Thermal Management for Pressurized Oxy-Combustion Applications

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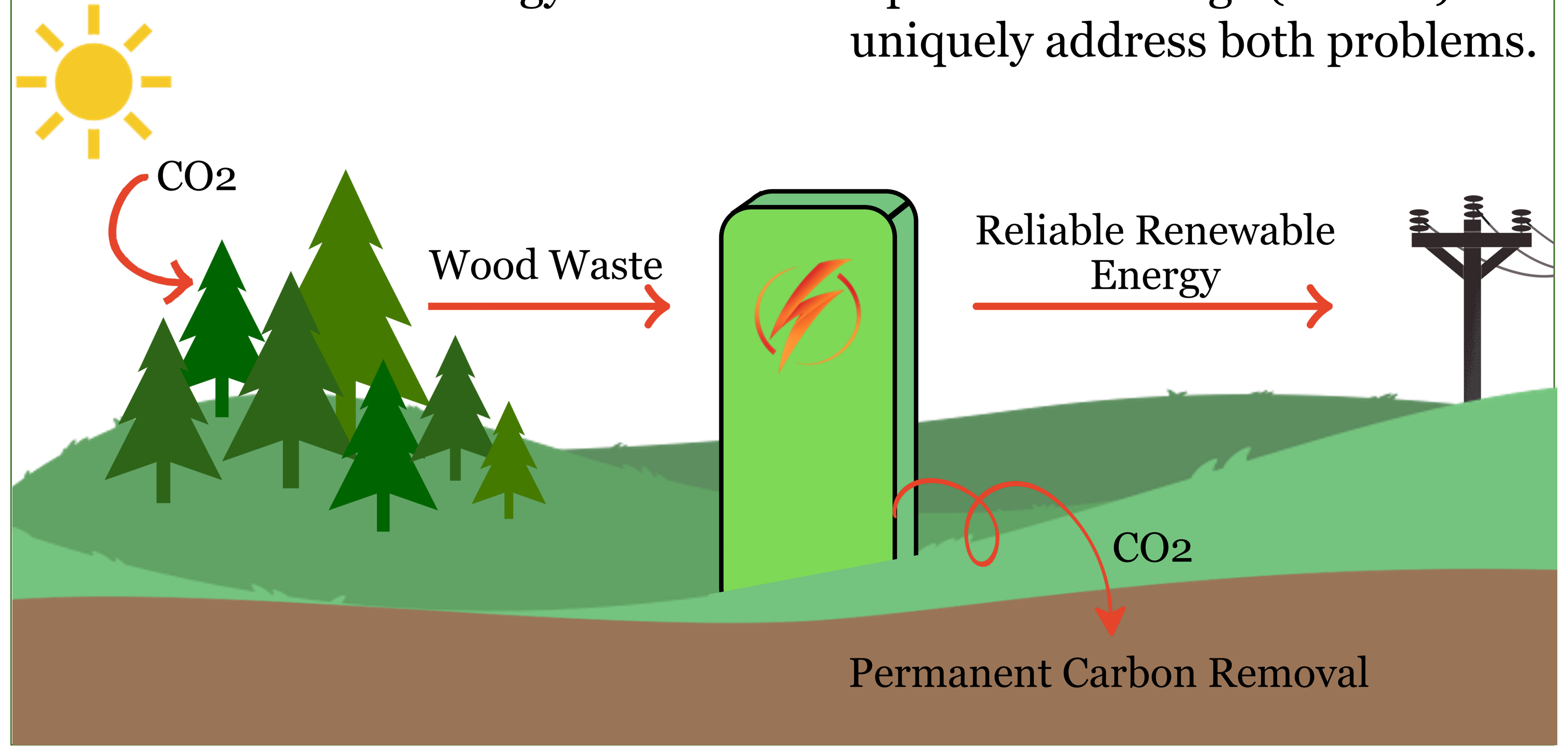
Two Competing Problems

