Carbon-Negative Energy and Renewable Hydrogen Projects: An Opportunity for California

19 November 2019: Stanford Center for Carbon Storage
AGENDA

• Introduction to Clean Energy Systems
  o CES Technologies

• Carbon-Negative Energy
  o What it is and Why we need it
  o How it works

• CNE Deployment
  o Potential Projects, Sizing, and Execution
  o Financial Estimates

• Summary & Next Steps
Clean Energy Systems is a global leader in the development and deployment of carbon reducing energy systems

The Power to Reverse Climate Change
CES | COMPANY

BACKGROUND & OVERVIEW

- Founded in 1993 by former Aerojet aerospace engineers
- Corporate engineering and headquarters in Sacramento area
- Kimberlina test facility, a former 5 MW biomass power plant (Bakersfield, CA)
- Initial $75,000 funding provided by the CEC leveraged more than $135 million deployed to date
- Focused on enabling technologies for advanced clean energy solutions
  - Oxy-fuel (O-F) pressurized direct and indirect steam gas generators and reheat combustors – modified rocket engines
  - O-F turbines (OFTs) with development partners
CES | CALIFORNIA FACILITIES

- CES Headquarters
- Kimberlina Power Plant (300 TPD)
- Placerita Power Plant (300 TPD)
Paxton Corporation is an energy-focused company based in Calgary, Alberta; Licensee for use of CES technology related to emulsified bitumen (MSAR) in North America; significant equity position currently held by the largest shareholder of Paramount Resources Ltd.

The AES Corporation ($10 B market cap) is a Fortune 500 global power company providing affordable, sustainable energy in 15 countries across a diverse portfolio; ~2.5% owner

TOTAL S.A. ($140+ B market cap) is a major energy operator; producer and supplier of oil, natural gas, and low-carbon electricity; active in more than 130 countries; licensee of CES technology (via acquisition of Maersk Oil)

Paramount Resources Ltd. (~$1 B market cap) is an independent energy company that engages in the exploration, development, and production of natural gas, natural gas liquids, and crude oil in North America; indirect shareholder and licensee of CES technology

More than $135 million invested to date
## Carbon Reduction Solutions (CRS)

- **Reduces the amount of carbon** released to the atmosphere from existing industrial processes.

  - This is accomplished by:
    - **Clean steam generation**
    - **Heat exchange solutions** to enable efficient renewable energy and clean power production
    - **Zero-emissions power production**
    - **Energy storage solutions**

  - In addition, CES offers engineering services and legacy aerospace work to drive technology advancements that can be incorporated into its products.

## Carbon Negative Energy (CNE)

- **Removes existing carbon (CO₂)** from the atmosphere and produces power.

  - **CES seeks to build** a portfolio of carbon negative energy (CNE) plants in California.

  - **California offers** a unique combination of opportunities to deploy CNE:
    1. Enormous potential for onshore carbon storage
    2. Excess of biomass wastes and idled resources
    3. Robust carbon pricing and trading network
    4. Strong government support and commitment to low carbon future
    5. Process produces valuable water in drought prone agricultural zone
Derived from the American space program, CES combustion systems burn nearly pure oxygen (instead of air) with gaseous (such as natural gas, associated gas, syngas, high-CO₂ content natural gas or liquid fuel) for a cleaner, more efficient combustion process.

The intimate mixing of gases via unique IP creates combustion with only water (high pressure steam) and CO₂ as its two products which are easily separated for capture and storage.
OXY-FUEL PROCESS OVERVIEW

Air Separation Plant

Fuel Processing Plant

Direct Steam Gas Generator

HPT

IPT

LPT

Multi-stage Turbines

RH

CO₂ Recovery

HX

Cond.

Electrical Generator

0₂

Fuel

Recycle Water

Fuel

NG, Low BTU, Biomass and Emulsified Fuels

EOR, EGR or Sequestration

C.W.

