# CIBO
# Virtual Environmental Committee Meeting

September 21, 2022

BABCOCK & WILCOX

RENEWABLE
ENVIRONMENTAL
THERMAL

# Decarbonizing Industrial Steam & Power with Chemical Looping and Oxygen Combusting Technologies


# Summary

- **Green Energy & Energy Transition**
  - A Low Carbon Future
- **No Sequestration Option**
  - Renewable Fuels
  - Renewable Energy
- **Yes Sequestration Option**
  - Carbon Capture
  - Oxy Combustion
  - BrightLoop

# Green Energy

## Renewable Power

**Solar**

**Biomass Energy**

**Waste to Energy**

Geothermal/Nuclear/Hydro/Wind

## Energy Storage

Li-ion/**other batteries**

Gravity Storage (PH)

**Thermal/Chemical Storage**

**Hydrogen**

## PtX | Synthetic eFuels

**Hydrogen**

**Methanol** (w/ Biogenic $CO_2$)/SAF

RNG/Renewable Diesel

Green Fertilizer $NH_3$/Urea

## Industrial Steam and Heat

**Re-firing Boilers with Hydrogen**

Electric Boilers/Heat Pumps

**Thermal Energy Storage**

Chemical Energy Storage

# Energy Transition

## Carbon Capture

**SolveBright**

**OxyBright**

**BrightLoop**

**Direct Air Capture**

**BECCS**

### Renewable Power

Solar

Biomass Energy

Waste to Energy

Geothermal/Nuclear/Hydro/Wind

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### Industrial Steam and Heat

Re-firing Boilers with Hydrogen

Electric Boilers/Heat Pumps

Thermal Energy Storage

Chemical Energy Storage

# Is Carbon Sequestration Available?

**No**

- Renewable Fuels
  - Biomass
  - Waste fuels
  - Renewable natural gas (RNG)
  - Re-fire with hydrogen
- Renewable Electricity
  - Electric boilers
  - Heat pumps
  - Thermal Energy Storage

**Yes**

- Post-Combustion
  - Amine Scrubber/Stripper System
- Pre-Combustion
  - Oxy-combustion 
- Chemical Looping
  - Bright Loop 

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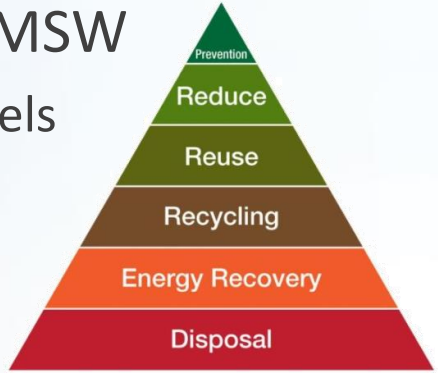
# Renewable Fuels (eFuels)

## “Low Carbon” Fuels

- Incentives…
- Special Category:
  - Transportation Fuels (LCFS)
- Biomass/Waste/MSW
  - Generally solid fuels
  - Waste Hierarchy
    - US version?




## Steam from eFuels

- Re-fire with hydrogen
  - Easiest, if hydrogen is available
  - $1/kg target ≈ $7.4/MMBtu (HHV)
  - Include: compression and transport
  - 45V gets to < $1/kg, but needs low CI
    - No electrolysis with grid power

BrightGen

- Renewable natural gas (RNG)
  - Many Sources and Options
    - Digesters/Synthetic/Gasification
  - Cost is not there (yet)…
  - Power to X (PtX)

# Renewable Energy

## Solar/Wind

- $0.02/kWh to $0.06/kWh
  - Intermittent
  - “Behind the Fence”
- Distribution
  - Not an insignificant cost
- Renewable Energy Certificates (RECs)
  - ISO dependent
  - Time stamps and verification

## Steam from Solar/Wind

- Electric Boilers
  - $0.02/kWh ≈ $6/MMBtu
  - Intermittent (no SH?)
- Heat Pumps (COP ≈ 2)
  - $0.02/kWh ≈ $3/MMBtu
  - Intermittent
- Thermal Energy Storage
  - Not Intermittent
  - Electric or Heat Pump

Green Steam

# Is Carbon Sequestration Available?

## No

- Renewable Fuels
  - Biomass
  - Waste fuels
  - Renewable natural gas (RNG)
  - Re-fire with hydrogen
- Renewable Electricity
  - Electric boilers
  - Heat pumps
  - Thermal Energy Storage

