



# WashU

## **Thermal Management for Pressurized Oxy-Combustion Applications**

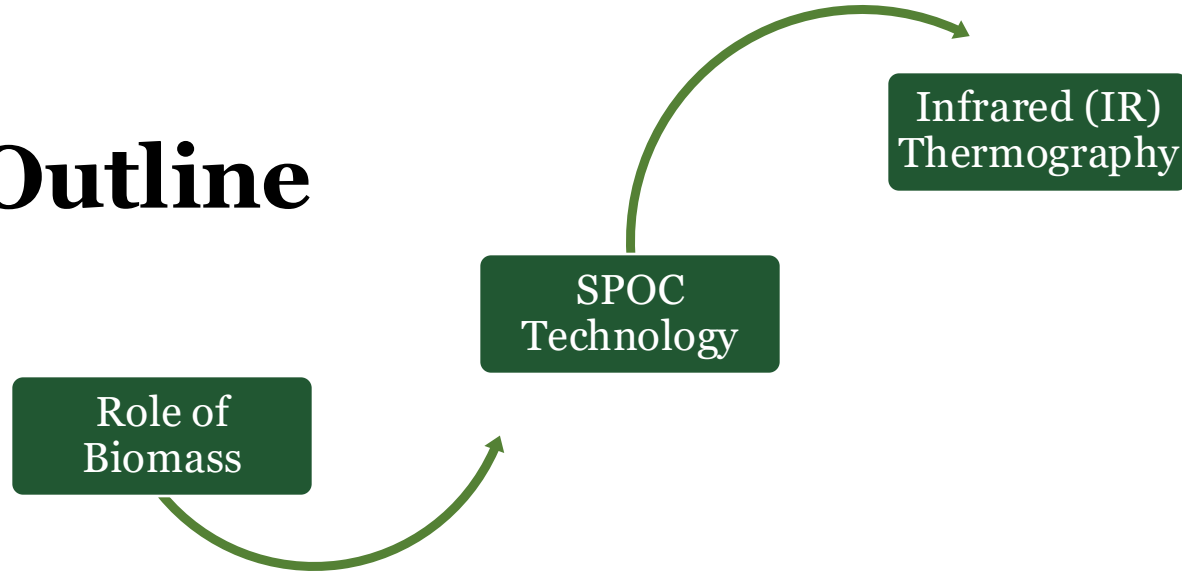
**Kayoko Thornton**

Richard Axelbaum, PhD

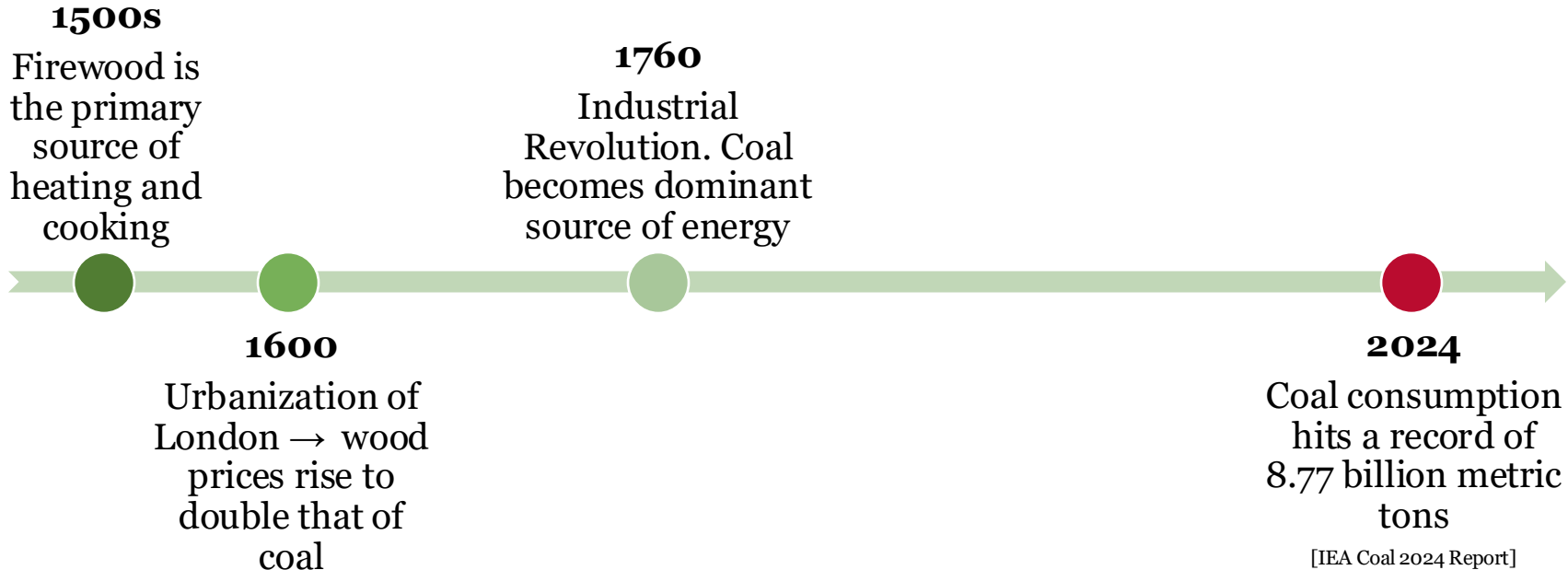
Duarte Magalhaes, PhD

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# Outline