CO₂

Excess Water

Technologies
ENABLING TECHNOLOGY | PLATELETS

• Precise, stoichiometric combustion enabled by proven, reliable, platelet injectors

• Hundreds of individual platelets are designed and photo-etched to create unique, intricate patterns

• Platelets are stacked in a set pattern to form 3D internal flow passages not possible via any other process

• Platelet stack is then bonded into a single monolithic structure that can then be machined and assembled

• The resultant intricate Individual pathways channel fuel, oxygen, and water to hundreds of combustion elements where intimate, stoichiometric mixing occurs, resulting in complete combustion
PRODUCT | DIRECT STEAM GAS GENERATORS

Compact system produces only steam and high purity CO$_2$ (when burning a hydrocarbon based fuel), and massive amounts of thermal energy

- Current designs with 10 cm (4 inch) or 30 cm (12 inch) internal diameters
- Range from 10 to 200 MWt over with temperatures up to 1,650 °C (3,000 °F) and pressures over 110 bar (1,600 psi)

- Water injection and jacket cooling incorporated for long life
- Standalone installation-Includes control and monitoring system
- Size of a shipping container
PRODUCT | DIRECT STEAM GAS GENERATOR PACKAGE

- Fully containerized oxy-combustion system ramps to full power in seconds
  - **Combustor:** 2 meters (6 feet) long with 30 cm (12 inch) internal diameter
  - **Container:** 3.3 meters (11 feet) x 3.3 meters (11 feet) x 12 meters (40 feet)
  - Fits on standard shipping trucks for easy transport and installation
  - Designed and built to ASME Section VIII, Division 1

- Fully automated fire detection and suppression system
  - Includes video monitoring and surveillance
Also known as reheaters, boost steam gas (steam or steam/CO₂) temperatures with minimal pressure loss

- Provide for reliable, efficient combustion with even temperature profiles and high turn down ratios

- Can replace conventional gas turbine combustion systems or operate as standalone devices

PRODUCT | REHEAT OXY-COMBUSTORS

OFT-900 Reheater

Combustor Chamber

Oxygen Inlet

Igniter

Fuel Inlet

Platelet Injector

Typical Reheater Platelet
PRODUCT | COMPACT PLATELET HEAT EXCHANGERS

*Diffusion bonded heat exchangers enable thermal energy storage (concentrating solar power) and next generation energy systems*

- Capable of handling extreme operating temperatures (-200 to 900 °C) and pressures (600+ bar)
- 4 to 6 times smaller and lighter than conventional exchangers
- Unparalleled thermal effectiveness
- Unique designs can take any shape or size

WWW.HEXCES.COM
Heat exchangers designed for a pressurized heat recovery steam generation system; tested at CES’ Kimberlina test facility

All met or exceed design goals; results verified by an independent third party

<table>
<thead>
<tr>
<th>Description</th>
<th>Superheater</th>
<th>Preheater</th>
<th>Saturation HX</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heat Rate</td>
<td>0.5 MW</td>
<td>1.4 MW</td>
<td>0.9 MW</td>
</tr>
<tr>
<td>Working Pressure</td>
<td>100 bar</td>
<td>110 bar</td>
<td>100 bar</td>
</tr>
<tr>
<td>Temperature</td>
<td>650 °C</td>
<td>300 °C</td>
<td>560 °C</td>
</tr>
<tr>
<td>Core Dimensions</td>
<td>29cm x 30cm x 15cm</td>
<td>57cm x 30cm x 12cm</td>
<td>81cm x 30cm x 15cm</td>
</tr>
<tr>
<td>Core Material</td>
<td>Inconel 600</td>
<td>SS 316L</td>
<td>SS 316L</td>
</tr>
<tr>
<td>Manifold Material</td>
<td>Cast Inconel 600</td>
<td>Cast Inconel 600</td>
<td>Cast Inconel 600</td>
</tr>
</tbody>
</table>
With development partners, turbines designed for high-quality steam and high CO₂-content drive gas
- Currently two turbines retrofit
- Removed front-end compressor section and replaced with thrust balance system
- Modified for pressurized steam/CO₂ gas
- Operate at gas turbine conditions

**GE J79 retrofit to OFT-J79**
- Up to 43 MWe from 12 MWe baseline

**SGT-900 (W251 B12) retrofit to OFT-900**
- Up to 150 MWe from 43 MWe baseline
- Makes use of CES reheat combustors
- CES, FTT, and Siemens design

Future turbine potential for new designs matching temperature/pressure profile of CES direct steam gas generators
Pressurized oxy gas generator (POGG), AKA process steam generator, uses platelet- based oxy-combustors and compact heat exchanger technology combined.

