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# UKCCSRC PACT CORE FACILITIES SHEFFIELD

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**EPSRC**  
Pioneering research  
and skills

- **UKCCSRC Pilot-scale Advanced Capture Technology facilities**
  - Funded by: BEIS (formerly DECC) and EPSRC
  - Cranfield, Edinburgh, Imperial, Leeds, Nottingham, Sheffield
  - Member of International CCS Test Centre Network (for UK)
- **Scope:** Specialist national facilities for research in advanced fossil-fuel energy, bioenergy and carbon capture technologies
  - Comprehensive range of pilot-scale facilities
  - Supporting specialist research and analytical facilities
  - Leading academic expertise
- **Aim:** Support and catalyse industrial and academic R&D to accelerate the development and commercialisation of novel low carbon technologies
- **Objectives**
  - Bridge gap between bench-scale R&D and industrial pilot trials
  - Provide shared access to industry and academia



Department for  
Business, Energy  
& Industrial Strategy

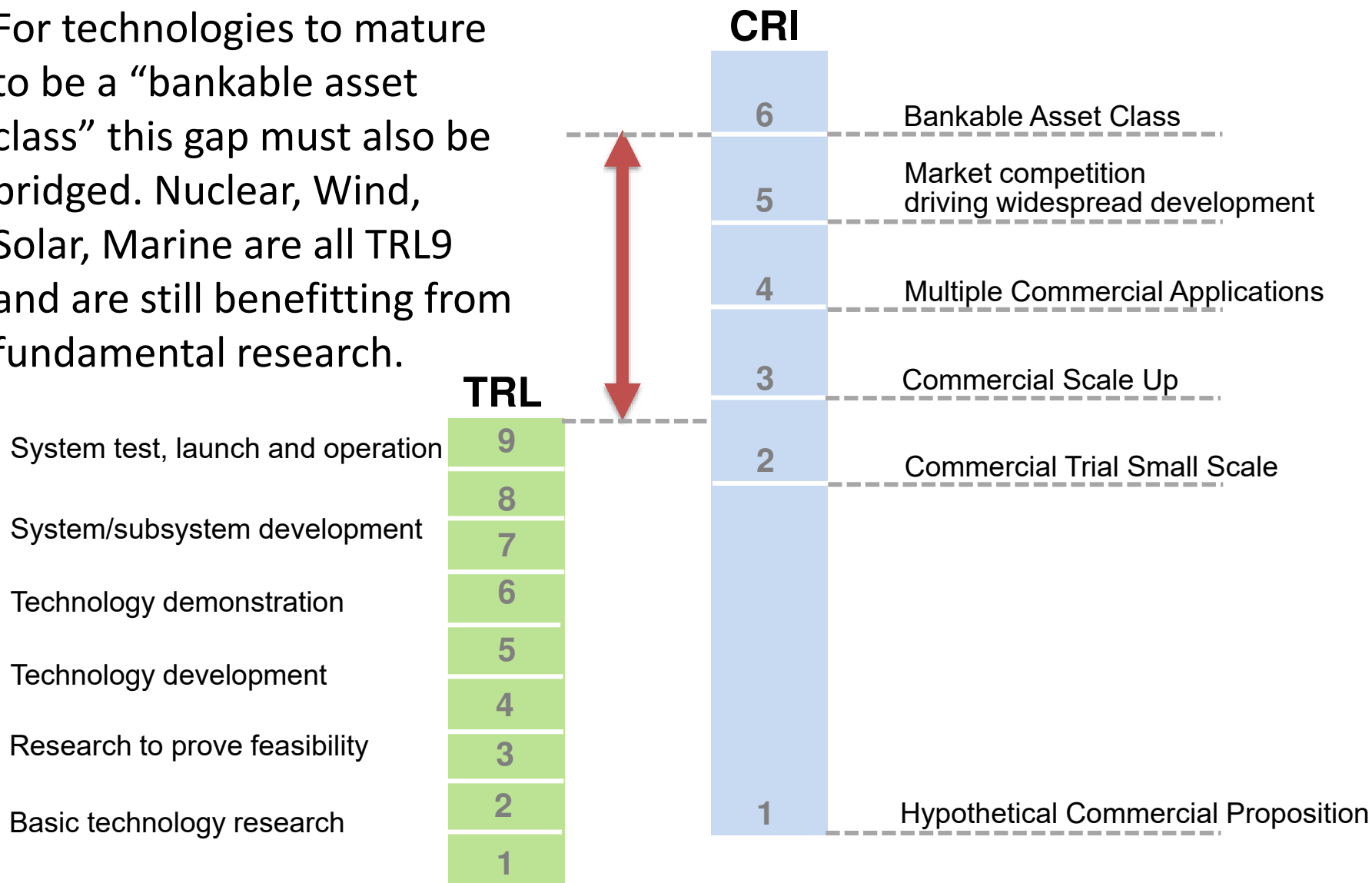
EPSRC

Engineering and Physical Sciences  
Research Council



# Fundamental research needed to increase Commercial Readiness as well as TRL

For technologies to mature to be a “bankable asset class” this gap must also be bridged. Nuclear, Wind, Solar, Marine are all TRL9 and are still benefitting from fundamental research.

