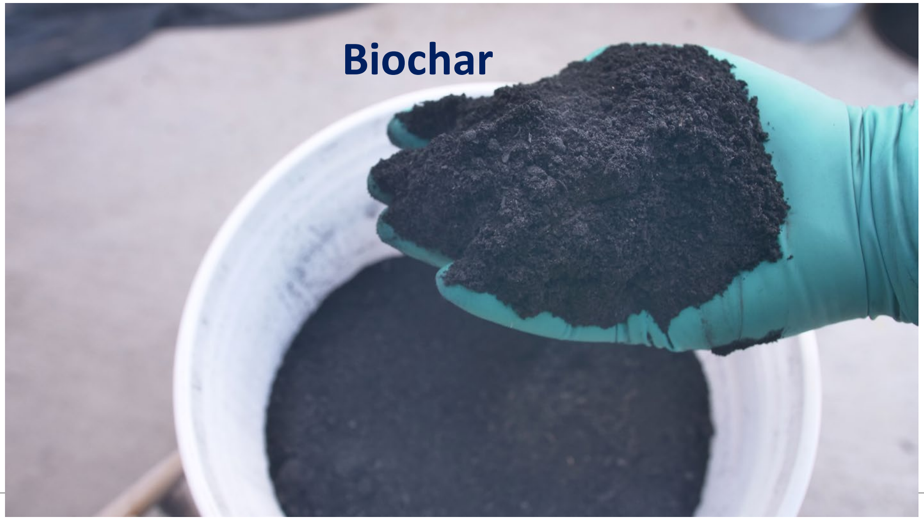
Project Overview

- Wood Innovation Project
- Applied research + collaboration with masonry and biochar industry
  - Produce biochar from wood slash sources in laboratory
  - Collect and characterize biochar samples from biomass energy sector in WA and across CA
  - Work closely with masonry industry to incorporate select biochars in permeable pavements



Industry Participation

- Wood and rice hull fly ash and bottom ash samples have been collected from 8 energy producers: a total of 18 plants
- 14 biochar samples from forestry and ag-based biomass feedstock (wood, walnut shells, rice hulls)
  - Pyrolysis or Gasification (Temp. 500-800 °C or 930-1470 °F)
  - Torrefaction (Temp. 200-300 °C or 390-570 °F)