Modular design offers numerous advantages:

- Compact solution with small footprint and easy logistics
- Easy maintenance and/or repair
- Identical modules reduces down time
- Easily scaled up or down
- Easily throttled up or down
Carbon Negative Energy
CARBON NEGATIVE ENERGY
WHAT IS CNE?

- **Carbon removal** refers to any process or system capable of removing and sequestering carbon from the air over its life cycle.

- **CNE (or BioCCS)** refers to any bioenergy process that captures and permanently stores carbon safely underground through carbon capture and storage (CCS).

- CNE can remove the harmful greenhouse gas carbon dioxide (CO₂) from the atmosphere while producing electricity and clean, renewable hydrogen.
CNE: WHY NOW?
CLIMATE CHANGE AND AIR QUALITY
## 2019 American Lung Association “State of the Air” Report

### Top 10 Most Polluted U.S. Cities:

<table>
<thead>
<tr>
<th>Rank</th>
<th>City Name</th>
<th>State</th>
<th>Ozone</th>
<th>Short-Term Particle Pollution (24-hour PM$_{2.5}$)</th>
<th>Year-Round Particle Pollution (Annual PM$_{2.5}$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Los Angeles-Long Beach, CA</td>
<td>CA</td>
<td></td>
<td>1 Bakersfield, CA</td>
<td>1 Fresno-Madera-Hanford, CA</td>
</tr>
<tr>
<td>2</td>
<td>Visalia, CA</td>
<td>CA</td>
<td></td>
<td>2 Fresno-Madera-Hanford, CA</td>
<td>2 Bakersfield, CA</td>
</tr>
<tr>
<td>3</td>
<td>Bakersfield, CA</td>
<td>CA</td>
<td></td>
<td>3 Fairbanks, AK</td>
<td>3 Fairbanks, AK</td>
</tr>
<tr>
<td>4</td>
<td>Fresno-Madera-Hanford, CA</td>
<td>CA</td>
<td></td>
<td>4 San Jose-San Francisco-Oakland, CA</td>
<td>4 Visalia, CA</td>
</tr>
<tr>
<td>5</td>
<td>Sacramento-Roseville, CA</td>
<td>CA</td>
<td></td>
<td>5 Missoula, MT</td>
<td>5 Los Angeles-Long Beach, CA</td>
</tr>
<tr>
<td>6</td>
<td>San Diego-Chula Vista-Carlsbad, CA</td>
<td>CA</td>
<td></td>
<td>6 Yakima, WA</td>
<td>6 San Jose-San Francisco-Oakland, CA</td>
</tr>
<tr>
<td>7</td>
<td>Phoenix-Mesa, AZ</td>
<td>AZ</td>
<td></td>
<td>7 Los Angeles-Long Beach, CA</td>
<td>7 Pittsburgh-New Castle-Weirton, PA-OH-WV</td>
</tr>
<tr>
<td>8</td>
<td>San Jose-San Francisco-Oakland, CA</td>
<td>CA</td>
<td></td>
<td>8 Salt lake City-Provo-Orem, UT</td>
<td>8 El Centro, CA</td>
</tr>
<tr>
<td>9</td>
<td>Houston-The Woodlands, TX</td>
<td>TX</td>
<td></td>
<td>9 Seattle-Tacoma, WA</td>
<td>9 Cleveland-Akron-Canton, OH</td>
</tr>
<tr>
<td>10</td>
<td>New York-Newark, NY-NJ-CT-PA</td>
<td>NY</td>
<td></td>
<td>10 Pittsburgh-New Castle-Weirton, PA-OH-WV</td>
<td>10 Medford-Grants Pass, OR</td>
</tr>
</tbody>
</table>
CNE: WHY NOW?
GRID RELIABILITY
Revenues have increased from $20 to $250/tonne for Carbon Capture in select markets