## Yes

- Post-Combustion
  - Amine Scrubber/Stripper System
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- Chemical Looping
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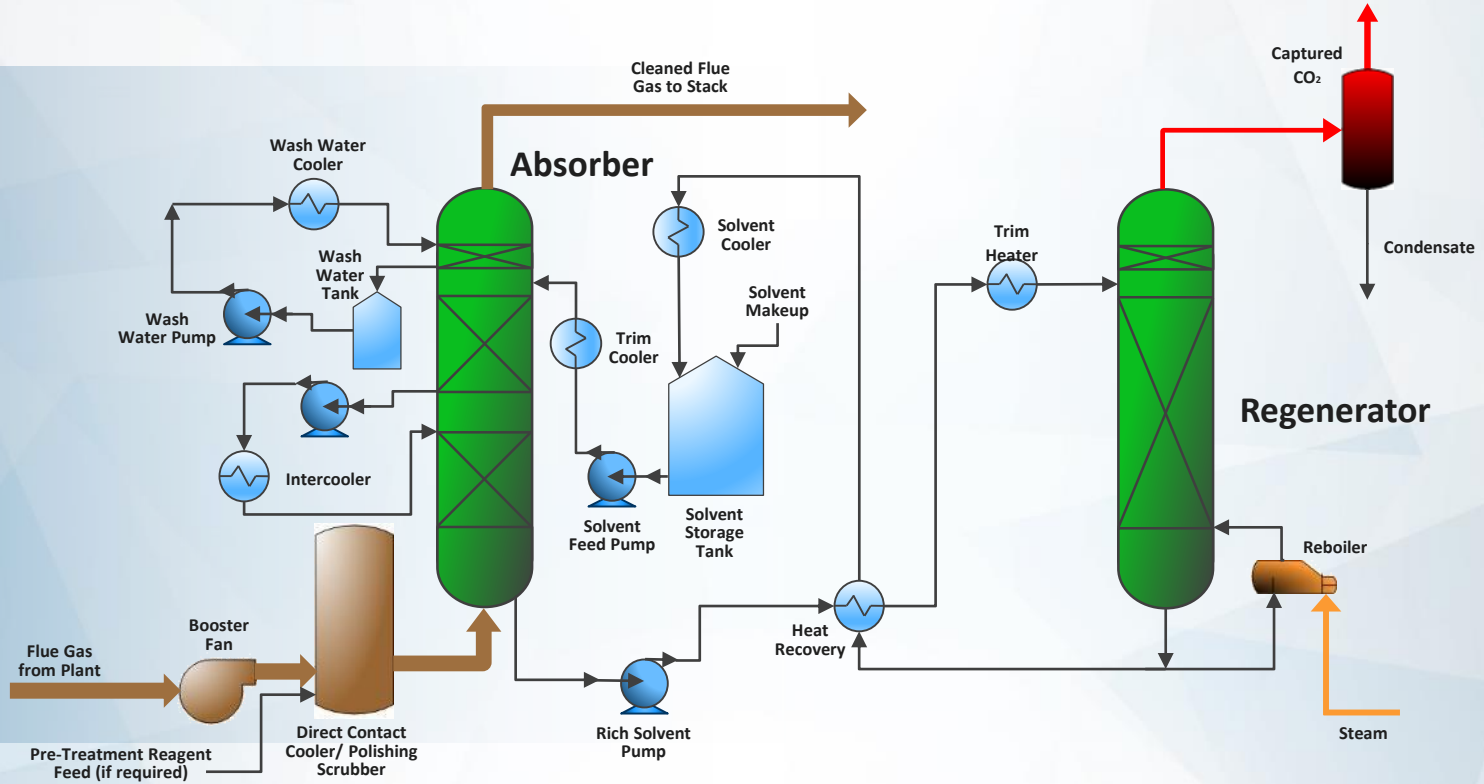
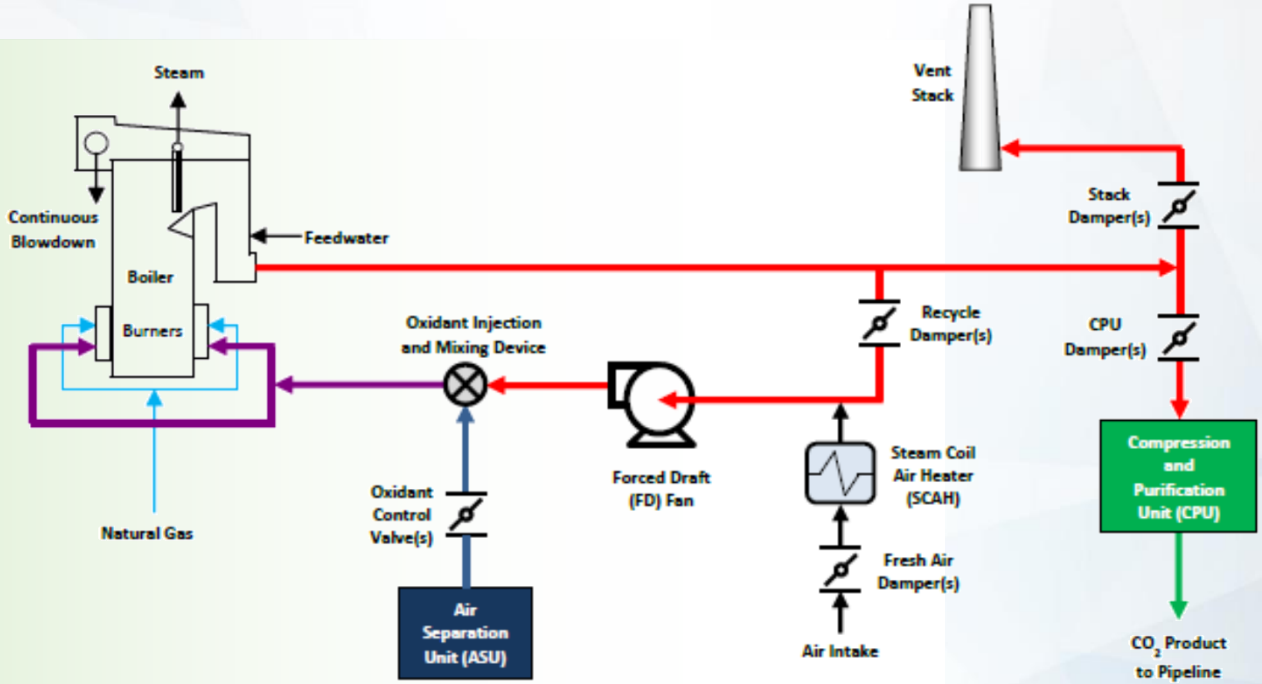
# Post-Combustion Carbon Capture with SolveBright