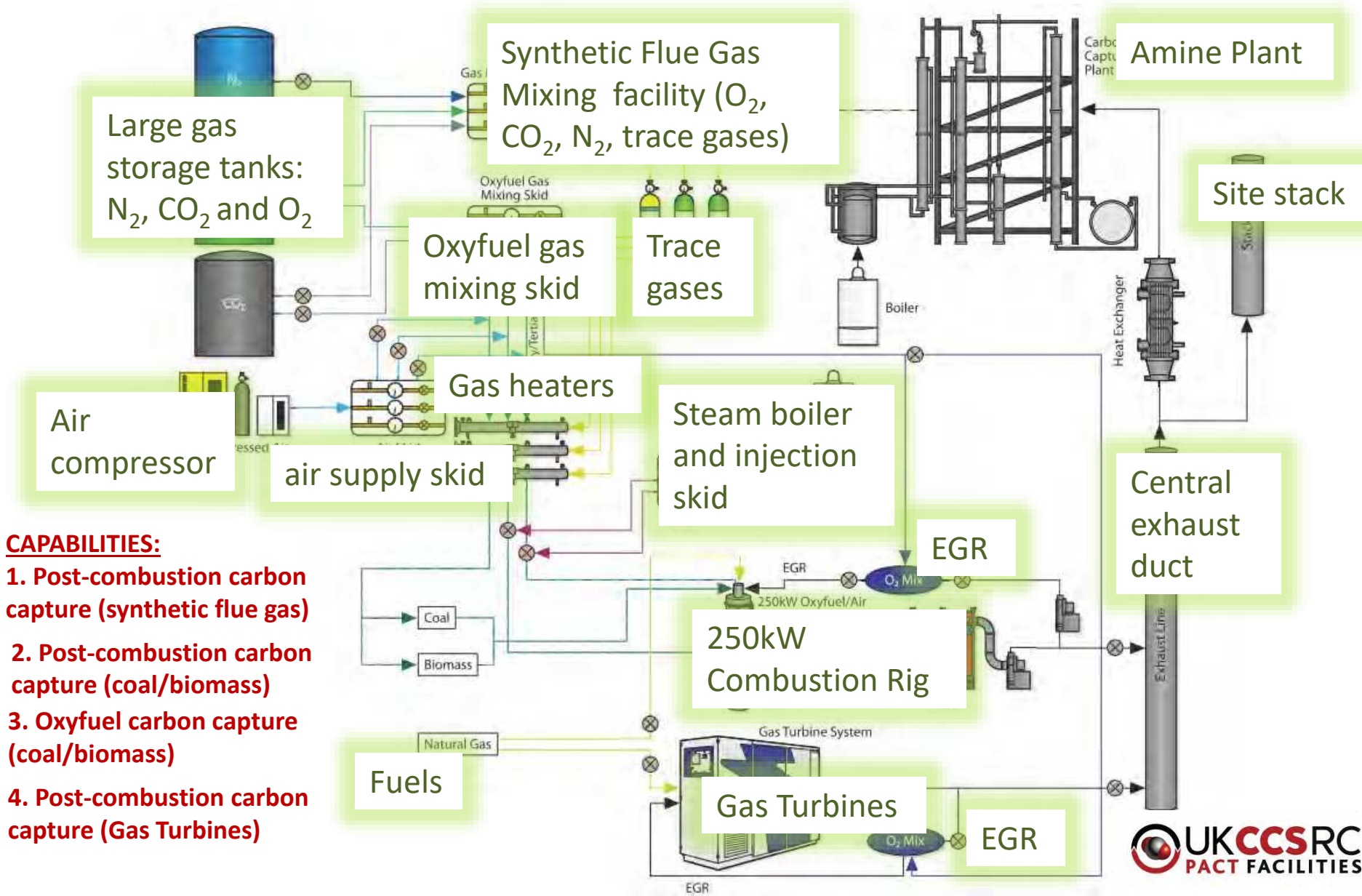


# **PACT Core Facilities**

**Coal/Biomass, NG-CCGT , Biofuel, CO<sub>2</sub>  
Capture Plant**

**Large –Scale Combustion Test  
Facilities**

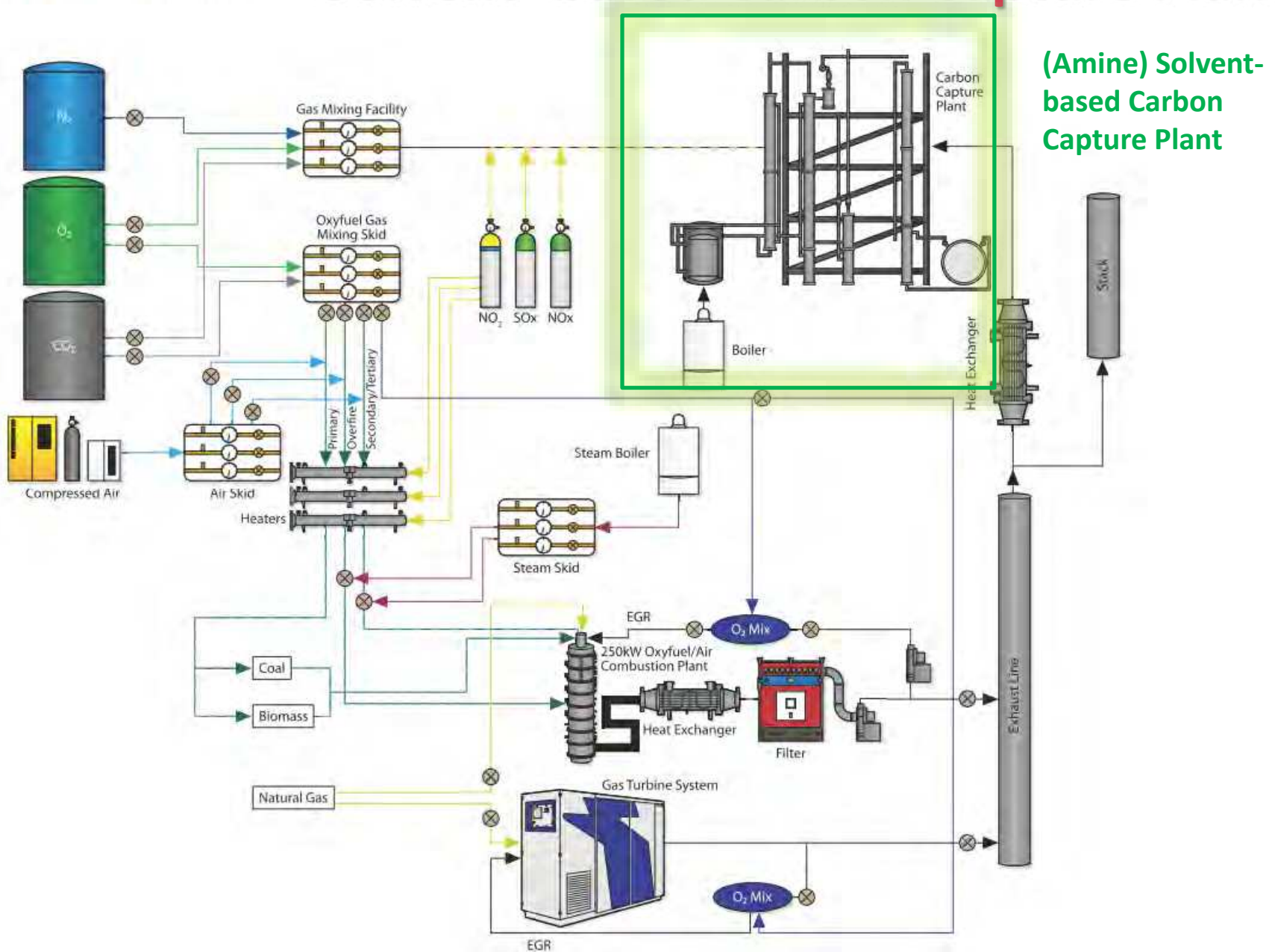
# PACT Core Facility: Overview



**CAPABILITIES:**

1. Post-combustion carbon capture (synthetic flue gas)
2. Post-combustion carbon capture (coal/biomass)
3. Oxyfuel carbon capture (coal/biomass)
4. Post-combustion carbon capture (Gas Turbines)

# Solvent- based Carbon Capture Plant



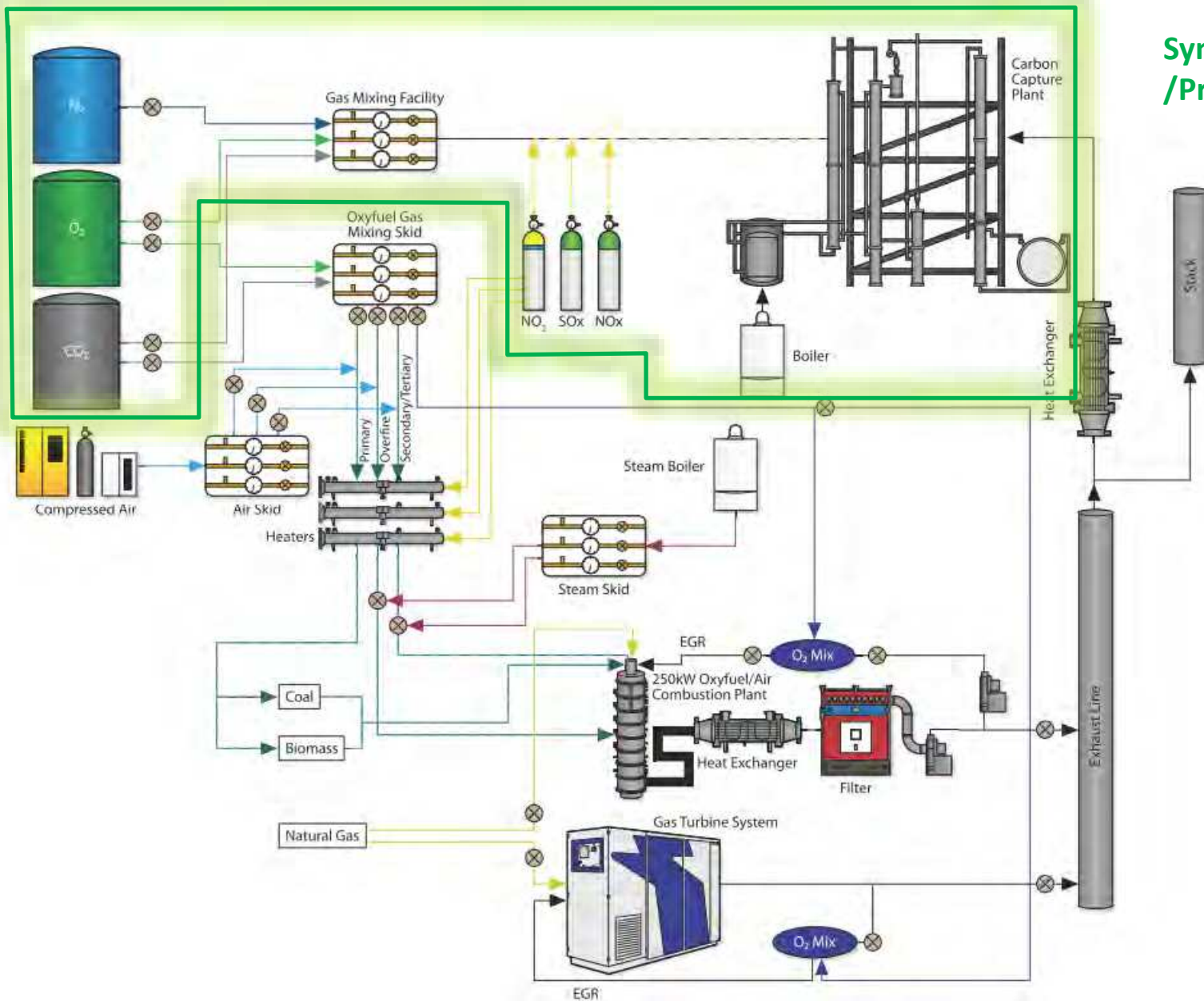
## Overview

- 8m/300mm Absorber and Desorber columns
  - 2x 3m packed sections
  - Random/structured packing
- Integrated FGD (carbonate) wash system for removal of SO<sub>x</sub> from coal flue gas
- Flue gas treated: 210 Nm<sup>3</sup>/h; equiv. to 150kW coal flue gas
- Removes 1 tonne of CO<sub>2</sub> per day (MEA) with over 98% purity
- Solvent sampling on absorber and desorber
- Material corrosion testing sites
- Trace gas injection capability
- Analytical capability
  - Gas composition
  - Temperature monitoring
  - Pressure monitoring (e.g. foaming)



