



# CLEAN ENERGY SYSTEMS

**Pressurized Oxy-Combustion with sCO<sub>2</sub>**  
**Rebecca Hollis; Clean Energy Systems, Inc.**

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# Clean Energy Systems | Overview



- Small business founded in 1993 by aerospace engineers (formerly of Aerojet); incorporated in 1996, Clean Energy Systems, Inc. (CES)
- Multiple locations in California:
  - Corporate Engineering and Headquarters, Rancho Cordova (Sacramento Area)
  - Kimberlina Test Facility, a former 5 MW Biomass Power Plant (Bakersfield, CA)
- Focused on developing and deploying enabling technologies for advanced clean energy solutions
  - Pressurized Oxy-Fuel Direct and Indirect Steam Gas Generators
  - Oxy-Fuel Reheat Combustors
  - Compact Diffusion Bonded Heat Exchangers
- Strong strategic partners supporting commercialization of zero-emission power and/or heat (steam) systems and global deployment

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# CES | Kimberlina Power Plant Test Site

## State-of-the-Art Capabilities for Oxy-Combustion Power Gen. and Related R&D:

- The 20 MWt Direct Steam Gas Generator ([DSGG400](#)) produces hot steam and CO<sub>2</sub> up to 100 bar for multiple test rigs and BOP
- The larger, 200 MWt [DSGG1200](#) is configured to provide steam-CO<sub>2</sub> working fluid to the OFTs on site up to 35 bar
- Oxy-Fuel Reheat Combustors (reheaters) have been designed and tested up to 29 MWt @ 1,080°C and 16.5 bar
- Multiple Oxy-Fuel Turbines (OFTs): 150MWe OFT-900 and 30MWe OFT-J79
- Heat exchanger test skid with high temperature heat source from DSGG400

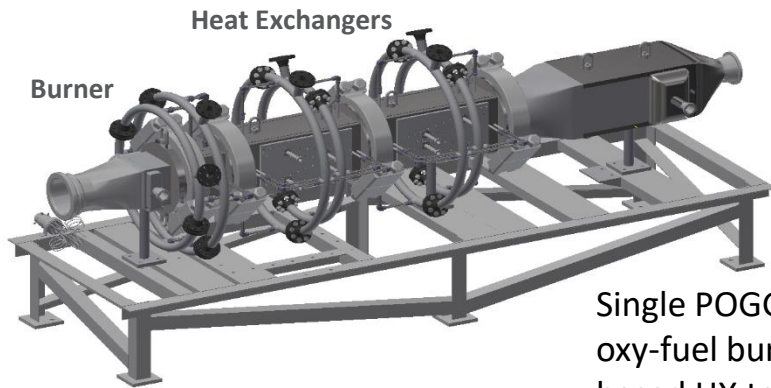


Aerial image of the Kimberlina Power Plant (KPP) Test Facilities, Bakersfield, CA;  
Not Shown: CO<sub>2</sub> supply system

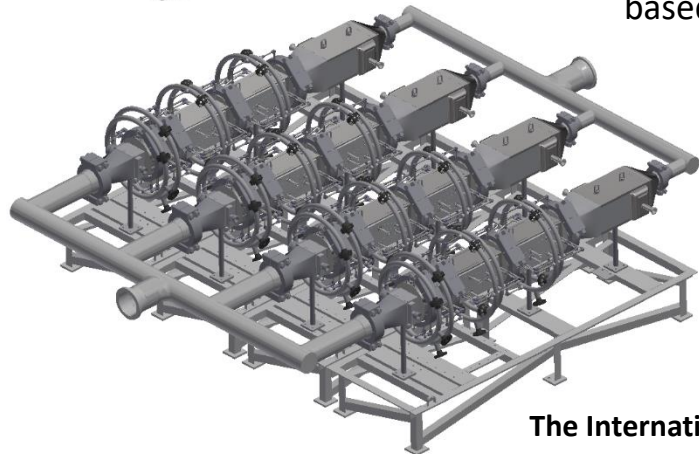
# CES | Oxy-Combustion Technology (2)

Developing our next gen. Pressurized Oxy-Gas Generator (POGG) that heats the desired working fluid across a series of compact, diffusion bonded heat exchangers;

- POGG indirectly powers commercial turbines with high-pressure (up to supercritical) steam or CO<sub>2</sub> working fluid
- Ideal for CHP applications and low-heating value or “waste” fuels, e.g. high-CO<sub>2</sub> NG, biomass or coal derived syngas

