Advanced Turbine Developments for Oxy-Combustion TriGen™ Plants

2012 WESTCARB Business Meeting
October 16, 2012
Agenda

- CES Overview
- CES Technology & Gas Generators
- First Commercial Oxy-Fueled Turbine (OFT-900)
- Manufacturing & Installation of OFT-900
- Next Steps
CES Overview
A technology company that uses proven rocketry principles to develop emission-free energy solutions for the energy industry:
  ➞ Principal deployment is the oxy-fuel combustor ("Gas Generator" or "GG")
  ➞ Focus is the power and oil & gas sectors

Diverse commercial applications:
  ➞ Zero-emission power plants ("ZEPP")
  ➞ Enhanced oil recovery (EOR) and Potable Water for Commercial Markets
  ➞ Fast response ultra-clean peaking power plants

Proprietary intellectual property and know-how: allows for creation of massive amounts of thermal energy, large volumes of high pressure steam, and CO2

Diverse commercial applications:
  ➞ 30 patents issued, 36 pending
  ➞ World’s largest oxy-fuel test facility: Bakersfield, CA
  ➞ Demonstration facility: Santa Clarita, CA
# CES Overview

## Equity and Strategic Partners

### Equity Partners

<table>
<thead>
<tr>
<th>Company</th>
<th>Description</th>
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<tbody>
<tr>
<td>Paxton Corporation</td>
<td>is an energy-focused company based in Calgary, Alberta; aggregator of technologies including CES’ oxy-fuel combustor for use in the extraction of hydrocarbons; significant equity position currently held by the largest shareholder of Paramount Resources Ltd.</td>
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<tr>
<td>Southern California Gas Company</td>
<td>(a subsidiary of Sempra Energy; $16.0 B+ market capitalization) sells, distributes, and transports natural gas in the United States.</td>
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<tr>
<td>The AES Corporation</td>
<td>($8.5 B+ market capitalization) is a global power company with generation and distribution businesses.</td>
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### Strategic Partners

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<tr>
<td>Maersk Oil</td>
<td>(subsidiary of A.P. Møller – Maersk A/S. with a $29 B+ market capitalization) is an international oil and gas company with operated production of about 625,000 barrels of oil (equivalent) per day.</td>
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<tr>
<td>Siemens Aktiengesellschaft</td>
<td>($80 B+ market capitalization) is a diversified international electrical and engineering company that provides solutions to the energy and other sectors.</td>
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<tr>
<td>Paramount Resources Ltd.</td>
<td>($2 B+ market capitalization) is an independent energy company that engages in the exploration, development, and production of natural gas, crude oil, and natural gas liquids in North America.</td>
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<tr>
<td>LM Alternatives Inc.</td>
<td>and its sister companies have been providing quality parts and related services to turbo machinery users in industrial, utility and aviation applications for more than four decades.</td>
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## CES Overview

### Government Partners

#### United States

**US Department of Energy**: Two contracts awarded under competitive bidding: $2.5 million in 2000 and $4.8 million in 2005; increased by an additional $30 million of ARRA funds in 2010. Total funding commitment: $37.3 million

**California Energy Commission**: 3 separate contracts awarded; two for $75,000 and one for $4 million

#### International

**UK Department of Energy and Climate Change (DECC)**: Co-funded a $2 million study led by Jacobs Consultancy, with Siemens, MAN, Imperial College and others to study retrofitting existing coal-fired plants with the CES system

**Norwegian Government**: Provided funding through Gassnova to study offshore and industrial applications

**Dutch Government**: €18 million commitment for a steel mill demonstration project using CO₂ contaminated “fizzy gas”
CES Overview

CES Facilities

- Kimberlina Power Plant
  - World’s largest oxy-fuel combustion facility
  - 6 MW carbon capture, oxy-fuel power plant
  - Primarily for R&D and sub-commercial operations

- Placerita Power Plant, Santa Clarita, CA
  - Formerly a 120 MWe CHP plant
  - Robust infrastructure ideal platform to deploy a wide variety of commercial products
CES Overview
Kimberlina: World’s First Oxy-Fuel 100% Carbon Capture Power Plant
• **CES Technology:** Platelet-Based Fuel Injectors
  ➔ Hundreds of individual platelets are photo-etched to form 3-D channels
  ➔ Precisely stacked the platelets get pressure bonded into monolithic structures
  ➔ Intricate pathways channel bulk fuel, oxygen, and water into hundreds of combustors
  ➔ Intimate, stoichiometric mixing for complete combustion
 CES Overview

The TriGen™ Oxy-Fuel Cycle

209 MW
CO₂: 2,300 TPD
Water: 508,000 GPD
CES Overview
Technology Development Plan

1. **1st Generation**
   - Proof of concept, Kimberlina steam turbine: 4” GG;
   - CES Overview

2. **2nd Generation**
   - 20-30% η; 50 MW; Deploying
   - J79, indirect cycle, or STG

3. **3rd Generation**
   - 35-45% η; 200 MW; Developing
   - CES/Siemens/TriGen OFT 900

4. **4th Generation**
   - 50% η; 400 MW; CES/Siemens/TriGen

Timeline:
- 2001
- 2004
- 2009
- 2012
- 2015+
CES Gas Generators

CES Gas Generators Evolution

• Bench-Scale (110kWt):
  ➞ 0.5” internal diameter
  ➞ Funded in part by the California Energy Commission
  ➞ Demonstrated proof-of-principle

