Carbon-Negative Energy
Renewable Hydrogen Project
An Opportunity for California
December 2019
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) – Indirect Air Capture.

• CNE can remove the harmful greenhouse gas carbon dioxide (CO₂) from the atmosphere while producing electricity and clean, renewable hydrogen.
CNE | HOW IT WORKS

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.

SIMPLIFIED SCHEMATIC

- Carbon Dioxide (CO₂) is captured from the air and depleted syngas.
- Oxygen is supplied from the air separation block.
- Syngas is produced from the gasifier.
- Renewable hydrogen is separated from the depleted syngas in the gas separation block.
- Captured CO₂ is stored safely and permanently.
- Existing infrastructure can be used for now negative emissions vehicles.
CNE | CES POWER BLOCK

Air Separation Unit

O₂

Fuel Processing

Fuel

Direct Steam Gas Generator

Recycle Water

CO₂ Recovery

CO₂

Permanent sequestration, or sold for use in EOR

OFT-J79

Electrical Generator

OFT-J79; Installed and tested at KPP

Cond.

HX

C.W.

Excess Water

*See www.CleanEnergySystems.com for info on CES technologies
**CNE: WHY NOW?**

**ECONOMICS**

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
<table>
<thead>
<tr>
<th>TODAY</th>
<th>TOMORROW</th>
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<tbody>
<tr>
<td>• Half the state’s biomass plants shuttered</td>
<td>• All biomass plants repurposed and life extended</td>
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<td>• Criteria pollutants from biomass plants</td>
<td>• Near-zero atmospheric emissions</td>
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<td>• Open field burning of agricultural waste</td>
<td>• Ag. waste used to produce renewable hydrogen</td>
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<tr>
<td>• Natural gas is used to make hydrogen</td>
<td>• Renewable hydrogen from ag. and green waste</td>
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<td>• Tree mortality and wild fire crisis</td>
<td>• Beneficial use of cleared forestry waste</td>
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<td>• Current biomass plants consume water</td>
<td>• CNE plants are net producers of water</td>
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<td>• Water shortages in the Central Valley</td>
<td>• Brackish water can be processed with waste heat</td>
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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

Estimated CO₂ Storage Resource: California Sedimentary Basins

- Low Estimate
- High Estimate

- 30–460 Gt onshore saline formation capacity
- 3.3–5.7 Gt natural gas reservoir capacity
- 1.4–3.7 Gt oil reservoir capacity

Courtesy of the California Energy Commission
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

#### Sedimentary Basin Status

- **Green**: Basin with Carbon Sequestration Potential
- **Gray**: Basins lacking Carbon Sequestration Potential
- **Pink**: Offshore Basins with Unknown Carbon Sequestration Potential

#### Other Reserves

- **Red**: Natural Gas Field
- **Green**: Oil Field

Courtesy of WESTCARB
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/eligibility
   - Currently results in a fixed CI, whereas CNE projects may have variable CI attributes
   - Increased trading/monetization opportunities
   - More favorable interpretation of the regulations
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
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

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<tr>
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<th>First Four CNE Plants</th>
<th>Future Potential</th>
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<tbody>
<tr>
<td></td>
<td>2022-2025</td>
<td>2025+</td>
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<tr>
<td>Fuel Production (tonne/day)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>RH₂ Produced</td>
<td>33</td>
<td>425</td>
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<tr>
<td>Emissions Avoided (tonne/yr)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CO₂ Captured &amp; Avoided</td>
<td>1,300,000</td>
<td>16,200,000</td>
</tr>
<tr>
<td>NOx Avoided</td>
<td>2,400</td>
<td>29,900</td>
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<tr>
<td>Particulates Avoided</td>
<td>5,100</td>
<td>64,100</td>
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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