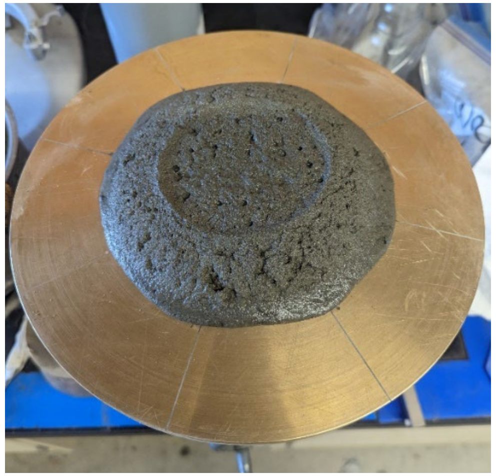


Sample Preparation & Characterization

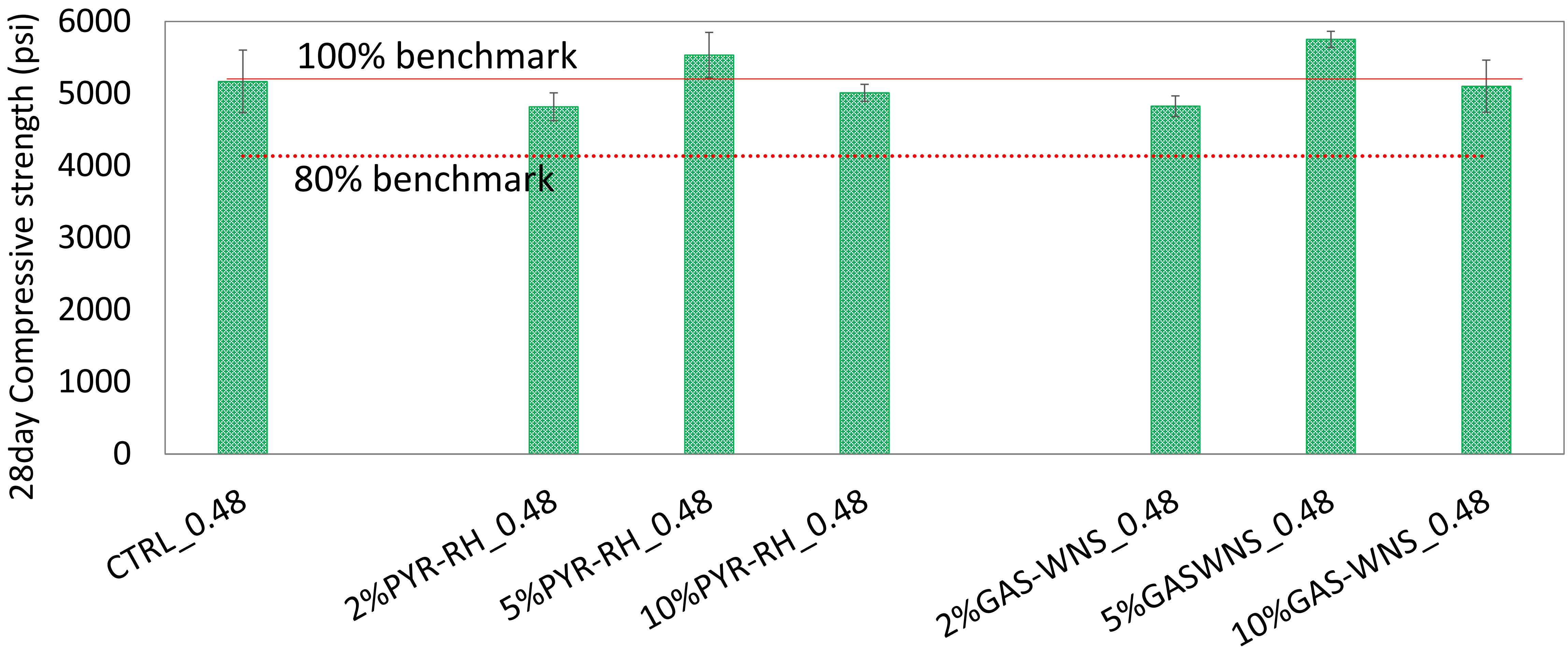
- Step 1: Grinding or ball milling
- Step 2: Fineness check by wet sieve #325 must retain < 34%
- Step 3: Chemical composition, moisture content, loss on ignition, density
    - Also, zeta potential, proximity test

Water Demand and Strength Activity Index

- Step 4- Batch mortar, measure water demand
  - 400 g of portland cement
  - 100 g of SCM (20% replacement of cement)
  - 1375 g of graded standard sand
  - mL of water required for flow ± 5 of control mixture
  - Water requirement, max, percent of control: Class N Natural Pozzolan: 115, Class F coal fly ash: 105, Class C coal fly ash: 105
- Step 5- Measure 7- & 28-day compressive strength of three cubes
  - Strength needs to be 75% or greater than the control mixture for coal fly ash