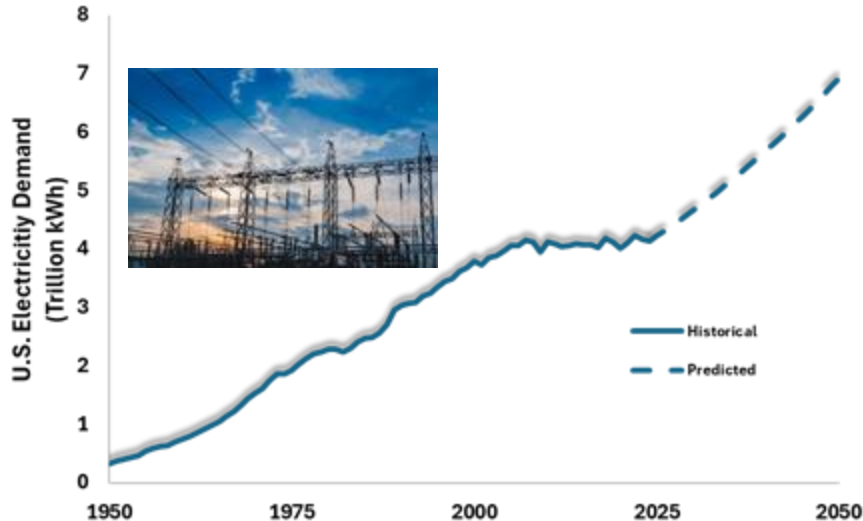


# Why did most of the world transition away from biomass?

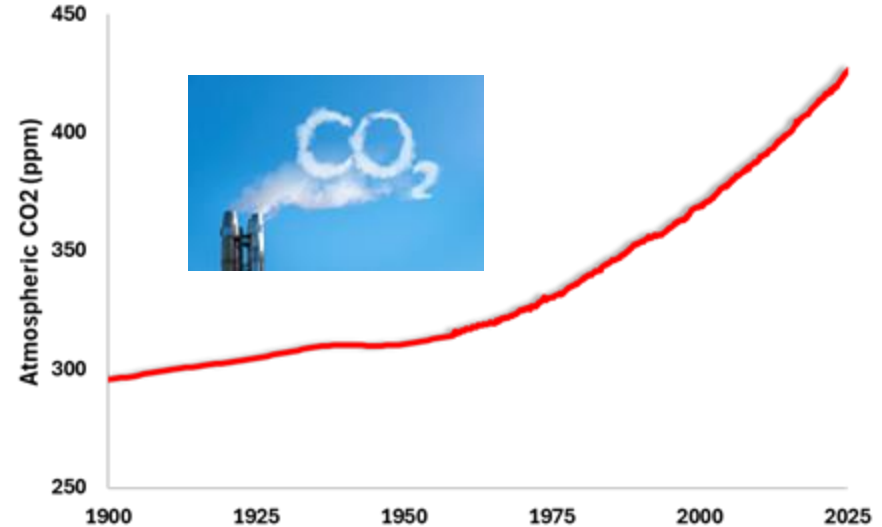


# The world is facing two *competing* problems

## Soaring Demand for Energy



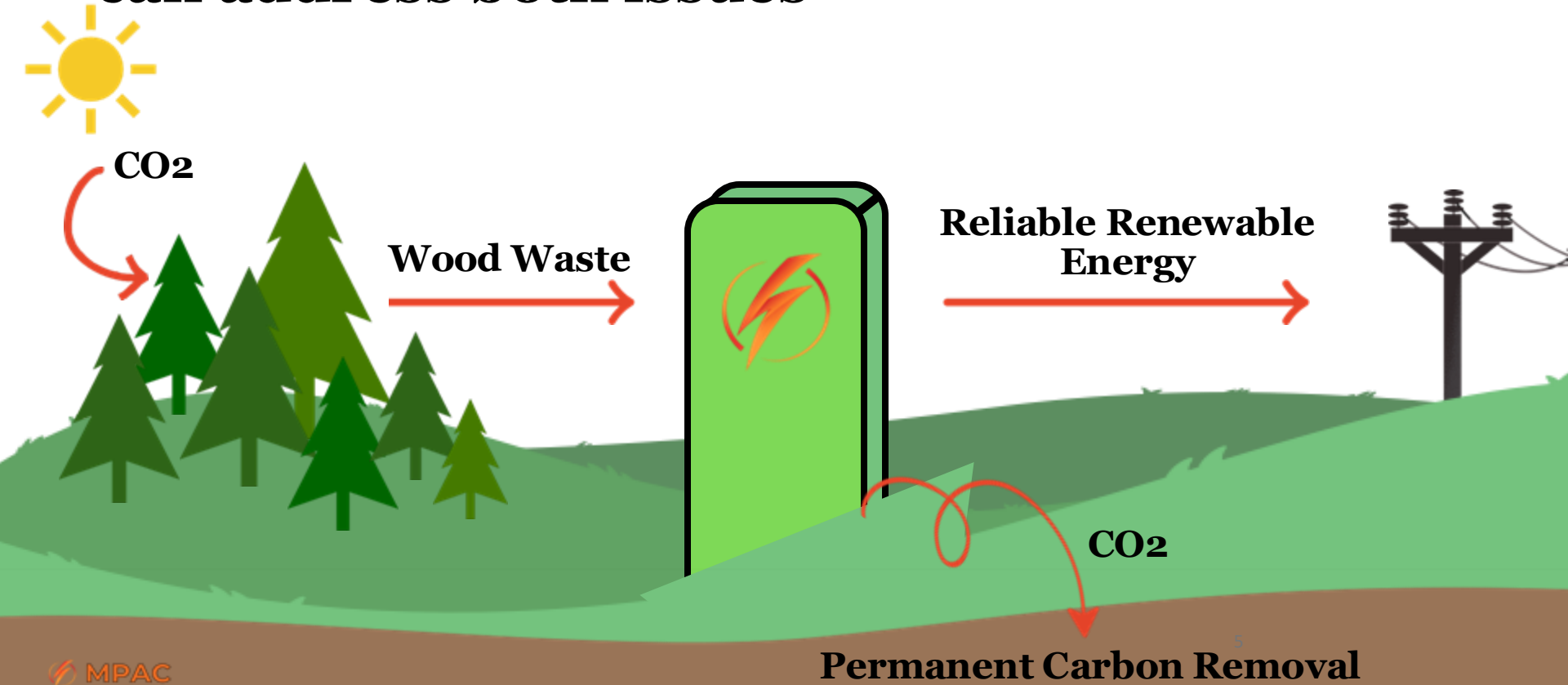
## Rising CO2 Levels



<https://www.precedenceresearch.com/carbon-dioxide-removal-market>