• Pilot-Scale (20MWt):
  ➞ 4” internal diameter
  ➞ Replaces Kimberlina’s boiler and drives 6 MW turbine
  ➞ Provides 100% carbon capture
  ➞ ~1600 starts
  ➞ ~2300 total run hours
CES Gas Generators
CES 12” Gas Generator For Powering Oxygen Fuel Turbines (OFTs)

- Gas Generator (200MWt):
  - 12” internal diameter
  - ~500 starts
  - ~36 total run hours
  - Ranges: 20–800psig &
  - 400–1250°F (exhaust)
CES Gas Generators

Oxy-Fuel Re-heater Assembly for the OFT-900
Top View; Pre-Bonding; Pre-Machining

Oxygen

Natural Gas

Steam

Completed Reheater

Bottom View; Post Machining

CES Gas Generators

Oxy-Fuel Re-Heater Assembly for the OFT-900
CES Gas Generators

OFT-900 Re-Heater Test Stand
CES Commercial Oxy-Fueled Turbine (OFT-900)
Objective: Design, manufacture & test a commercial-scale oxy-fuel turbine (OFT) for use in industrial O-F plants that:

- Capture and sequester 99% of produced CO2
- Operate at competitive cycle efficiencies

Budget & Schedule:

- 48 months; FY2011 thru FY2014
- $30M DOE (ARRA) funds & $13M match funding

Major Strategic Partners:

- Siemens Energy: Oil & Gas Division; TurboCare
- Florida Turbine Technologies, Inc.

Results

- CES will complete all objectives by first quarter 2013; one-year ahead of schedule and on budget
Main Tasks:

- Prepare 12” GG for powering OFT-900
- Finalize oxy-fuel turbine design
- Evaluate & purchase base SGT
- Design & manufacture OFT from base SGT
- Upgrade existing Kimberlina Test Site for OFT testing
- Install and test oxy-fuel turbine
CES – First Commercial Oxy-Fueled Turbine

Major Changes to Convert an existing SGT-900 to an CES OFT-900

- Converting a 50MWe W251 turbine to a 150MWe oxy-turbine:
  - Replace air intake with inlet steam flow system
  - Replace compressor with new thrust balance system
  - Convert air-breathing combustors to oxy-fuel (O-F) reheaters
  - Add guide vanes at exit of turbine
CES – Commercial Oxy-Fueled Turbine
Final OFT-900 Design

- **Inlet Case Cover**: (QTY: 8)
- **O-F Reheater**
- **Transition** (QTY: 8)
- **Refurbished 3-Stage Turbine**
- **Exhaust Frame with New Exit Guide Vanes**
- **Inlet Plenum**
- **Existing Rear Engine Flex Mount**

**Components**:
- **Shaft Cover & Flow Guides**
- **Existing Forward Engine Mount**
OFT-900 Manufacturing and Installation
Manufacturing and Installation of the OFT-900

Turbine Removal from Abitibi Bowater Facility: March 2011
Manufacturing and Installation of the OFT-900

Arrival at TurboCare Facility: April 2011
Manufacturing and Installation of the OFT-900

SGT-900 Disassembly and Inspection: June 2011
Manufacturing and Installation of the OFT-900

Rotor Removal and Inspection: July 2011
Manufacturing and Installation of the OFT-900

Rotor Work Including Removal of Air Compressor: January 2012

Air compressor blades and disks have been removed.
Manufacturing and Installation of the OFT-900

Turbine Shaft With Power Turbine Blades Re-Installed: May 2012
Manufacturing and Installation of the OFT-900

Manufacturing of OFT-900 Components: March 2012

Inlet Housing Cover

Inlet Plenum

Inlet Housing Cover
Manufacturing and Installation of the OFT-900

Construction of OFT-900 Foundation at Kimberlina: May 2012
Manufacturing and Installation of the OFT-900

Re-Assembly of the SGT-900 as OFT-900: June 2012
Manufacturing and Installation of the OFT-900
Completion and Shipping of the OFT-900: July 2012
Manufacturing and Installation of the OFT-900

Arrival of the OFT-900 in Bakersfield: August 2012
Manufacturing and Installation of the OFT-900

Placing the OFT-900 on Foundation: September 2012
Manufacturing and Installation of the OFT-900

Installed OFT-900: September 2012
Manufacturing and Installation of the OFT-900

Installing the Generator: September 2012
Manufacturing and Installation of the OFT-900

Installation of Temporary Stack: September 2012
Manufacturing and Installation of the OFT-900

Completed Installation of OFT-900 and Generator: September 2012
CES’ Next Steps
Next Steps

1. Complete DOE contract during 1st qtr. 2013: on schedule and on budget.
2. Conduct post DOE system testing to further demonstrate commercial readiness of the OFT-900 system.
3. Place KPP-45 into long-term operations.
   1. CO2 supply contract(s) to EOR operations
   2. PPA and/or wholesale electric supply contract(s)
   3. Potable water supply agreement
4. Develop alternative project plans/locations if KPP-45 contracts and funding are better achieved elsewhere.
5. Continue ongoing discussions with strategic partners for US and global TriGen (i.e. zero-emission power, CO2, potable water) projects