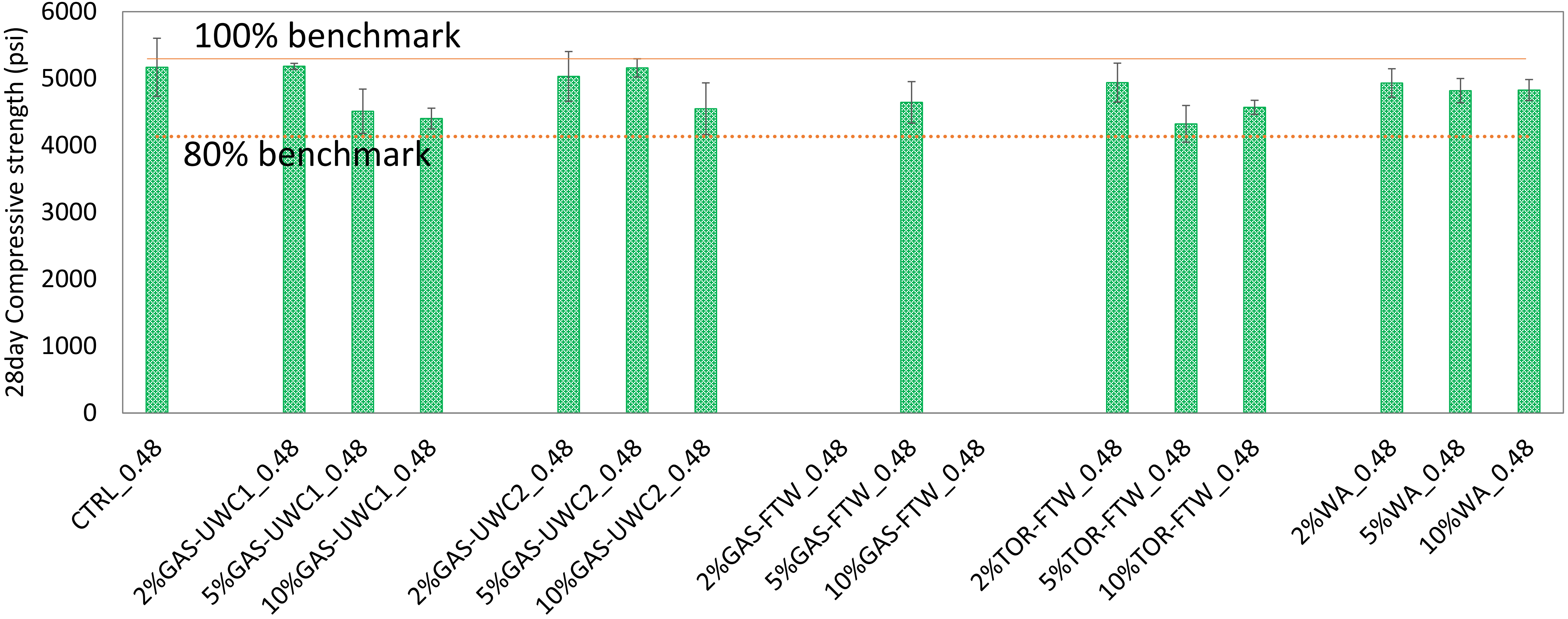


Strength Results: Agricultural Biochar



- PYR: Pyrolysis; GAS: gasification; TOR: torrefaction
- RH: rice hulls; WNS: walnut shells