<https://www.utilitydive.com/news/us-electricity-demand-will-grow-50-by-2050-electrical-manufacturing-study/744575/>

# Bioenergy with Carbon Capture and Storage can address both issues



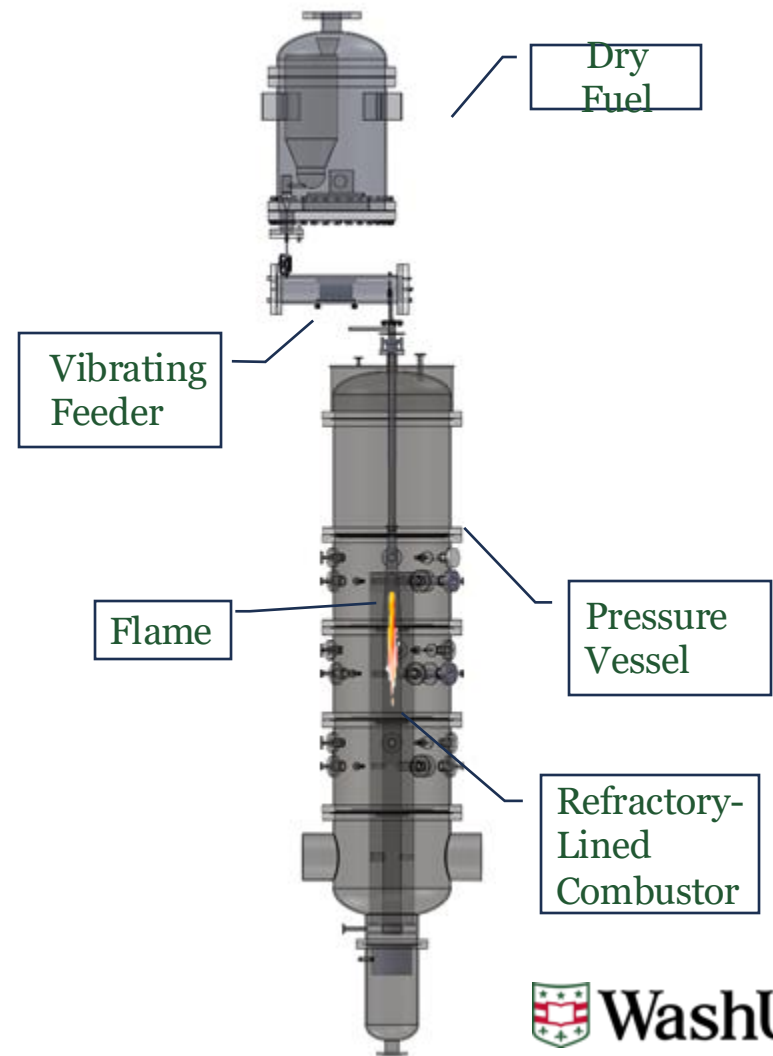
# Staged pressurized oxy-combustion (SPOC) is a promising bioenergy technology

- Oxy-combustion utilizes oxygen (diluted with CO<sub>2</sub>) instead of air to combust the fuel
- Produces a CO<sub>2</sub>-rich flue gas for carbon capture
- Extra advantages of pressurization:
  - Higher thermal efficiency
  - Smaller, modular units
  - Lower cost