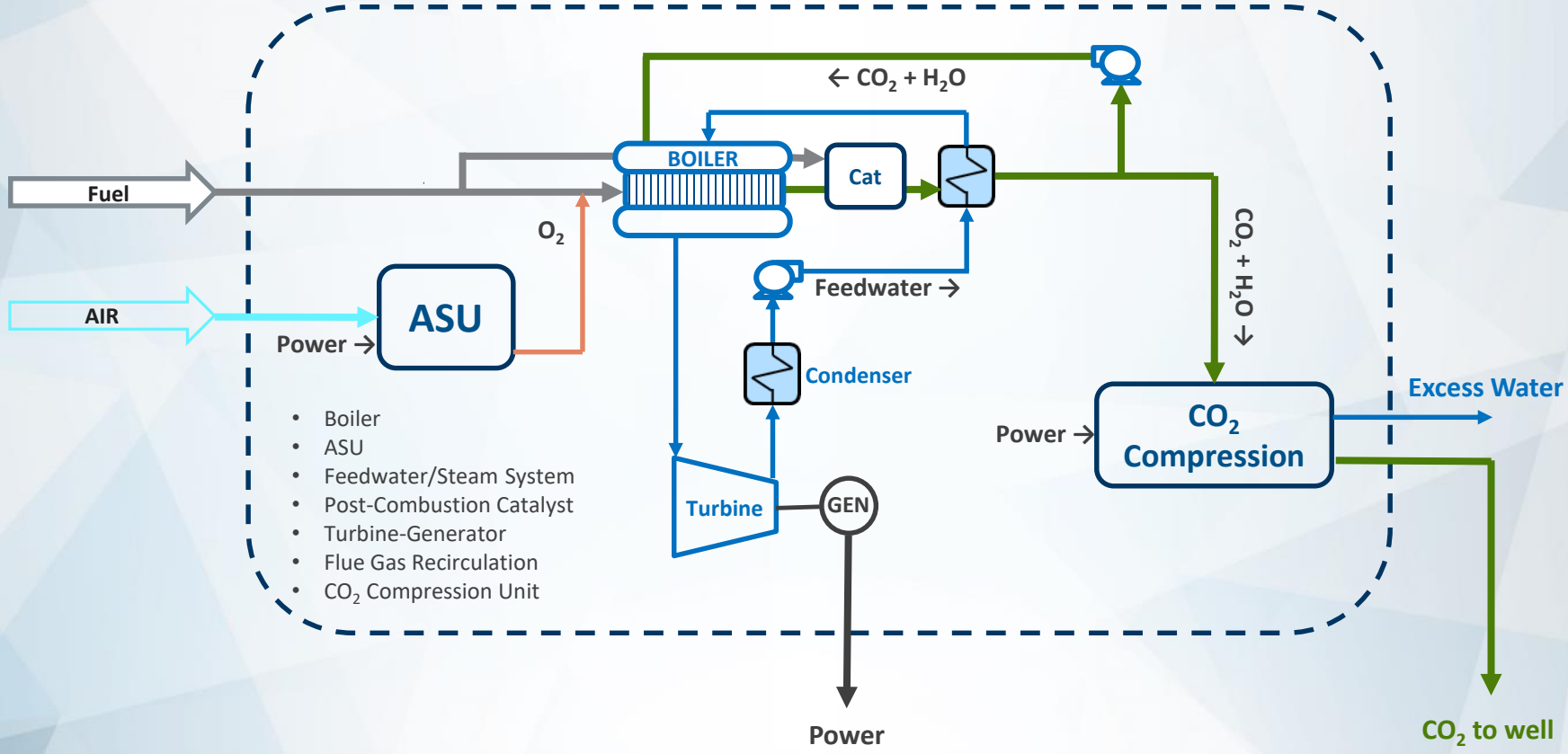


# Oxy Combustion




Natural Gas Oxy-Firing Process Schematic

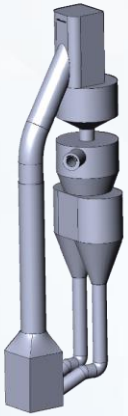
# Package Oxy Boilers



# BrightLoop Chemical Looping is a Platform Technology

**FEEDSTOCK**

- Waste
- Natural Gas
- Biomass
- Biogas
- Coal (Petcoke)