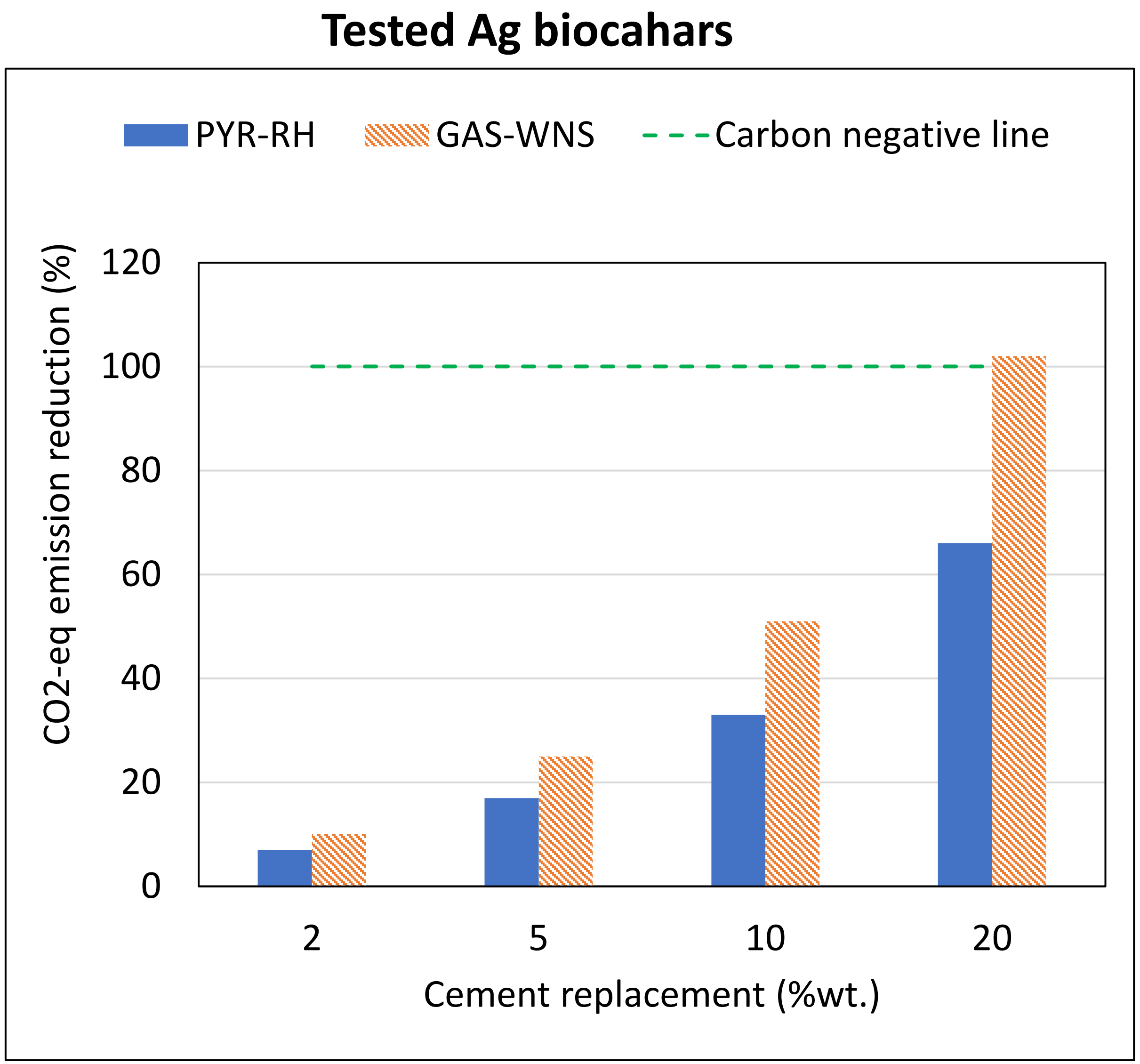
Strength Results: Wood Biochars



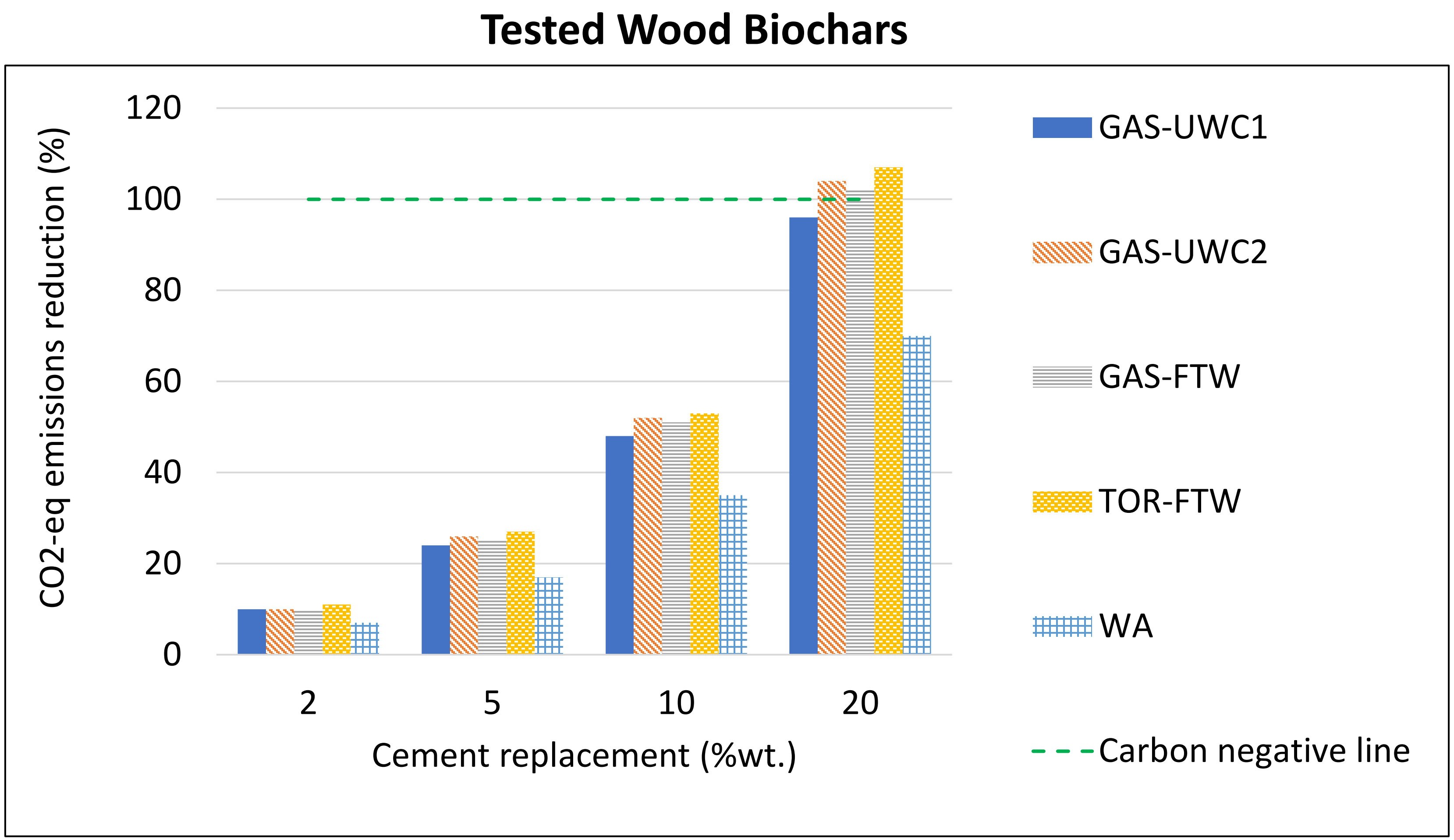
- PYR: Pyrolysis; GAS: gasification; TOR: torrefaction
- UWC: urban wood chip; FTW: forest thinning wood; WA: high carbon wood ash from sawmill

Carbon Reductions: Approximate Estimates for Tested Biochar Concrete

- CO_2-eq of biochar assumed based on the measured carbon content
  - Emissions of biochar (drying, milling), transportation to our lab not factored in
- CO_2-eq of 1 tonne of portland limestone cement is 844 kg according to Portland Cement Association
- A percentage of carbon reductions are from cement avoidance depending on replacement rates
- 20%wt. replacement of cement with some biochar may result in carbon-negative concrete.
- How much strength are we willing to sacrifice to achieve carbon-negativity?



Carbon Reductions: Approximate Estimates for Tested Biochar Concrete



Conclusions and Look Ahead

- Carbon capture, use and storage needed to meet the 2045 neutrality goal in the cement sector
- Biochar replacements up to certain amounts acceptable impact on strength
- Durability and compatibility with chemical admixtures need to be assessed
  - Implementation easier for certain applications
- Standardization required for concrete use lacking for structural concrete use
- Demonstration projects needed
- Cost competitiveness in the construction market

Thank you!

Contact us at:
nassiri@ucdavis.edu

Thanks to sponsors and materials suppliers:

Basalite Concrete Products, Dixon, CA

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