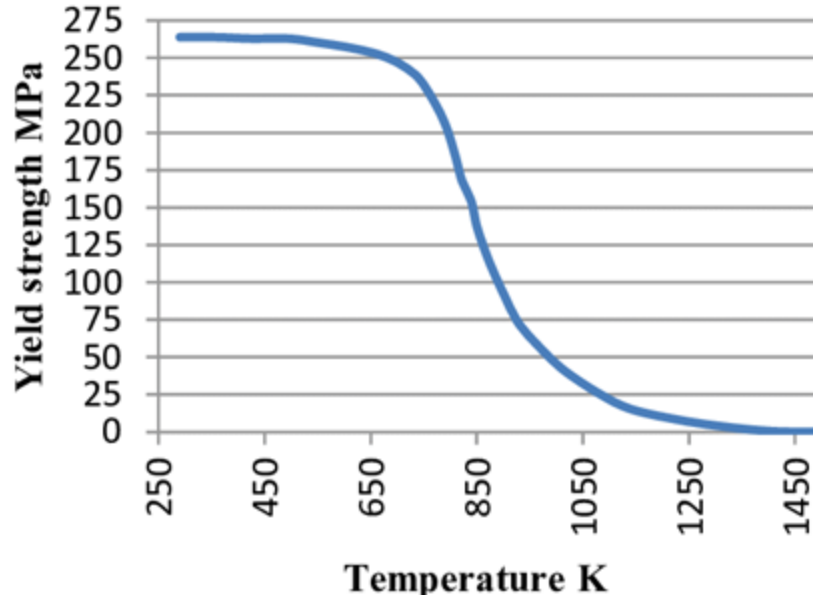
# Pressurized Oxy-Combustion Facility at WashU

- Flame develops inside combustor
- System is housed in a pressure vessel
- What happens if there is a leak?



# We must ensure the pressure vessel does not overheat

- Material strength drops rapidly as temperature rises
  - E.g. for mild steel: [Figure adopted from Nandan et. al. 2007 P885]



- Need to monitor for hotspots (3 ft diameter, 6 ft tall)