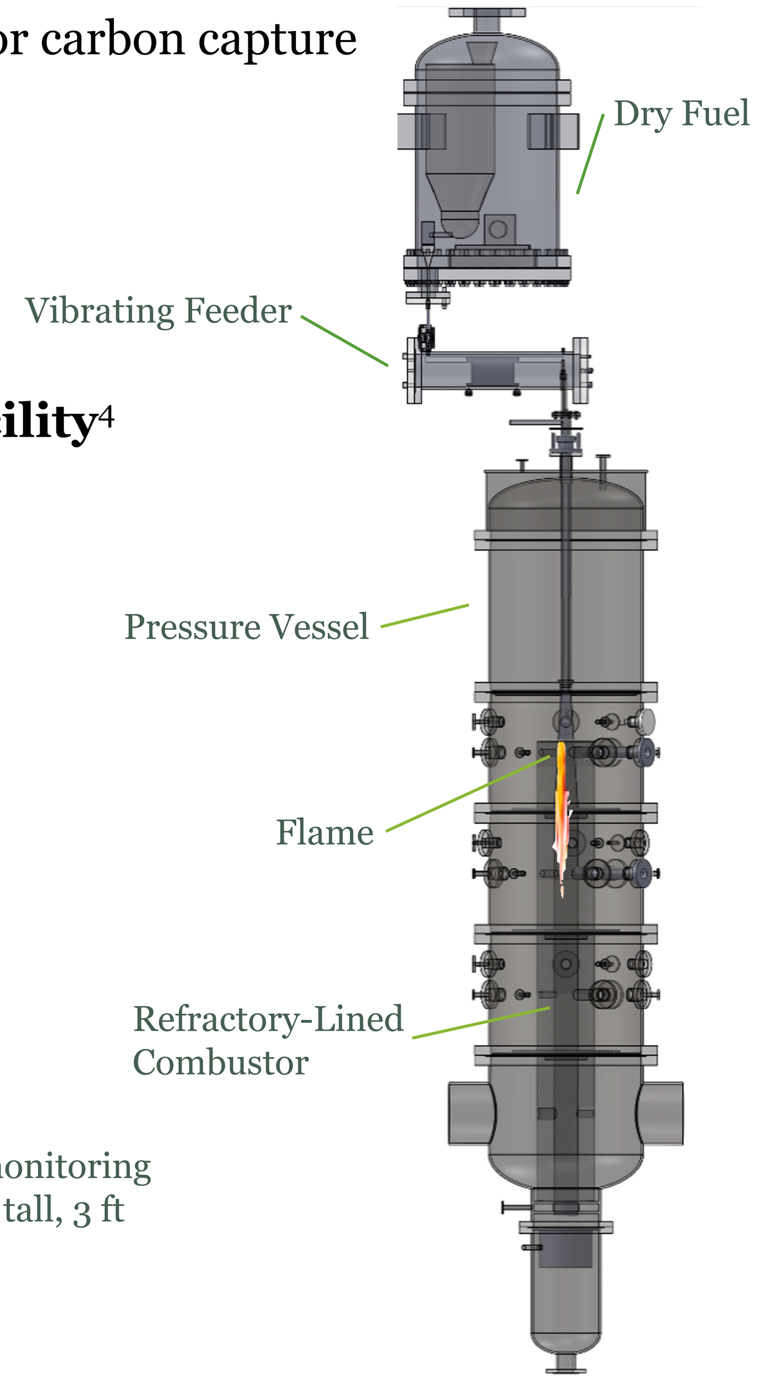
The world faces a dual challenge: rising energy demand[1] and soaring CO_2 levels[2]. Bioenergy with carbon capture and storage (BECCS) can uniquely address both problems.