**BrightLoop™**
Chemical Looping Technology

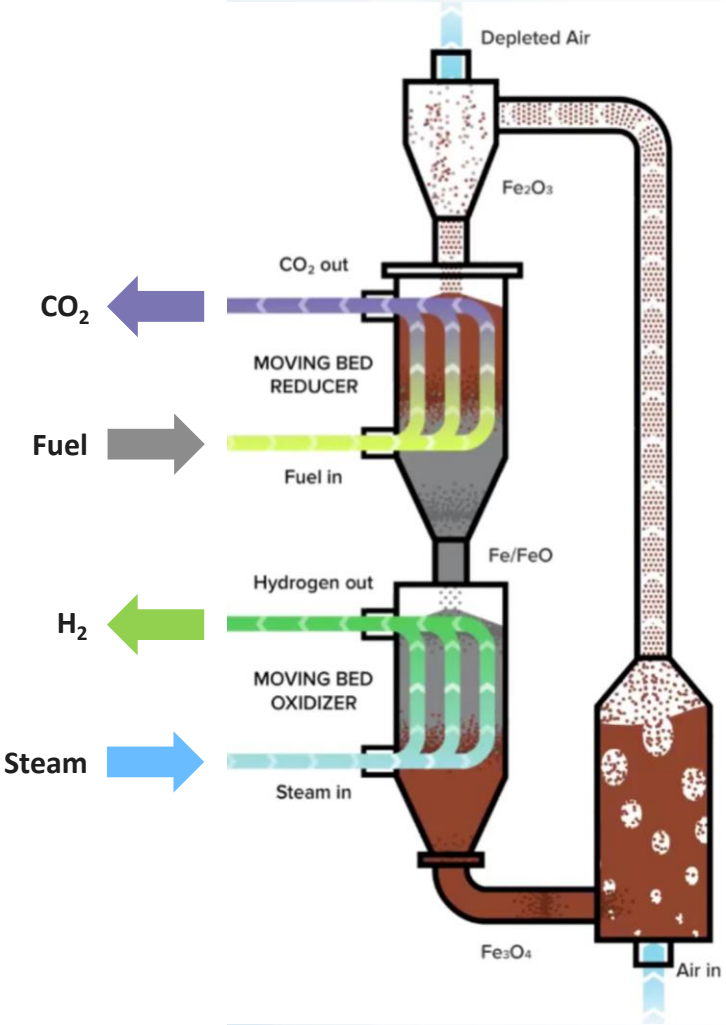
$CO_2$ for Storage and Beneficial Use

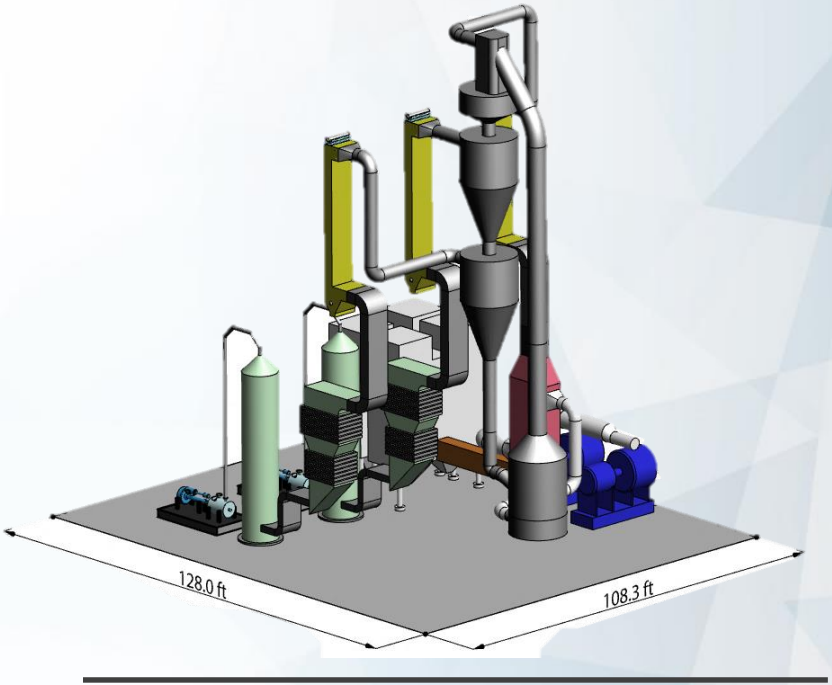
**OUTPUT**

- **Combustion:** Steam
- **Gasification:** Hydrogen
- **Partial Oxidation:** Syngas

- Process → HEAT
- Turbine → POWER
- Fuel Cell/Boiler → POWER
- Hydrogen Storage → HYDROGEN
- Shift Reaction → HYDROGEN
- Methanation → METHANOL
- Fischer-Tropsch → FUELS (Gasoline, Diesel, Jet Fuel)

# $H_2$ Generation




The Ohio State University

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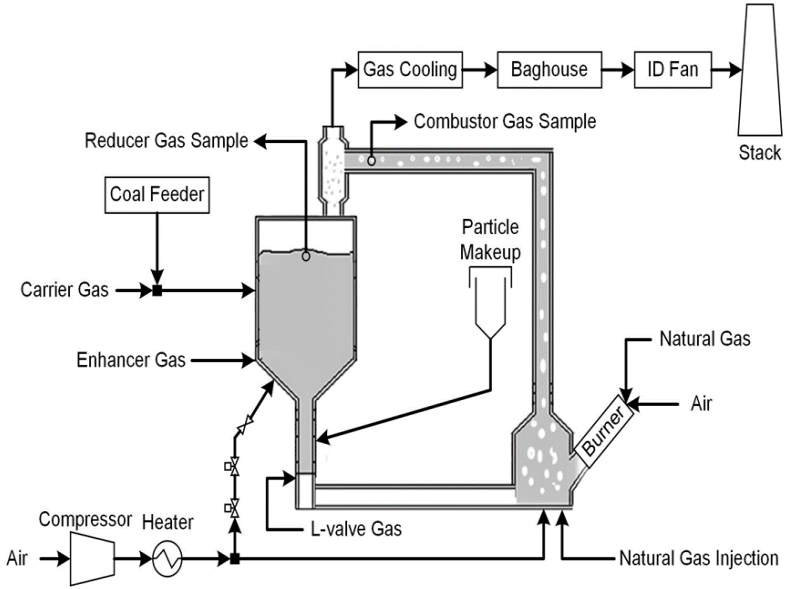



