Clean Energy Systems, Inc.
Oxy-fuel Combustion Technology

Advanced Turbine Development for Pressurized Oxy-Combustion Commercial Scale-Up
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Presentation Overview
Topics

• Company Background & Technology

• Advanced Oxy-Turbine Development

• Kimberlina Demonstration Project
Company Background

Vision

A new way to make power without pollution.

We use aerospace technology to change the way power is produced, and eliminate atmospheric emissions.

CES technology – process and plant
CES Technology
Oxy-Fuel Combustion Gas Generator

Applications
Technology Sectors

Natural Gas
Micronized Pet coke
Emulsified Solutions
Synthesis Gas
Geothermal Steam + Natural Gas

CO2 + H2
Steam/CO2
HRSG
Steam Turbine
Multi Stage Turbines + CES Re-Heater

Methanol / F-T Liquids / Hydrogen / Chemicals
Heavy Oil EOR
Power / Peaker / EOR / SAGD
Light Oil EOR / CCS / Industrial CO2
Power

Water / Oxygen

Clean Energy Systems, Inc.
Power Without Pollution™
CES Core Gas Generator
Compact Power – 200Wth – 100% Mobility

CES Facilities
The World’s Largest Oxy-Fuel Facility
Major Global Investors/Partners

- AES Corporation
  - One of the largest global power companies, with 40 GW in 30 countries (4 GW in CA)

- Southern California Gas Co.
  - An energy services company with $8 billion in revenues.

- Paxton (Subsidiary of Paramount Resources Ltd.)
  - A Canadian oil exploration, development and production company

- Siemens Power Generation
  - Not an investor, but shares a strong synergic relationship with CES in the mutual development of oxy-fueled turbines, combustors and balance-of-plant systems

- Maersk Oil and Gas
  - A subsidiary of the world’s largest shipping company operating in 130 countries and producing 0.5-1% of total global oil production

- California Energy Commission Pier Grant

- Investors/Partners Support Ongoing CCUS ($$$) Projects in Europe, Canada, Middle East and US
Advanced Oxy-Turbine Development

CES Technology
CES Power Turbines

Proof of concept, Kimberlina steam turbine: 4" GG; 1st Generation

25-30% \( \eta \); 50 MW; 2nd Generation
J79, indirect cycle, or STG - Developing

40-45% \( \eta \); 200 MW; 3rd Generation
CES/Siemens OFT 900 - Developing

50% \( \eta \); 400 MW; CES/Siemens; DOE


Clean Energy Systems, Inc.
Power Without Pollution™
CES Oxy-Fuel Technology

2nd Generation Turbine: CES J79

- Originally a GE J79 turbine
- Used for 12 MW industrial applications (LM 1500) and F4 Phantom
- Converted to a 40 MW oxy-turbine (below)
- “No-load” testing commenced in 2010. Part-Load testing completed.
- Can be used in peaking or base load plants

CES Technology

CES Power Turbines

- 50% η; 400 MW; CES/Siemens; DOE
- 40-45% η; 200 MW; 3rd Generation CES/Siemens OFT 900 - Developing
- 25-30% η; 50 MW; 2nd Generation J79, indirect cycle, or STG - Deploying
- Proof of concept, Kimberlina steam turbine: 4” GG; 1st Generation
The Next Generation Turbine
3rd Generation Turbine: OFT-900

**Main Tasks:**
- Finalization of OFT-900 Design
- Develop Oxy-Fuel Reheater System
- Purchase, Disassemble SGT-900: 50 MW
- Manufacture New Components
- Design OFT Test Site
- Upgrade Test Site
- Test OFT-900: 150 MW
- $43MM Program - $30MM of DOE

Refining & Finalizing OFT Design
Conversion of 50 MW turbine to 150 MW OFT-900
Reheater Assembly for the OFT-900

Reheater Burner Assembly

Combustor Chamber

Steam from Gas Generator

To OFT-900

Transition Duct

8 Reheater Assemblies Required

Reheater Injector Face

Igniter Port

Fuel Orifices

Ox Orifices

Steam Orifices

Clean Energy Systems, Inc.
Power Without Pollution™

West Coast Regional Carbon Sequestration Partnership
Annual Business Meeting

Lodi, CA
October 24-26, 2011

Devanna p.9
Purchase & Inspect SGT-900

Disassemble & Inspect

- May 27: Disassembly & Inspection activity kicked off
  - Work area setup, activities commenced (platform, tent, etc.)
- June 21: SGT-900 top half cover removed

Schedule

Conversion from SGT-900 to OFT-900

Schedule (estimated completion):

- Dismantle SGT-900: 28-Jul-11
- Inspect Components: 23-Aug-11
- Inspection Reports: 28-Sep-11
- Refurbish Components: 24-Nov-11
- New Component Mfg: 6-Jan-12
- Reassemble OFT: 12-Apr-12
- Ship to CES KPP: 21-Apr-12
Kimberlina Demonstration Project

California’s Energy Future: 2050

- The CCST report provides guidance to state regulators on meeting GHG emission requirements
- AB-32 requires
  - Reduction of GHG emissions to 25% of 1990 levels by 2020.
- Executive Order S-3-05 requires
  - Reduction in GHG emission to 80% below 1990 levels by 2050 (while the population increases from 37 mil to 55 mil).
- The report concludes that:
  a. reduction of 80% will require the development of certain critical technologies including ZELB for non base load generation.
  b. CCS is a critical technology for decarbonizing natural gas and other fuels to produce hydrogen.
Project Objectives

1. Demonstrate ZELB power generation with varying power output (i.e. non-base load).
2. Demonstrate 100% CCS effectiveness (vs. 90%) with CO₂ sequestration into a saline formation.
3. Demonstrate the successful sequestration of CCS into a saline formation.
4. Demonstrate biofuel production of electricity with CCS.
5. Demonstrate the permitting and monitoring, reporting, verification (MRV) requirements necessary for CCS.
6. Demonstrate the CCS decarbonization of natural gas to produce hydrogen.

Project to Demonstrate ZELB, 100% CCS and Sequestration: 42MW; 300,000 TPY
Kimberlina’s In-Place Equipment Provides Access to Proven Operating Systems and Reduces Project Costs

- CES’ 12” “zero-emission” gas generator can be used to demonstrate 100% CCS.
- CES’ 40 MW oxy-fuel turbine can be used to demonstrate ZELB.
- CES’ 20 MW “zero-emission” generator can be used for the decarbonization of natural gas.
- CES’ extensive infrastructure will be used throughout the testing program.

Work by WESTCARB has Characterized the Kimberlina Geological Formations for CCS

Existing boreholes around Kimberlina plant that provided stratigraphic data
Initial Geological Model Based on Available Well Data

(From J Waggoner, LLNL)

Project Cost Structure

- Locate at Kimberlina an 8 or 20 MW ZELB power plant with 100% CCS
- Operations by 2013 possible
- Plant output a function of capex vs. energy price trade-off
- Sets the stage for deployment of 200 MW ZEPPs currently under development
- Levelized Cost of Electricity for 200 MW estimated at $0.10-0.15/kWh, dependent on CO2 revenues and gas pricing.
- Commercial plants can be online by 2015-2016