# Synthetic Flue/Process Gas Facility

Synthetic Flue  
/Process Gas System



# Synthetic Flue/Process Gas Facility

## Overview

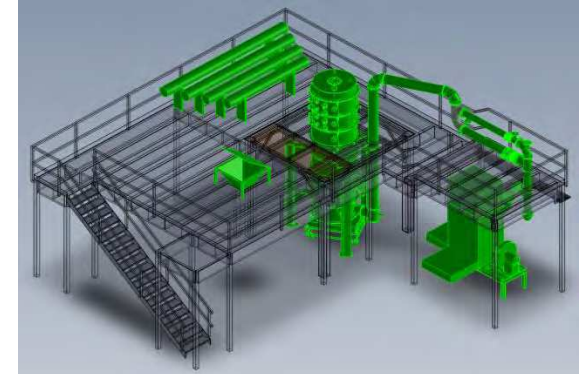
- Three **gas metering and mixing** lines, fed from O<sub>2</sub>, CO<sub>2</sub> and N<sub>2</sub> storage tanks
- Complemented by **trace gas injection** NO<sub>x</sub> and SO<sub>x</sub>, other trace gasses
- Generate simulated flue/process gases
- Connected directly to the **Solvent-based Carbon Capture Plant**



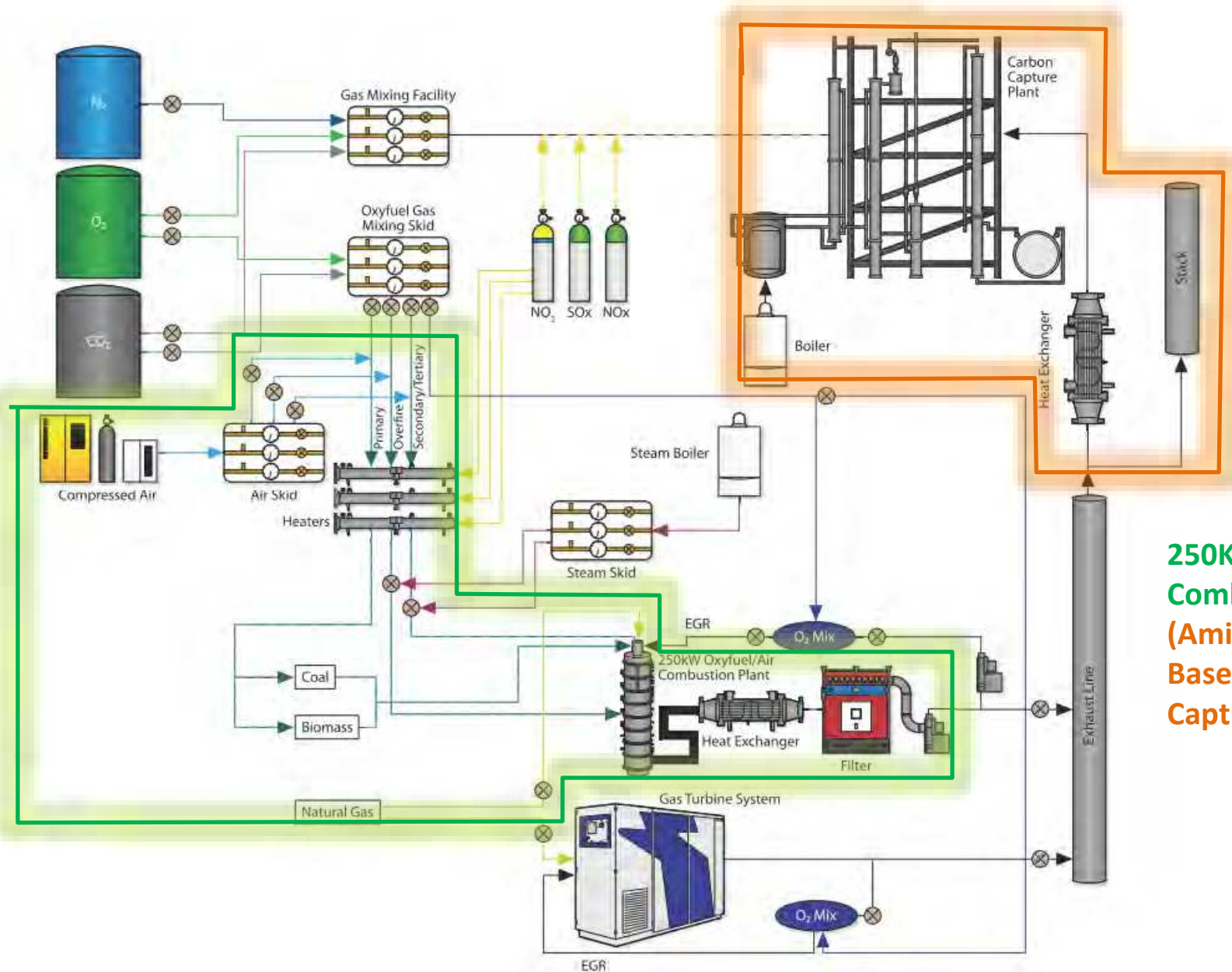
# 250kW Air Combustion Plant

## Overview

- ~250kWth, 4.5m high; 0.9m radius, cylindrical, down-fired rig with 8 sections
- Fuel: Coal, Biomass, Co-firing, Gas (primarily preheating)
- 2 x (interchangeable) coal/biomass burners - scaled from Doosan Power Systems commercial low-NO<sub>x</sub> burners
- Dedicated, high precision air metering skid
- Flue gas candle filter ( >99% ash removal);
- Furnace pressure (negative) balanced by exhaust fan
- Temperature and flow monitored water cooling system for the combustion rig, flue gas duct and heat exchanger.
- SCADA operating system with internet monitoring