- Value Proposition for CCS projects today:
  - Renewable Hydrogen sales at avoided cost
  - Federal Tax Credit (45Q); increased from $20 to $50/tonne CO₂ in 2018
  - California’s Low Carbon Fuel Standard (LCFS); credit prices exceeding $190/tonne
- Concurrently, the Biomass Power industry in California has collapsed due to competition from wind and solar
  - Stranded assets may be used for alternative purposes
  - Feedstock pricing collapse; long-term contracts available
- Required CES capture tech. ready for commercial deployment
  - More than 25 years and $135 million invested
CES Carbon Negative Energy (CNE) plants use waste biomass fuels that are gasified to produce a synthesis gas. This “syngas” is then used to produce renewable hydrogen (RH₂), and/or electricity with full carbon capture using proprietary oxy-combustion technology.
**CNE | CES POWER BLOCK**

- **Air Separation Unit**
  - Oxygen (O₂)

- **Fuel Processing**
  - Fuel

- **Direct Steam Gas Generator**
  - Recycle Water

- **CO₂ Recovery**
  - CO₂

- **OFT-J79**
  - HX
  - Cond.

- **Electrical Generator**

- **Permanent sequestration, or sold for use in EOR**

*See [www.CleanEnergySystems.com](http://www.CleanEnergySystems.com) for info on CES technologies*
California Offers Very Large CO₂ Storage Capacity:

- California’s on-shore sedimentary have capacity for roughly 1,000 years of current CO₂ emissions (point source)
- The largest storage capacity identified in the state’s Central Valley basin
CNE POTENTIAL FOR BioCCS IN CALIFORNIA

- More than 15 idle biomass power plants in California today (>375 MW), with more anticipated to close in the coming years
- Excellent overlay of plant locations with CCS storage sites
- Suitable for delivery to state refineries or the Hydrogen Highway

CNE | POTENTIAL FOR BioCCS IN CALIFORNIA

More than 15 idle biomass power plants in California today (>375 MW), with more anticipated to close in the coming years. Excellent overlay of plant locations with CCS storage sites. Suitable for delivery to state refineries or the Hydrogen Highway.
• Revitalization of existing biomass plants
• Elimination of criteria pollutant and CO₂ greenhouse gas emissions
• Reduction of open field burning of agricultural
• Supports decarbonization of California’s transportation sector
  o Hydrogen from CNE plants removes ~3 lbs of CO₂ from the atmosphere for every mile driven
• Helps address tree mortality and wild fire crisis in the state
• A net water producer, with the ability to desalinate brackish water in the Central Valley
• Absolute necessity to meet the world’s goal of less than 2 °C global temperature rise
CES DEPLOYMENT | ENVIRONMENTAL IMPACT

• CES plans to deploy a fleet of CNE plants across California by retrofitting existing, idled biomass facilities
• First plants will be deployed in the Central Valley; CES has site control for the first four plants to be deployed by 2025
• Significant fuel production and environmental benefits for the state by replicating and scaling CNE plants

<table>
<thead>
<tr>
<th>First Four CNE Plants</th>
<th>Future Potential</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Fuel Production (tonne/day)</strong></td>
<td></td>
</tr>
<tr>
<td>RH₂ Produced</td>
<td>33</td>
</tr>
<tr>
<td><strong>Emissions Avoided (tonne/yr)</strong></td>
<td></td>
</tr>
<tr>
<td>CO₂ Captured &amp; Avoided</td>
<td>1,300,000</td>
</tr>
<tr>
<td>NOx Avoided</td>
<td>2,400</td>
</tr>
<tr>
<td>Particulates Avoided</td>
<td>5,100</td>
</tr>
</tbody>
</table>
CNE | INITIAL PROJECT SIZING

Initial projects sized based upon 600 TPD of feedstock but can be scaled for larger future plants.

Approx. 600 TPD; Sourced from local municipality or agriculture

Approx. 700 TPD total

Commercially available cryo or PSA system

Air Separation

Oxygen

Hydrogen

Depleted Syngas

Gasifier

Syngas

Bio Char

Commercially available steam/O2 blown gasification package

Approx. 300k tons per year; Equivalent to removing more than 63,000 cars from the road

Cover house loads

Approx. 10,800 kg RH2 per day; Enough to fuel ~2,000 FCEVs

Or used in refineries to reduce the carbon intensity of existing fuels, e.g. ULSD