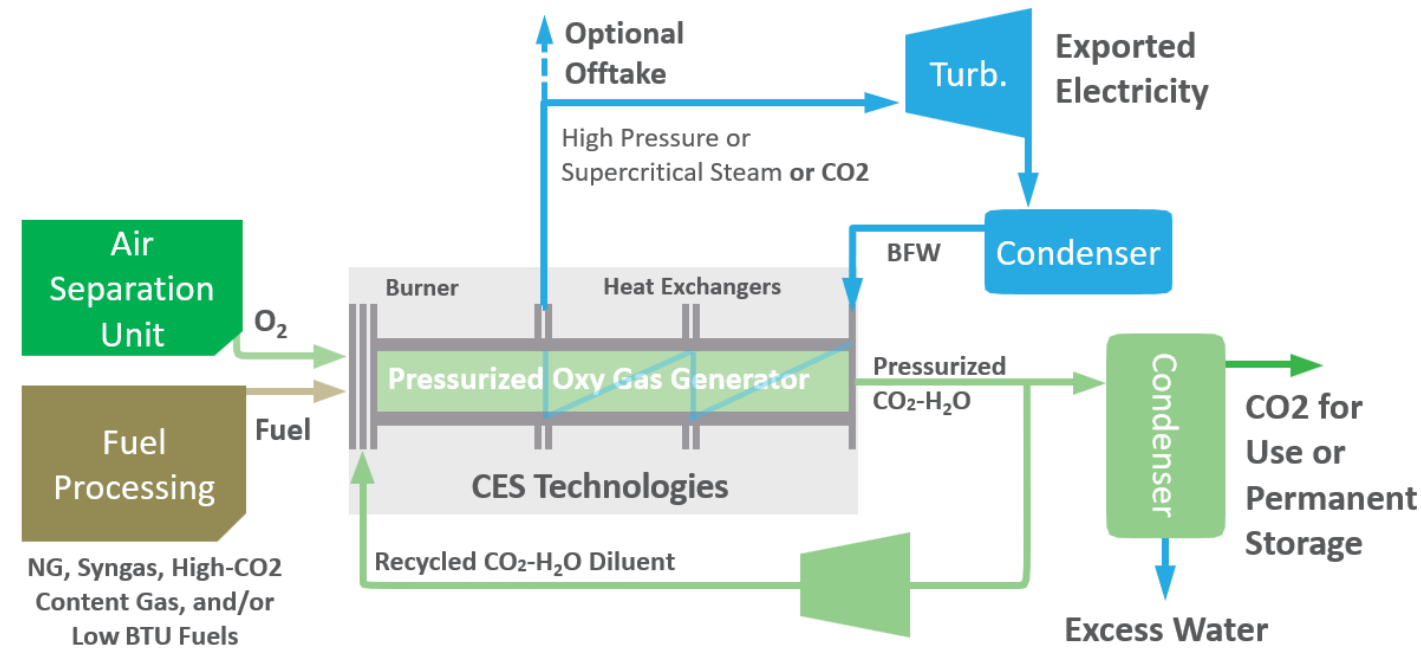


Single POGG; integrates CES oxy-fuel burner and platelet-based HX technology



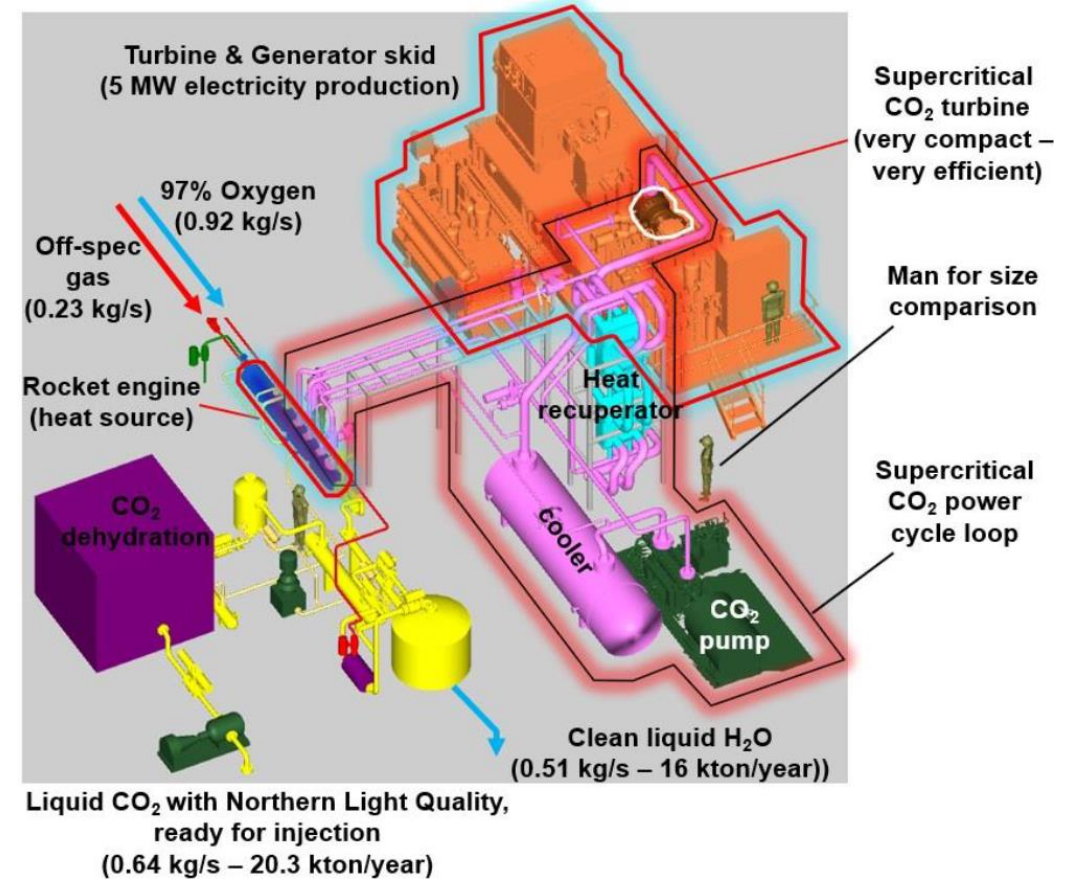
“4-pack” POGG Modular Solution

## Simplified POGG “Indirect” Cycle Schematic



# CES | ZEUS Partnership

- 2024-Aug: Memorandum of Understanding (MOU) executed between CES, Petronas Carigali Sdn. Bhd., MISC Berhad (MISC), and Aker Solutions AS (AKSO) during Offshore Northern Seas (ONS) Conference in Stavanger, Norway;
- 2025-June: Same parties execute Zero Emission Power Station (ZEUS) Demo Front-End Engineering and Design (FEED) agreement at Energy Asia Conference in Kuala Lumpur, Malaysia;
- 2026 (anticipated): Final Investment Decision (FID) for ZEUS Demo project
  - 2027: Initial testing at CES Kimberlina facility
  - 2028: System demonstration at selected site
- 2029+: Commercial deployment at existing assets



Ref: Pedersen, K., et al., "Development of ZEUS - Zero-Emission Unmanned power Station," [The 8th International Supercritical CO<sub>2</sub> Power Cycles Symposium](#), 27-29-Feb-2024, San Antonio, TX

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# CES | Oxy-Combustion with sCO<sub>2</sub>; Summary and Research Needs

## Summary

- CES developing oxy-combustion with sCO<sub>2</sub> as a part of the ZEUS Demonstration program targeting use of high-CO<sub>2</sub>, low-BTU fuel gases – converting otherwise be stranded assets into clean, reliable electricity
  - Builds upon CES' decades of oxy-fuel combustion experience and recent CO<sub>2</sub>-based work

## Research Needs (selections from SwRI sCO<sub>2</sub> Power Cycles Fundamentals Tutorial)

- Fluid properties:
  - Mixture of sCO<sub>2</sub> and other fluids, e.g. H<sub>2</sub>O, O<sub>2</sub>, N<sub>2</sub>, NO<sub>x</sub>, CO, etc.
  - Physical property testing of CO<sub>2</sub> mixtures at extreme conditions with significantly reduced uncertainties (i.e. <1%)
- Materials - Corrosion Testing: Long-term (10,000 hrs), diffusion-bonded materials (PCHE HX) and tests under stress
- Dynamic Control & Simulation: Improved system transient analysis – ramp, shutdown, and flameout
- Heat Exchangers:
  - Improved heat transfer correlations in the transcritical region
  - HX durability – studying effects of material, fabrication, channel geometry, fouling, corrosion, and maintenance

Thank you!

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