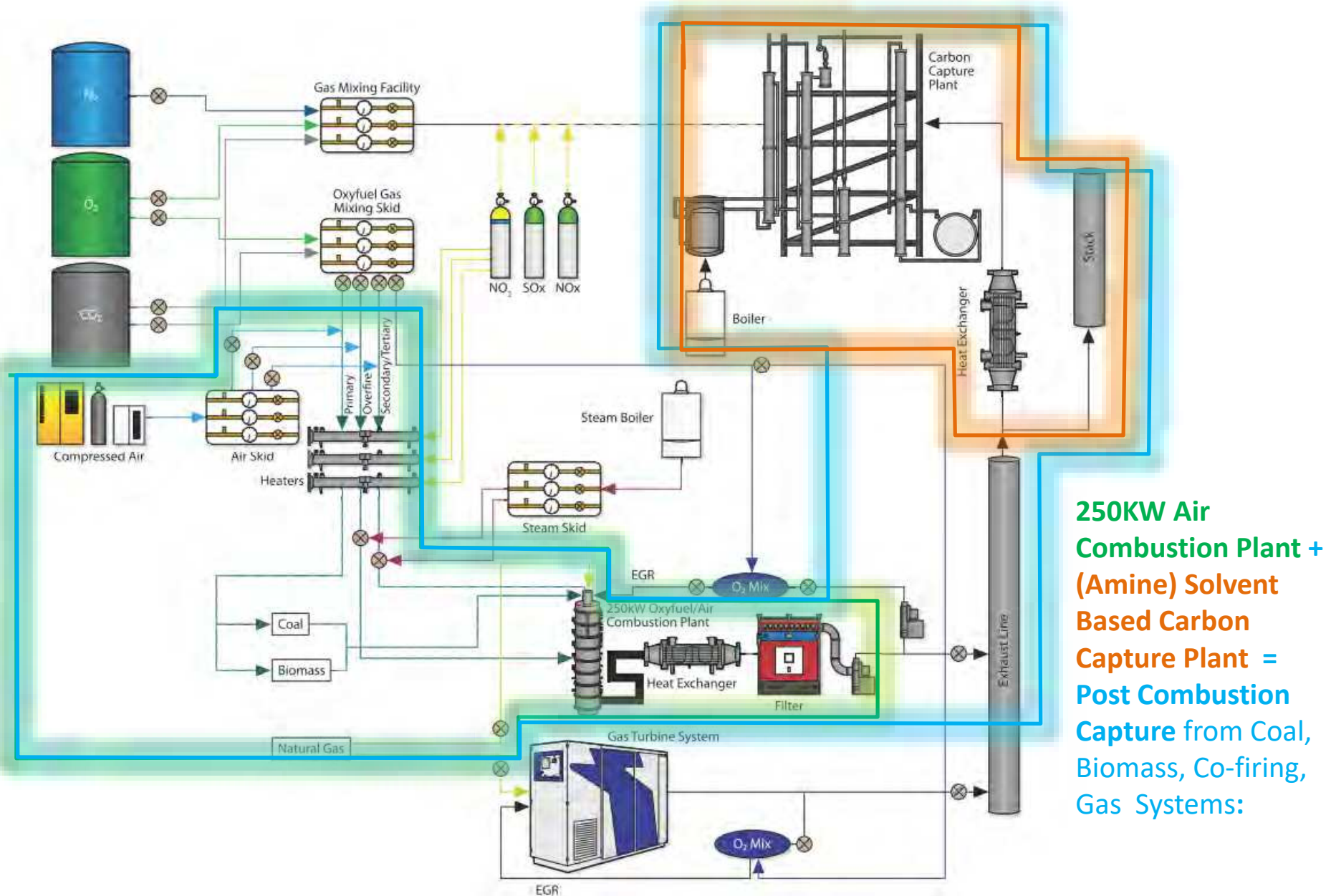


# PACT Core Facility: Layout

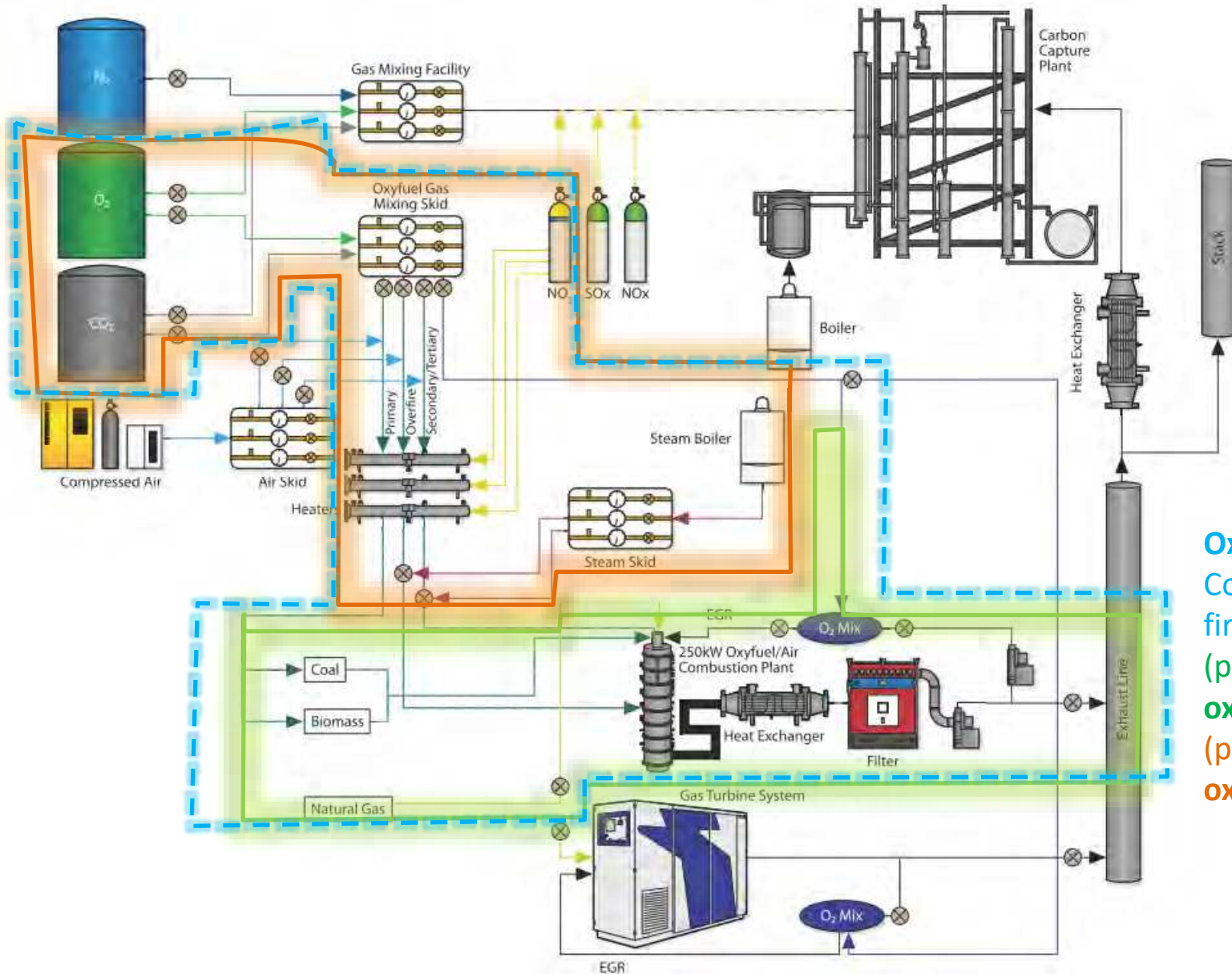


**250KW Air  
Combustion Plant +  
(Amine) Solvent  
Based Carbon  
Capture Plant =**

# PACT Core Facility: Layout

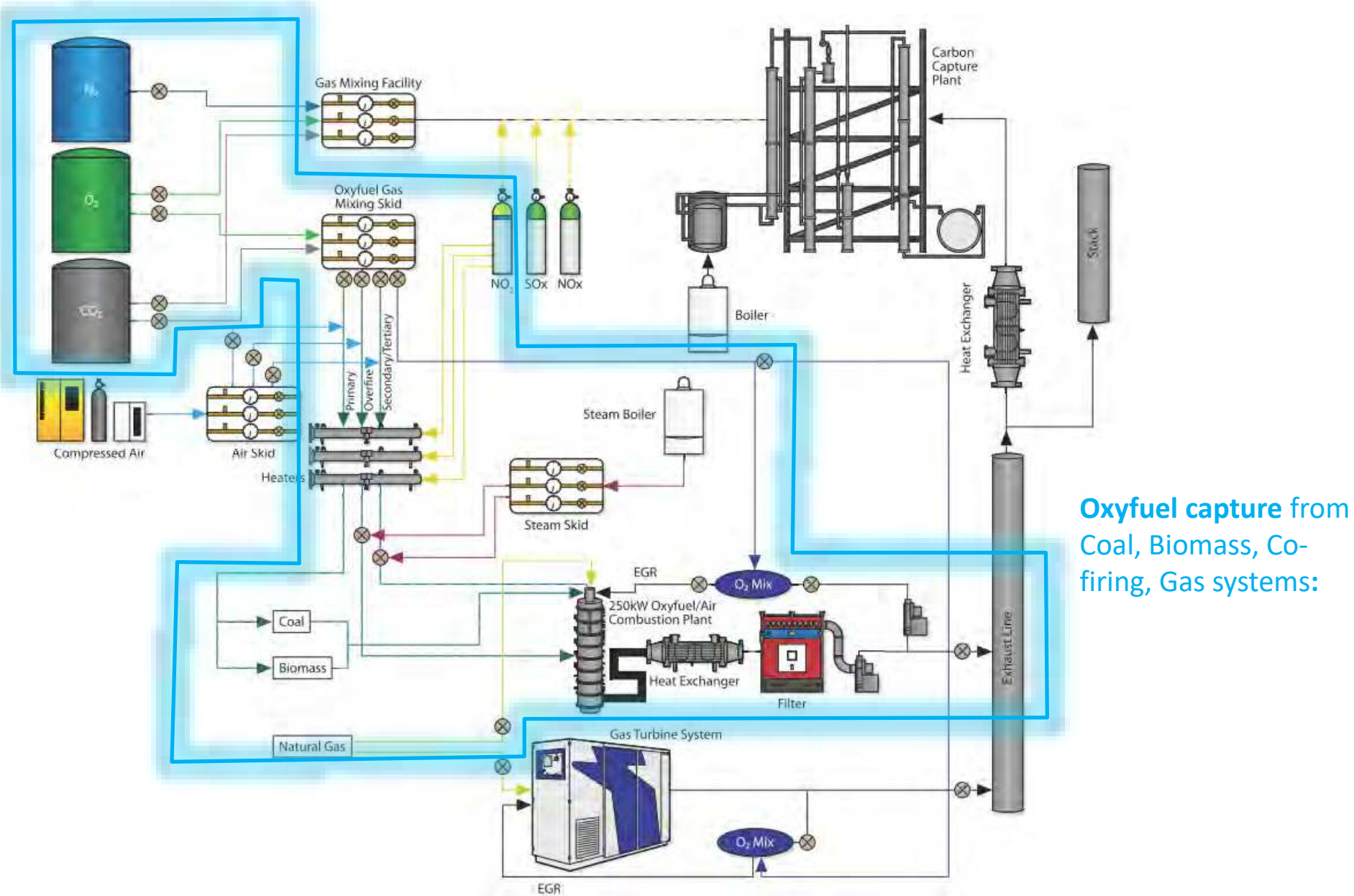


# 250kW Oxyfuel Combustion Plant



Oxyfuel capture from Coal, Biomass, Co-firing, Gas systems:  
 (primarily) **Real oxyfuel mode+**  
 (primarily) **Synthetic oxyfuel mode**

# 250kW Oxyfuel Combustion Plant



Oxyfuel capture from Coal, Biomass, Co-firing, Gas systems:

# 250kW Oxyfuel Combustion Plant

## Example Applications

- ❑ Oxyfuel combustion R&D for coal, biomass or co-firing using a synthetic mixture of dry or wet  $\text{CO}_2/\text{O}_2$  or wet flue gas recycle
- ❑ Fuel and process testing and optimisation;
- ❑ Integrated system modelling, for optimising Air Separation Unit (ASU) operation, combustion system control, and simulating the effect of different fuels on the combustion process
- ❑ System modelling and optimisation for flame visualisation and analysis, and latest modelling software for combustion system design, development and optimisation.