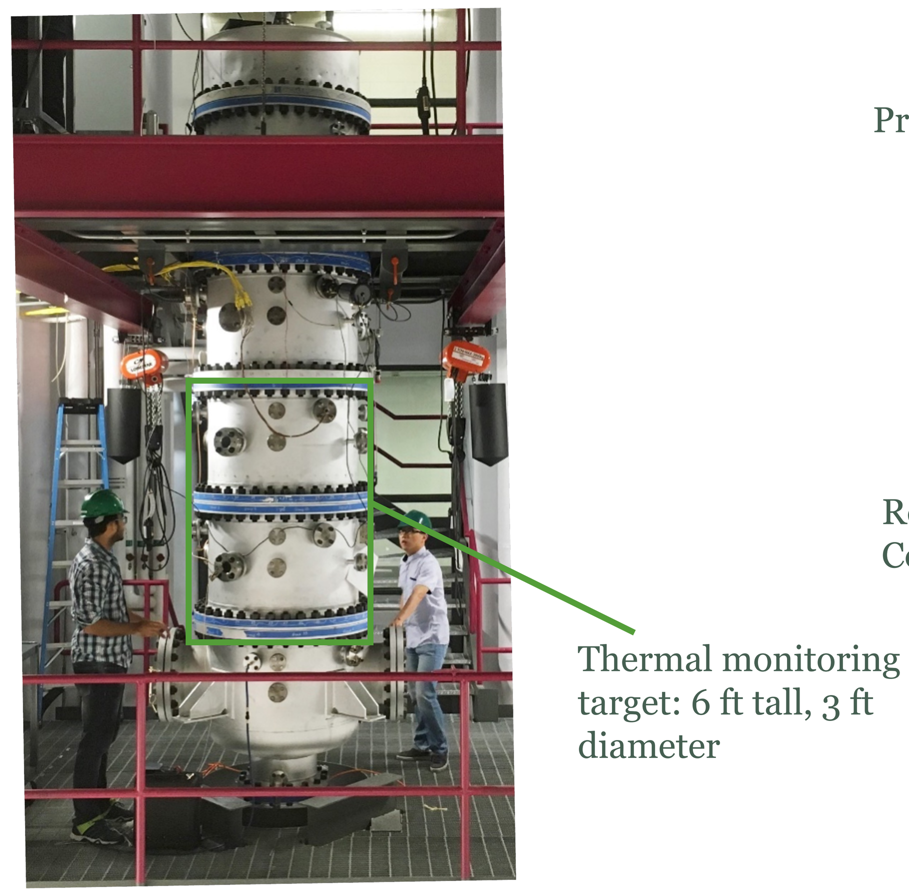
One Unique Solution

Staged Pressurized Oxy-Combustion (SPOC)[3]

- Efficient BECCS technology
- Utilizes oxygen diluted with CO_2 to combust woody biomass
- Creates CO_2-rich flue gas ideal for carbon capture
- High pressure allows for:
  - Increased thermal efficiency
  - Smaller, modular units
  - Lower cost

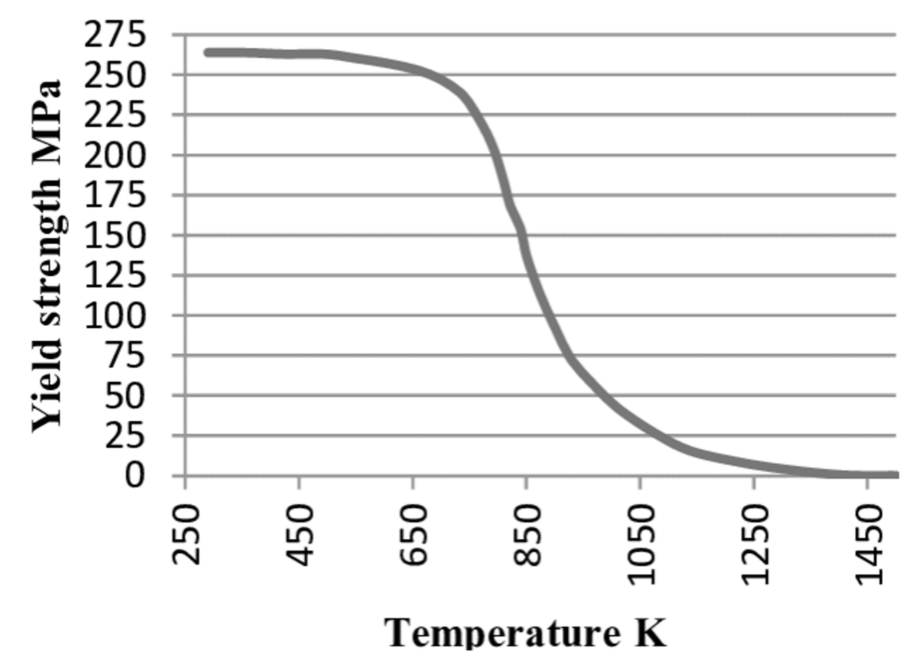


Three-story **pilot-scale SPOC facility**[4] in Urbauer Hall at WashU



Thermal Monitoring Challenge

- Pressure vessel (PV) is not meant to withstand temperatures >200°C
- Material strength drops rapidly as temperature rises[5]:



- Leaks or failures in the combustor could lead to PV failure
- Must monitor for hotspots

Current system does not allow for continuous, full-surface monitoring

Current system combines thermocouples (left) and a spectral-band infrared thermometer (right). The former is too small to be adhered everywhere on the PV, and the latter must be manually pointed.