Gas Separation

Renewable Hydrogen

Traditional PSA or Membrane technology

CES Power Block

Captured CO2

Electricity

Gas

Separation
CES | POWER BLOCK

Air Separation Plant
Fuel Processing

Direct Steam Gas Generator

O2
Fuel
Recycle Water
CO2

CO2 Recovery

Permanent Sequestration, or sold for use in EOR

OFT-J79

Electrical Generator

30 MWe OFT-J79; Installed and tested at KPP

C.W.
Excess Water

CES 12", 200 MWe; Installed and tested at KPP
Low execution risk

- Long-term fixed price contracts available for carbon-negative energy projects
- All required equipment can be vendor or project financed
- Debt financing available through tax-exempt Private Activity Bonds or DOE Loan Guarantees
- Site control for first 4 projects obtained (up to 6 more identified in the California market)
- Classic project development opportunity with a phased approach
- Lack of atmospheric emissions facilitates project permitting
- Projects will focus on hydrogen sales due to shorter time to secure contracts and achieve positive cash flow
- Strong Partners
CES’ Kimberlina Power Plant

- Located in the heart of the California’s Central Valley
  - Surrounded by fruit and nut orchards
  - Sitting on top of a WESTCARB identified CO₂ storage site, &
  - Between heavy and light oil fields in need of steam and CO₂
- Currently home to CES’ commercial and test equipment
  - World’s largest pressurized O-F combustion test facility
- Existing 300 TPD biomass plant; requires install of gasifier, ASU and RH₂ liquefaction and transportation system
- CO₂ to be sequestered on-site
- RH₂ to be liquefied and sold into transportation sector through California refineries to reduce the carbon intensity of existing fuels...
Projected Surface Footprint of Plume Over Time Affects Project Planning
Idled Biomass Power Plant

Expected online by 2022

• 80 acre site; operational through 2015
• CES currently in due diligence to acquire site; anticipated close in Dec 2019
• 600 TPD biomass; ~10,800 kg/day RH₂; ~1060 tonne/day captured CO₂
• Hydrogen off-takers: Major Refineries or the Hydrogen Highway
• Site has existing biomass system infrastructure and other useful BOP
• Requires CES oxy-fuel power block (12” DSGG and OFT-J79)
• CO₂ to be sequestered on-site
• Large power and gas lines on site can be further optimized
  • Integrating carbon-neutral power production with low Cl gas
  • Working with natural gas producer on an out-of-state CCS project
Baseline Assumptions (conservative analysis):
CES’ Placerita Power Plant

- Former 120 MWe combined heat and power plant offers substantial infrastructure, making repower option attractive.
- Requires new biomass handling system, gasifier, and CES powerblock.
- CO₂ storage not available on-site; would be piped to nearby storage sites (CCS) and/or for use in enhanced oil recovery (EOR).
- Potential to transport RH₂ through existing pipeline infrastructure.
- TBD: Site permitting due to close proximity to housing development.
- May be a better option for RNG production and/or energy storage to serve the LA Basin.
CES Carbon Negative Energy plants have the potential to generate renewable power and/or fuels (RNG, RH₂) while effectively removing millions of tons of CO₂ from the atmosphere.

- Plants can be scaled and configured to suit specific site needs.

CES plans to develop a portfolio of CNE plants across California making use of currently idled biomass facilities; revitalizing valuable assets and improving the state’s air quality.

- CES is in the project development stages for a first CNE plant at an idled biomass power plant near Fresno, including securing feed and offtake agreements, kicking off permitting activities, etc.

- The next three sites are secured and development will lag by 6-12 months per project.

- Identify, locate, and secure additional sites for CNE plants.
1. Fast-track approval of CCS projects
   • Resolution of permanence storage protocol
   • Coordination between state agencies and US EPA
2. Greater flexibility in LCFS pathway calculations/monetization
   • Currently results in a fixed CI, whereas CNE projects may have variable CI attributes
   • Increased trading/monetization opportunities
3. Predictability of LCFS pricing to support project financing
   • A floor price is optimal, but highly problematic
   • Opportunities through the Pollution Control Tax-Exempt Bond Financing Program
4. Renewable Hydrogen Portfolio Standard
   • Greater market pull to expand production and reduce costs
“Carbon-dioxide removal could be a trillion-dollar enterprise, because it not only slows the rise in CO₂, but reverses it.”
For more information, please contact:

Keith L. Pronske, President and CEO
KLPronske@CleanEnergySystems.com
Office: +1 916-638-7967
Or visit us at: www.CleanEnergySystems.com