# Pilot-Scale Integrated Experimental Facilities for BIO-Cap Project

**Gas Mixing Facilities**



**250kW Air/Oxy Rig**

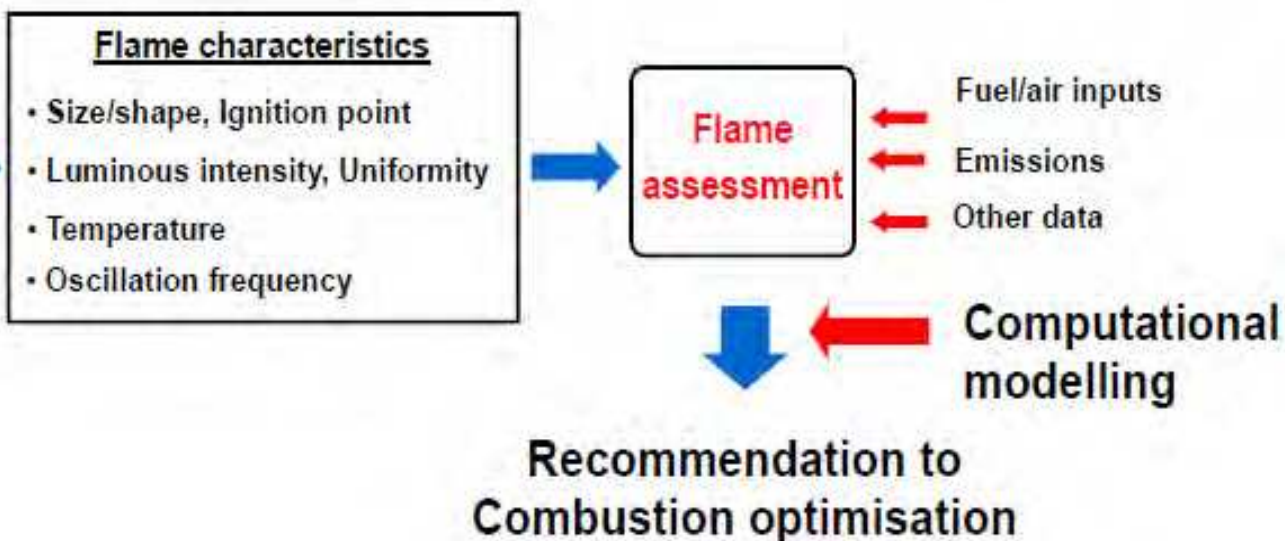
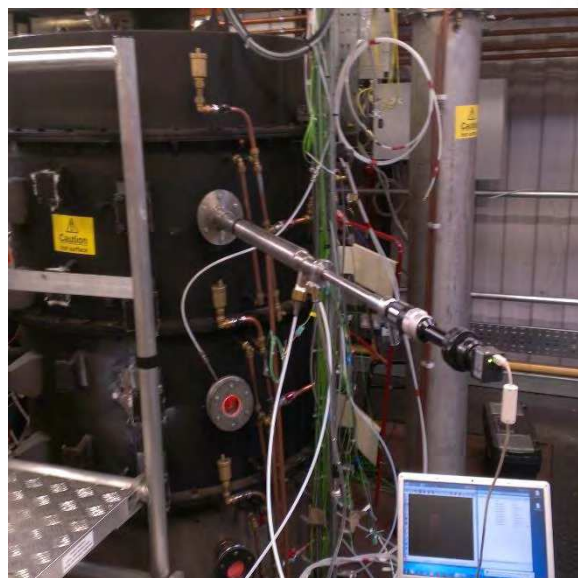
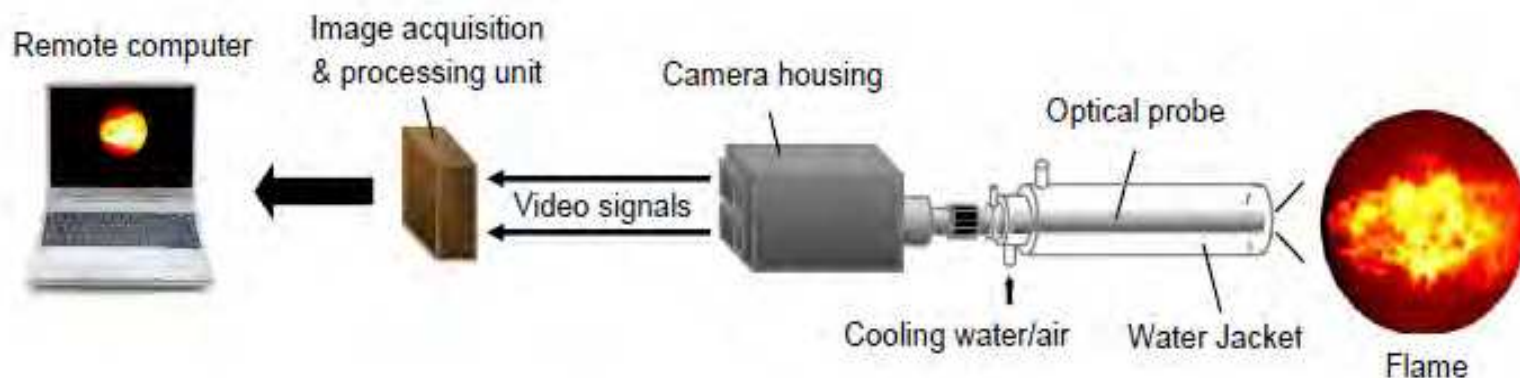


**ICP-OES & DMS 500**



**Carbon Capture Plant**

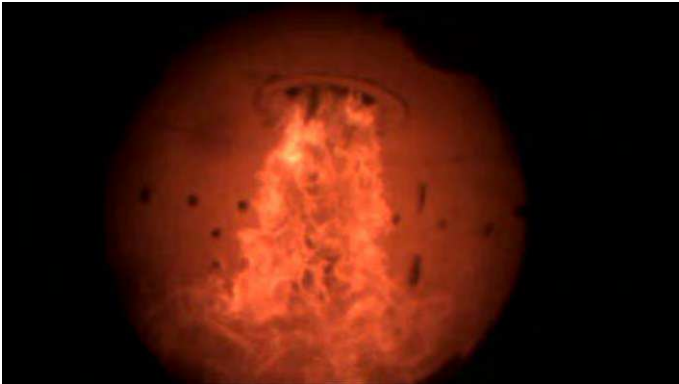
# Flame Imaging System



# Results

Experimental calculation of the oscillation frequency - COAL

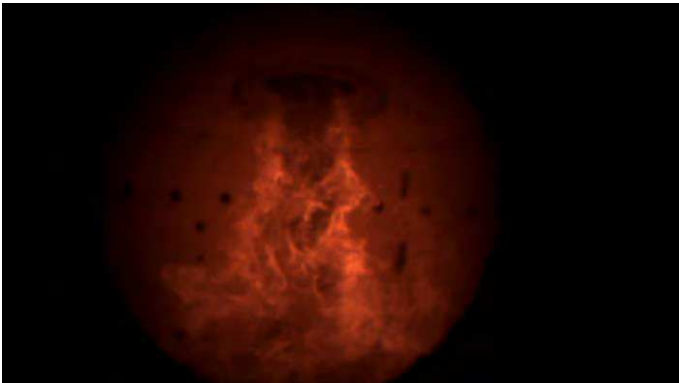
Original videos



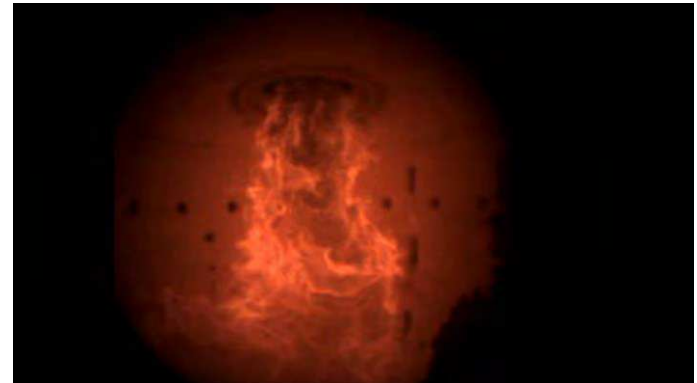
Air



Oxy24



Oxy27



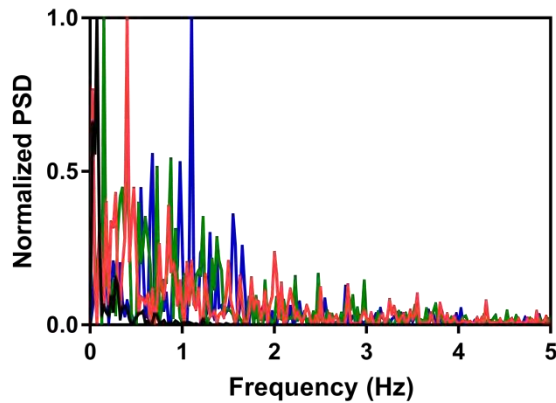
Oxy30

# Results

Experimental calculation of the oscillation frequency

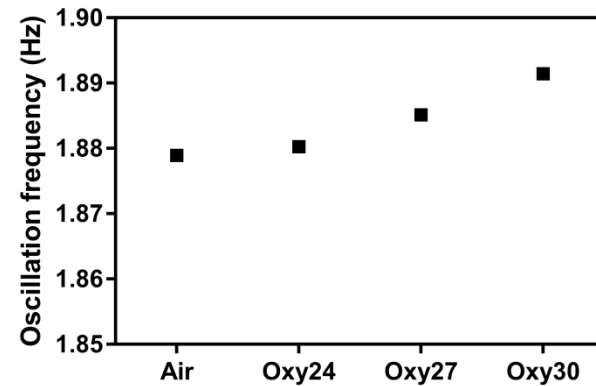
COAL

Frequency spectrum  
(luminance based)