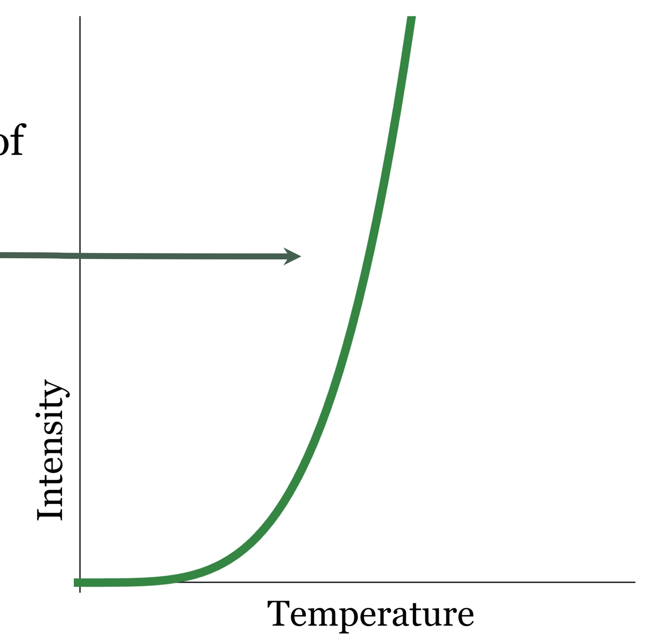
Infrared (IR) Thermography

- All objects follow Stefan-Boltzmann's Law:

Intensity
Total energy emitted per unit area of the surface per second

$$E = \varepsilon \sigma T^4$$

Emissivity
Material property that must be correctly set for accurate measurements



- IR devices measure incoming IR intensity to find temperature

IR Camera Testing & Validation

Selected thermal imaging camera:

- Temperature detection range of 20-200 °C
- Thermal resolution of 60 x 80 pixels
- Modest cost of $1200
- Continuous streaming via Ethernet

FLIR AX-8

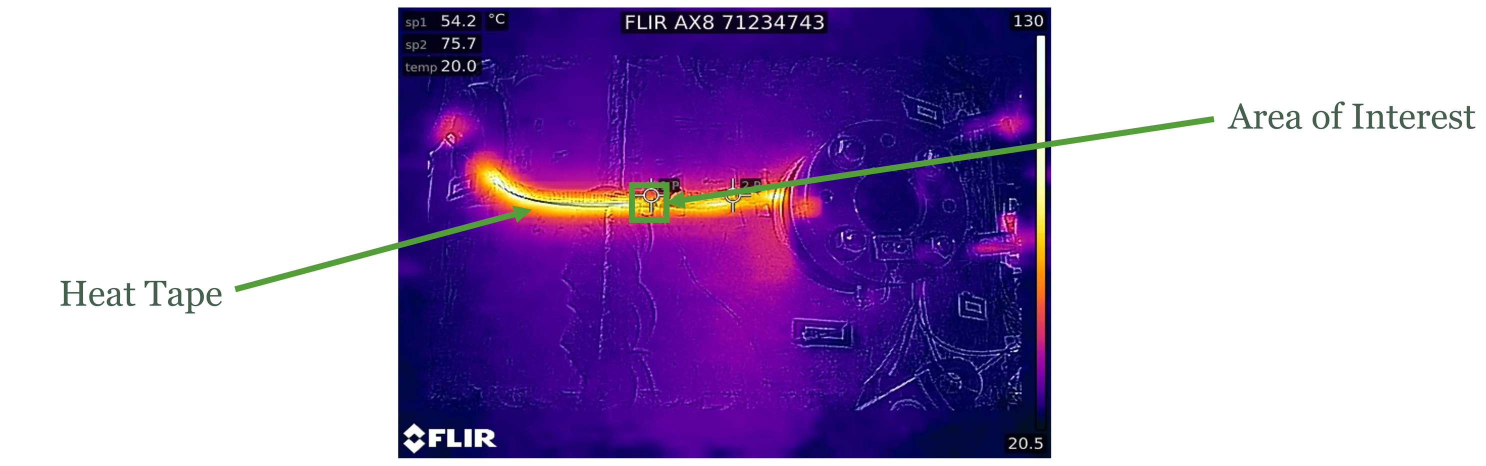
Developed MATLAB script:

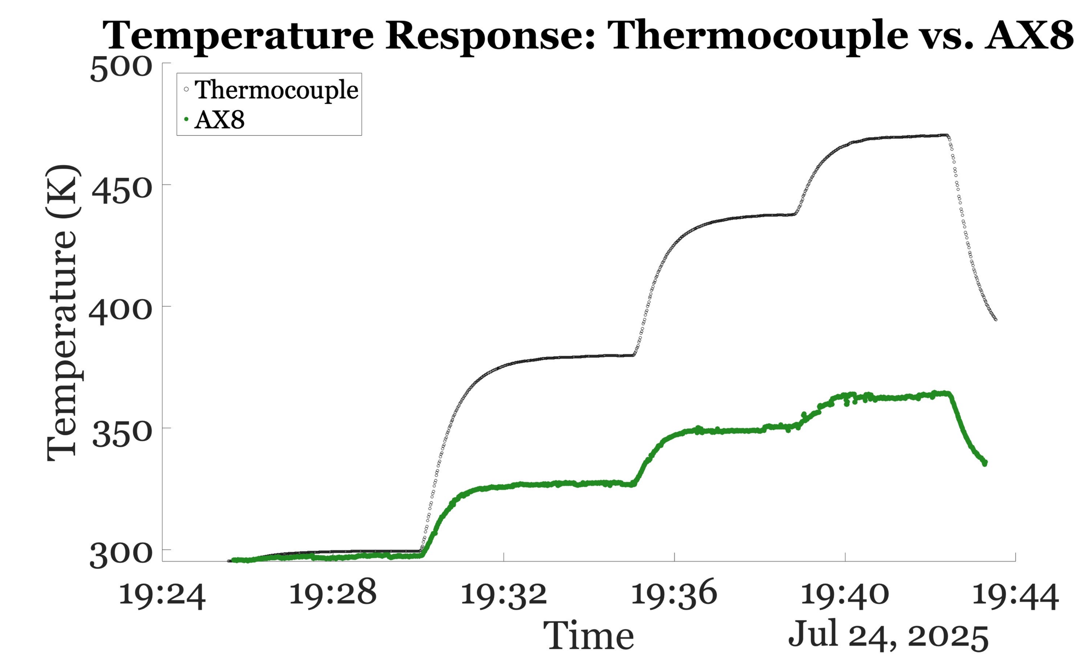
- FLIR alarm software only alerts for absolute temperature thresholds

→ MATLAB script for temperature deviation alerts

- Allows for early detection of hotspots
- Acquires real-time data via Modbus TCP

Validation:

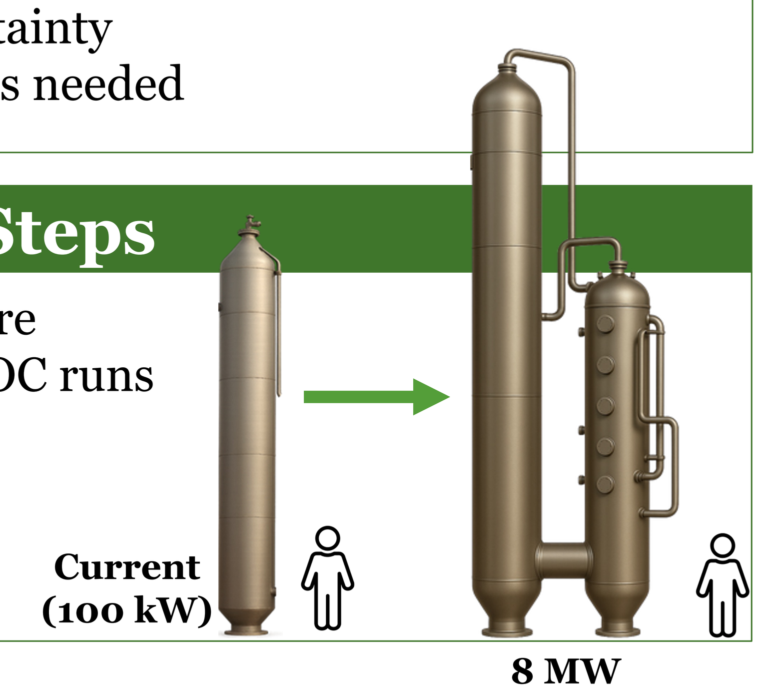




- AX-8 response rate ≈ thermocouple response rate
- Disparity between absolute temperature measurements
  - Likely due to emissivity uncertainty
  - Further validation experiments needed

Next Steps

- Continue developing alarm software
- Expand sensor validation with SPOC runs
- Install multi-camera system
- Commercialize and scale up SPOC



References

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2. "Carbon Dioxide Removal Market Size to Surge USD 2,849.22 Mn by 2034." *Precedence Research.*
3. Gopan et al., 2014, "Process design and performance analysis of a Staged, Pressurized Oxy-Combustion (SPOC) power plant for carbon capture," Applied Energy, vol. 125.
4. Yang et al., 2021, "Experimental study and demonstration of pilot-scale, dry feed, oxy-coal combustion under pressure, Applied Energy, vol. 285.
5. Figure adopted from Nandan et. al. 2007 P885.

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