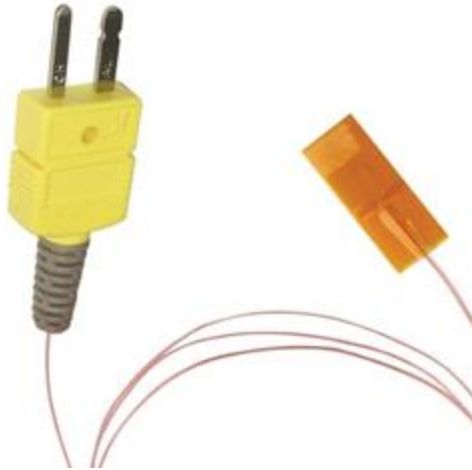




# The facility's current system does not allow for continuous monitoring everywhere

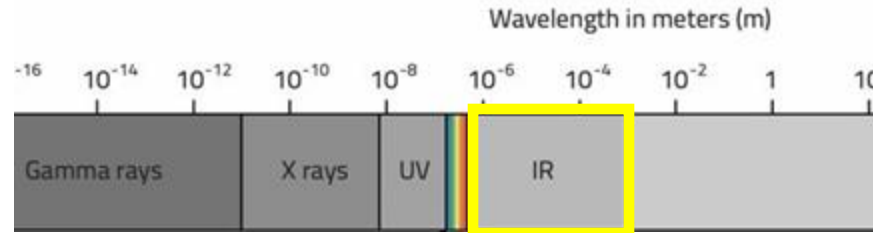
## Thermocouples

- Can't cover the whole surface



## Spectral-Band IR Thermometer

- Non-contact
- Measures infrared radiation



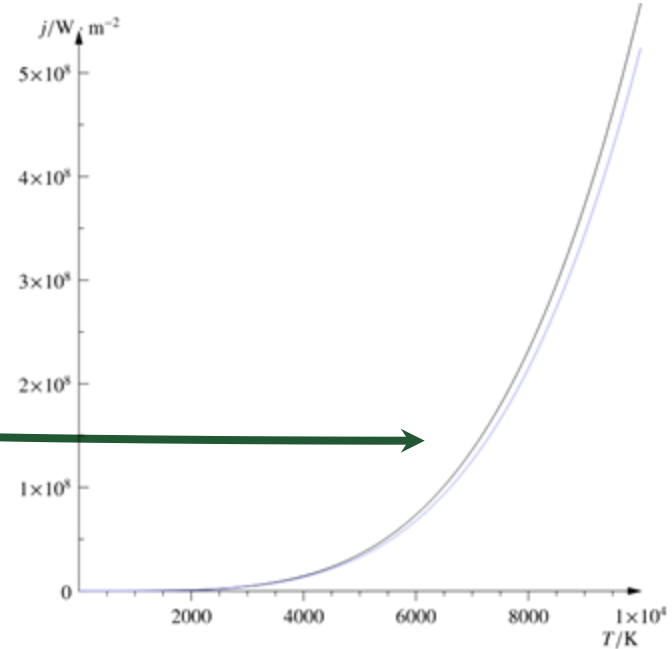
# Infrared thermography allows for non-contact temperature measurement

- All objects emit radiation
- Radiation follows Stefan-Boltzmann's Law

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

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

**Emissivity**  
Must be set correctly for accurate  
measurements



- Strong temperature dependence enables detection of small changes
- Actual calculation is more complicated and based on general Planck's Law

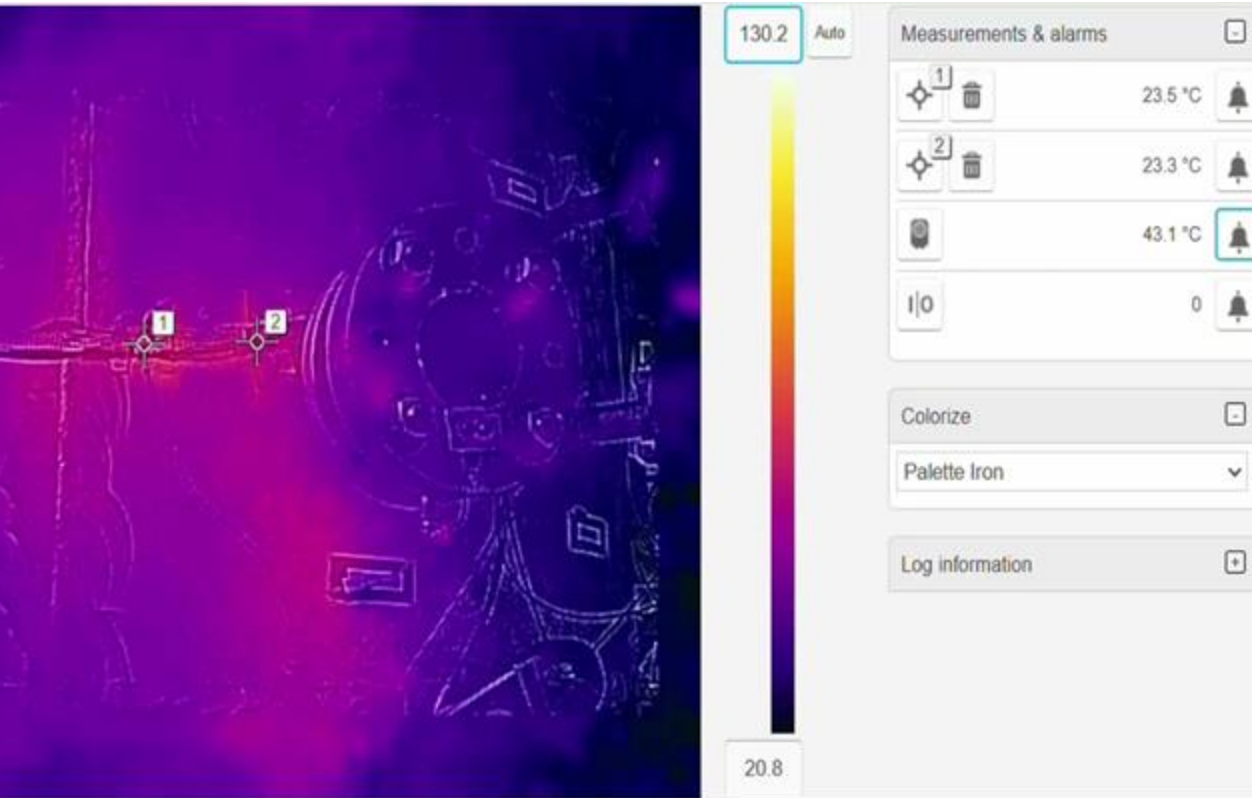
# The FLIR AX-8 allows for hands-off monitoring