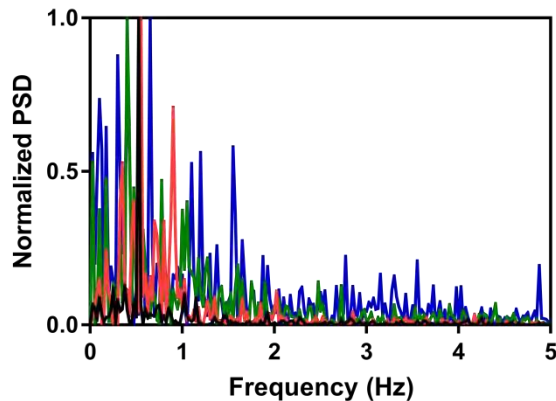


- Air
- Oxy24
- Oxy27
- Oxy30

Weighted frequency  
(temperature based)

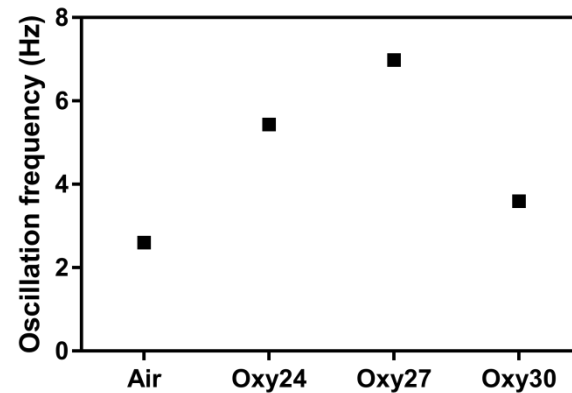


Frequency spectrum  
(temperature based)



- Air
- Oxy24
- Oxy27
- Oxy30

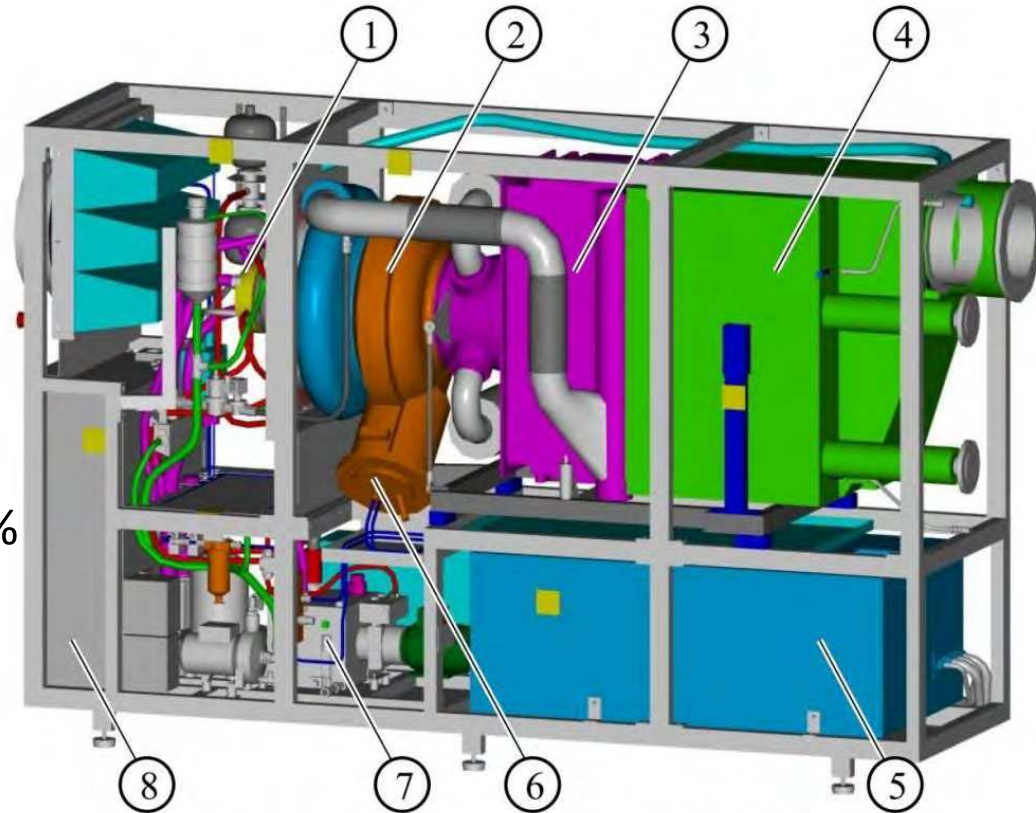
Weighted frequency  
(temperature based)



# Gas Turbine System

## Overview

- ❑ Two Turbec T100 Microturbines
- ❑ Consume 330kW of Natural gas
- ❑ Fuel: Natural gas, biogas, syngas, diesel, kerosene, methanol, LPC
- ❑ Generation 100kWe and 150kWth
- ❑ Overall efficiency up to 77% (33% electrical)



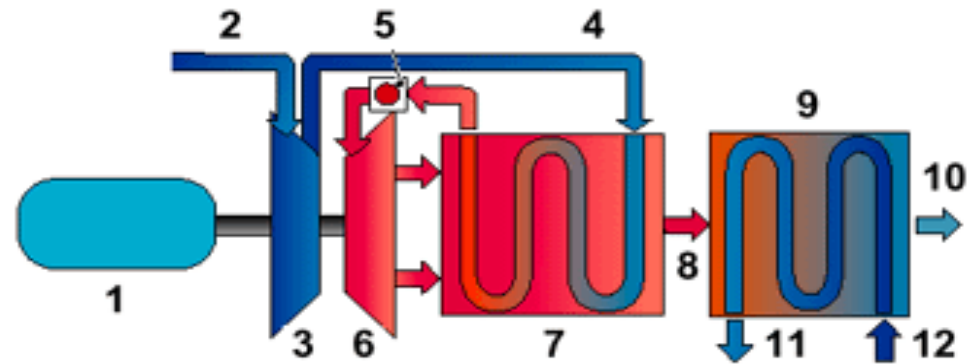
1. Electrical Generator
2. Gas Turbine Engine
3. Recuperator
4. Heat Exchanger

5. Power Electronics
6. Combustion Chamber
7. Auxiliary Systems
8. Control System

# Gas Turbine System

## System description

- ❑ **compressor** – radial centrifugal compressor compresses ambient air before sending to recuperator
- ❑ **recuperator** – preheats the compressed combustion air with the heat from the flue gases
- ❑ **combustor** – a lean combustion environment ensures low NO<sub>x</sub>, CO and hydrocarbon emissions
- ❑ **Turbine** – the hot, pressurised gas expands through the turbine to drive the turbine and the compressor and generator, which are all on the same shaft
- ❑ **Flue gas heat exchanger** – uses the hot flue gas to heat water