# 250 $kW_{th}$ CDCL Pilot Test Unit
## (Equivalent to 0.4 ton/h Steam)

## Specifications

- **Materials:** Refractory-lined carbon steel
- **Max Operating Temperature:** 1100°C
- **Overall Height:** 10 m
- **Footprint:** 3 m x 3 m
- **Thermal Rating:** 250 $kW_{th}$
- **Design Feed Rate:** 16 kg/h
- **Oxygen Carrier:** Iron based
- **Particle Diameter:** 1.5 mm

# 250 $kW_{th}$ Syngas Chemical Looping (SCL) Pilot Plant

## Pilot Plant and Installed Components

Pressure
- 10 atm

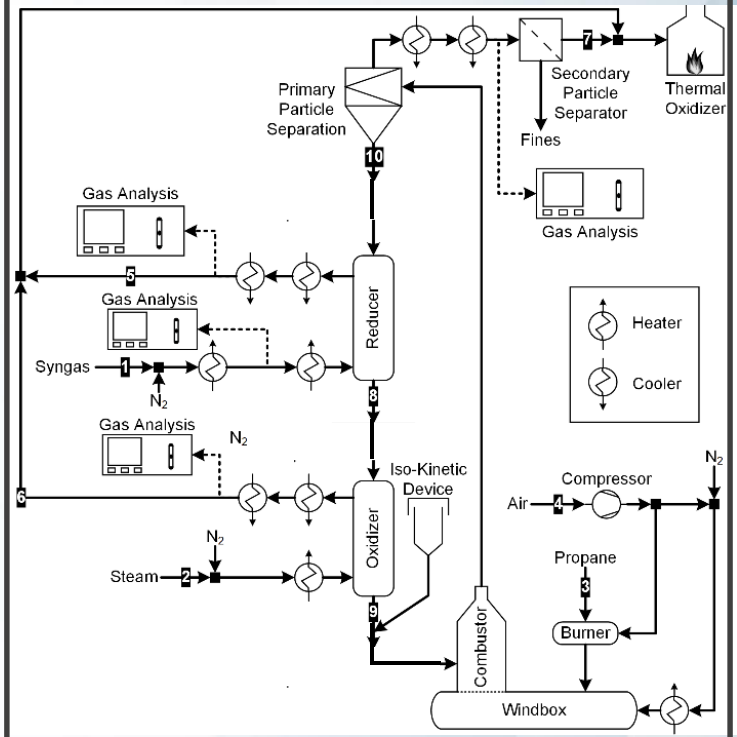
Reducer:
- Feed: Syngas (KBR)
- Moving Bed

Oxidizer:
- Feed: Steam
- Moving Bed

Combustor
- Feed: Air
- Fluidized Bed

Project led by OSU. B&W served as EPC and involved in testing and operation.

## SCL Process Flow Diagram

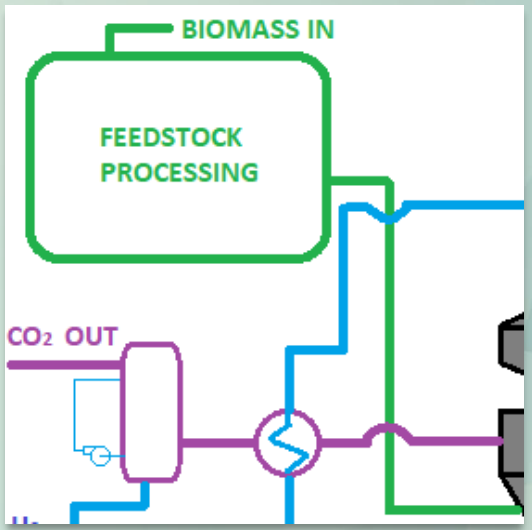


# Feedstock Processing and Feeding

- Plant feedstock to be clean forestry waste material including potential woody industrial waste products
- BrightLoop requires fine particulate feeding (500 – 750 µm)

## Initial Concept

- Pre-processing – screening for tramp metals and sizing
- Pyrolysis / carbonization to create a biochar and gaseous exhaust, both of which will be fed to BrightLoop 3-reactor
  - Gaseous exhaust product piped directly to 3-reactor (Reducer module)
  - Biochar to be pulverized (<300 µm) and transported via a pressurized $CO_2$ stream into the 3-reactor (Reducer module)

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# QUESTIONS?