Key considerations:

- Temperature detection range of 20-200 C
- Thermal resolution & field of view
- Modest cost (\$1200)
- Continuous streaming via Ethernet
- Alarm system



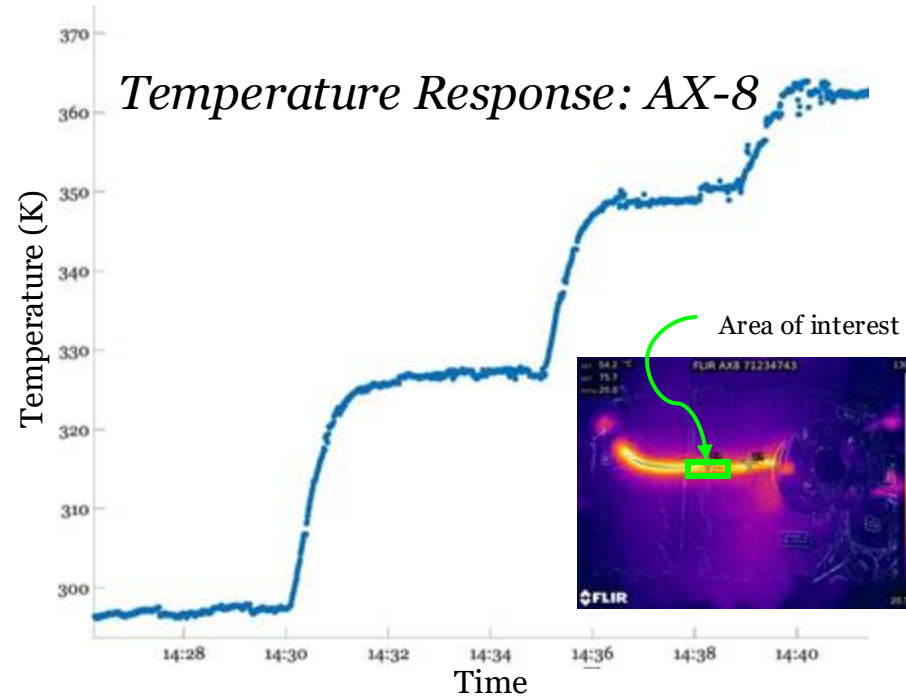
# Existing FLIR software does not meet our needs



- Can only set absolute temperature threshold alarms
- We want to detect *deviations*
  - Gives early warning of hot spots
  - Removes emissivity complications

# Bypassing the web interface enhances camera functionality

- Developed MATLAB script that acquires real-time AX-8 data via Modbus TCP
  - Enables custom alarms
  - Used to validate AX-8 response rate with thermocouples
- AX8 response time to 10% of the total temperature change  $\approx$  thermocouple response time



# Next Steps:



Current



8 MW

- Continue developing image processing software
- Expand sensor validation with real SPOC runs
- Install multi-camera system
- Commercialize and scale up the technology

# Acknowledgements

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# Questions?