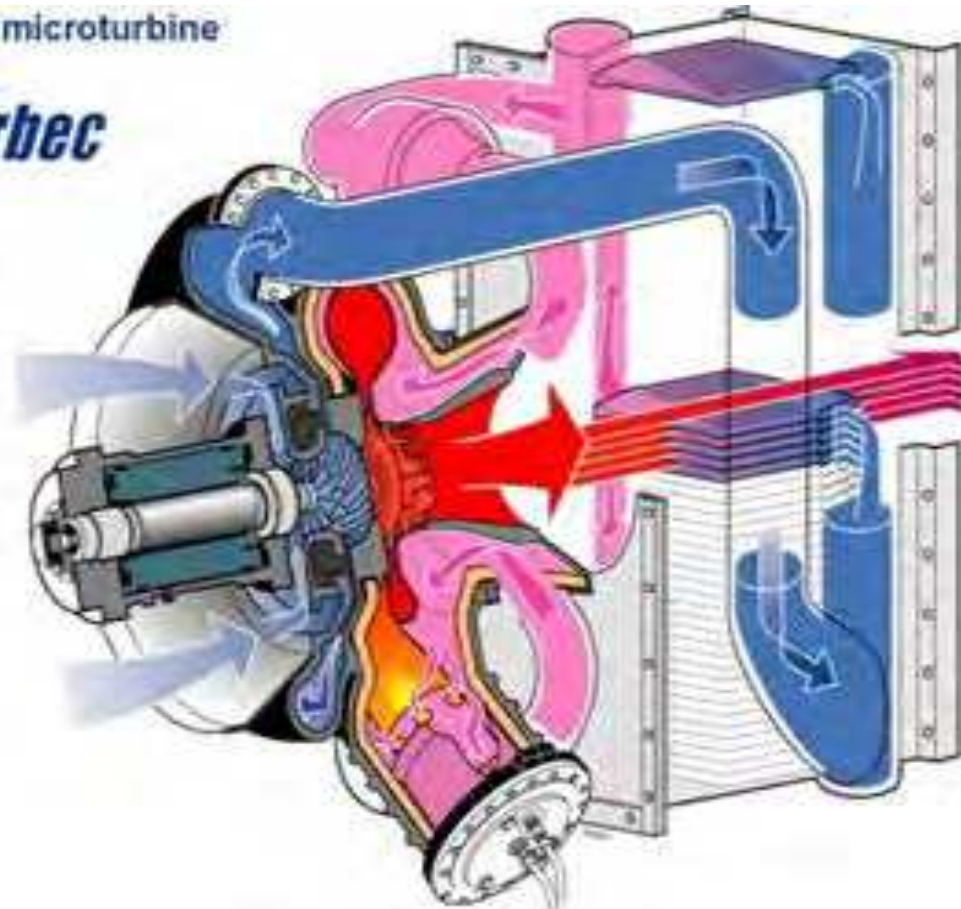
- |                       |                        |
|-----------------------|------------------------|
| 1. Generator          | 7. Recuperator         |
| 2. Air inlet          | 8. Exhaust gases       |
| 3. Compressor         | 9. Heat exchanger      |
| 4. Air to recuperator | 10. Exhaust gas outlet |
| 5. Combustion chamber | 11. Hot water outlet   |
| 6. Turbine            | 12. Water inlet        |

# Gas Turbine System

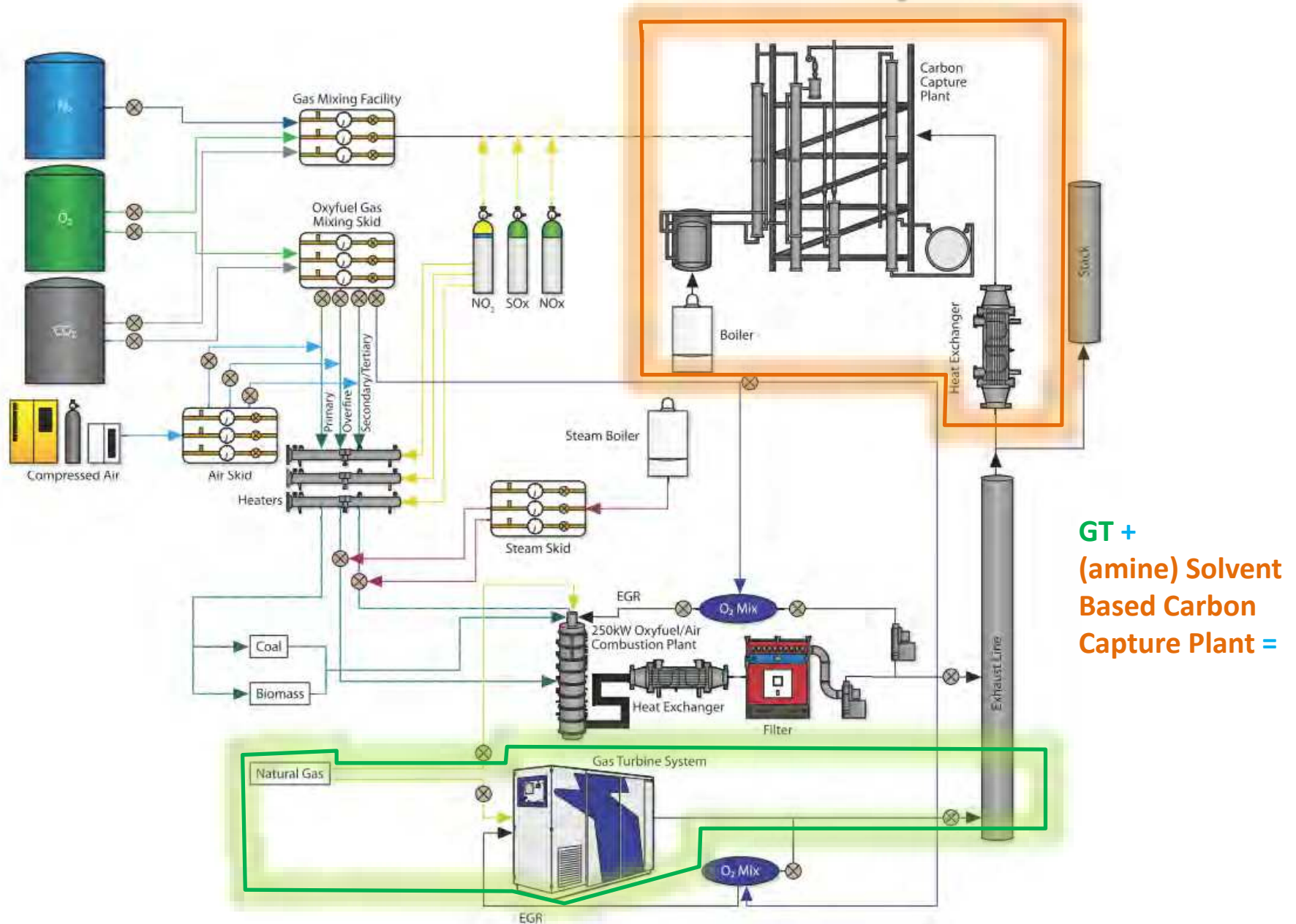
## Analytical Facilities

- ❑ Flow rates, temperatures, dew points and pressure measurements throughout the system.
- ❑ Electrical and thermal power measurement
- ❑ Combustion Gas Analysis
  - Horiba VA-3000 Analyser I: Model VA-3002 for CO and NO<sub>x</sub> analysis
  - Horiba VA-3000 Analyser II: Model VA-3113 for CO<sub>2</sub>, O<sub>2</sub> and SO<sub>2</sub> analysis
  - Signal 3000HM Heated FID for total hydrocarbon analysis
- ❑ Particulate Spectrometer (Cambustion DMS500 Fast Particulate Spectrometer)
  - Classification by particle electrical mobility
  - Online analysis of particle mass, number and size spectra
  - range (5 – 1000nm)

T100 microturbine  
*turbec*

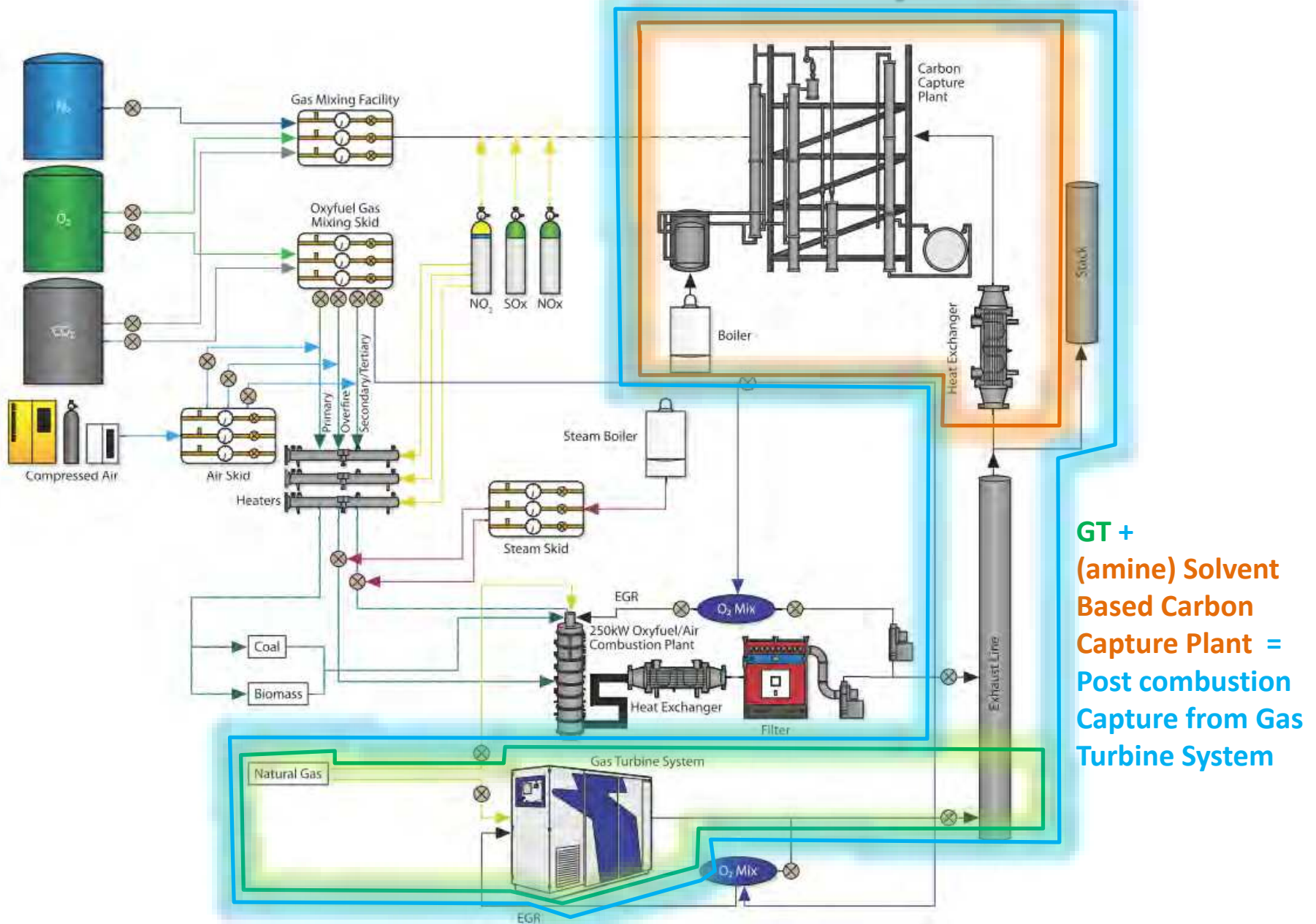


# Gas Turbine System



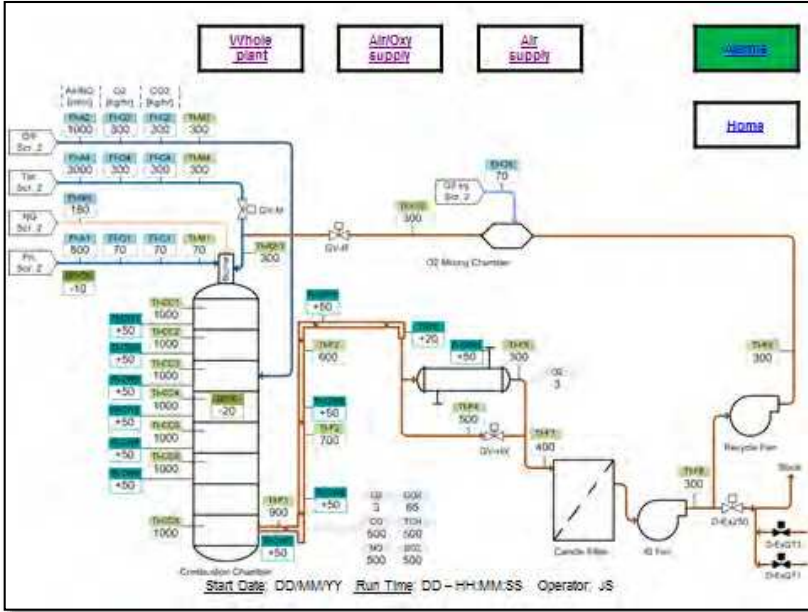
GT +  
(amine) Solvent  
Based Carbon  
Capture Plant =

# Gas Turbine System

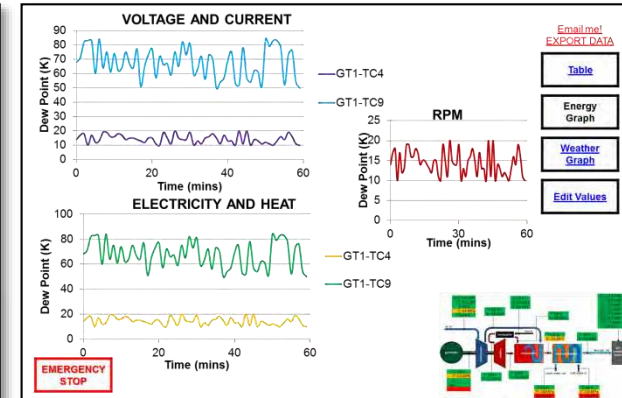
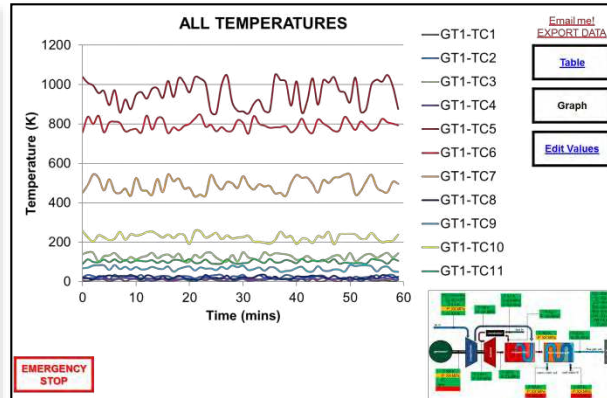
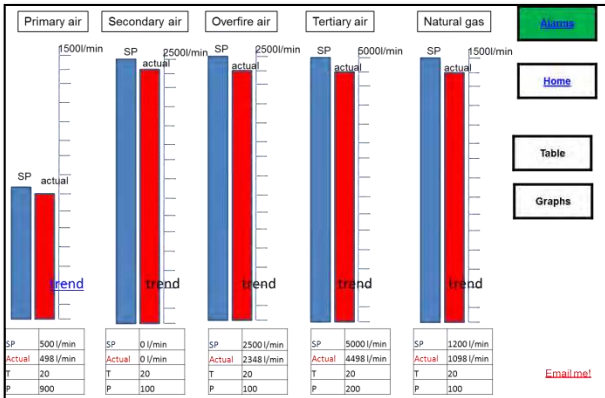
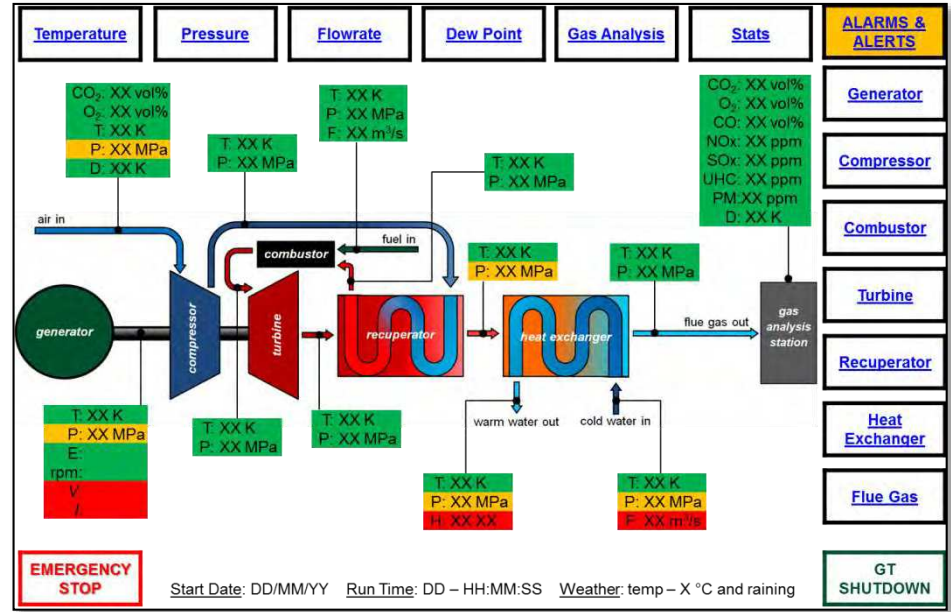


**GT +  
(amine) Solvent  
Based Carbon  
Capture Plant =  
Post combustion  
Capture from Gas  
Turbine System**

# 250 kW plant



# Gas Turbine



# Analytical Facilities: Labs

## Analytical labs

- ❑ Unique CEM mobile laboratory for solid-state detector based ICP-OES (SUWIC)
- ❑ Cambustion DMS500 Fast particulate analyser
- ❑ CHNS/O Elemental Analyser
- ❑ GC MS and TG-MS
- ❑ Thermogravimetric Analyser and TG-MS
- ❑ FT-IR and TG-IR
- ❑ Portable SERVOMEX MiniMP gas analysers (CO<sub>2</sub> and O<sub>2</sub>)



- Gas analysis systems for both 250kW plant and the gas turbine.
- Particle size analyser
- Continuous Emissions Monitoring Laboratory (CEML) mobile laboratory, (Inductively Coupled Plasma) for monitoring metallic emissions from thermal processes;
  - Real-time, online diagnostics
  - Simultaneous multi-metal analysis

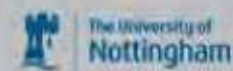
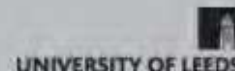
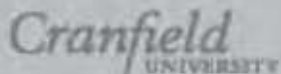
# Summary

- Comprehensive research capability and support
- Consolidating a wide range of facilities and supporting expertise
- Maximising equipment utilisation through shared access to industry and academia
- Services
  - R&D Services
    - Collaborative research
    - Contract research
  - Analytical services
  - Technical consultancy
  - Training

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