NET Power

Truly Clean, Cheaper Energy

Carbon Sequestration Leadership Forum

October 2016
Contents

1. Cycle Design
2. Turbine and Combustor Development
3. 50MWth Plant Development
Cycle Introduction
sCO₂ Allam Cycle Introduction

• **Novel, highly-efficient supercritical CO₂ power cycle**
  - Uses high-pressure carbon dioxide as the cycle working fluid
  - Uses oxy-fuel combustion of fossil fuels

• **Generates low-cost, emissions-free power**
  - No atmospheric emissions: near-100% CO₂ capture at pipeline pressure
  - Does not lead to an increase in the cost of electricity compared to the best current systems without CO₂ capture, due to:
    - High efficiency: competitive with current combined cycle systems that do not capture CO₂
    - Low capital costs: simple cycle design; elimination of steam cycle components; single turbine
The Allam Cycle Natural Gas Platform

- 58.9% (LHV) net efficiency, with full carbon capture
- Oxy-fuel, closed-loop, CO₂ working fluid
- 200-400 bar; 6-12 pressure ratio
- CO₂ and water are the only byproducts
- All components, other than combustor and turbine, currently available
- Combustor and turbine developed by Toshiba

Fuel Combustion
CO₂ Turbine
Heat Rejection
Water Separation
Compression and Pumping
Additional Heat Input
Heat Recuperation
Allam Cycle Pressure-Enthalpy Diagram
### Other Allam Cycle Variations

<table>
<thead>
<tr>
<th>Technology</th>
<th>LHV Efficiency</th>
<th>Other Benefits</th>
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</thead>
<tbody>
<tr>
<td>Coal</td>
<td>51.4%</td>
<td>Greatly simplifies coal gasification.</td>
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<tr>
<td>LNG Regasification</td>
<td>66%</td>
<td>Recovers energy put into liquefaction</td>
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<tr>
<td>Solar-Natural Gas Hybrid</td>
<td>74%†</td>
<td>True integration, not dual plants; enables reliable availability.</td>
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Turbine and Combustor Development
Gas Turbine Technology
1300-1600°C

- Working fluid: CO₂
  - Pressure: 2 MPa ⇒ 30 MPa

Combustor Technology
1300-1600°C

- Working fluid: CO₂
  - Pressure: 2 MPa ⇒ 30 MPa

Steam Turbine Technology
USC & A-USC
- Pressure: 24-31 MPa
- Temperature: 600-750°C

- Working fluid: CO₂
  - Temperature: ⇒ 1150°C

- Turbine & Combustor for Allam Cycle
  - Temp.: 1150°C
  - Press.: 30 MPa
Combustor Development

Testing has been completed using facility in California

Test Combustor

Exhaust Duct

Test Stand
50MWth Plant Development
50 MWth Demonstration Plant Description

• **50MWth natural gas plant**
  ▫ Scaled down from 500 MWth pre-FEED design to ensure scalability
  ▫ Site is in La Porte, TX
  ▫ First fire: Q2 2017

• **Includes all core Allam Cycle components**
  ▫ Combustor/turbine, heat exchangers, pumps/compressors, controls, etc.
  ▫ Full operation tests (startup, shutdown, ramping, hot/warm/cold starts)
  ▫ Oxygen will be pulled from a pipeline as opposed to a dedicated ASU
  ▫ CO₂ quality (pressure; purity) will be confirmed for off-take viability

• **$140 million (USD) program funded**
  ▫ Includes first of a kind engineering, all construction, and testing period
  ▫ Partners include Exelon Generation, CB&I, 8 Rivers and Toshiba
50MW the Plant Layout: 3D Drawing

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50MWth Demonstration Plant Development Status

Groundbreaking March 3, 2016 – On Schedule
Most Major Equipment/Components On-Site – Turbine Ships in October
Commercial Plants Are Under Development

- **Initial 295MWe pre-FEED completed**
  - Currently undergoing a “refresh” following learnings from demo plant detailed design
  - Pursing several advanced design concepts
  - Seeking to issue a notice to proceed following successful demonstration plant operation in 2017
  - Several projects under development and in consideration to host first plant

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<thead>
<tr>
<th>NET Power Commercial Natural Gas Plant</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Electric Output</strong></td>
</tr>
<tr>
<td><strong>CO₂ Output</strong></td>
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<tr>
<td><strong>N₂ Output</strong></td>
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<td><strong>ASU Output Demand</strong></td>
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<td><strong>Site Area</strong></td>
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</tbody>
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Acknowledgements

• The following entities have supported development of NET Power and/or the coal-based Allam Cycle:
  ▫ UK Department of Energy and Climate Change funding of £6.3m:
    • “Path to Coal” study on coal variation of the Allam Cycle coal
    • Development of manufacturing processes for advanced turbine and heat exchanger materials used by the Allam Cycle
    • Pre-FEED study for a UK-based demonstration plant
    • Series of process design improvement studies
  ▫ The US Department of Energy National Energy Technology Laboratory:
    • Design of a coal-syngas combustor for use with supercritical CO₂ power cycles
  ▫ The State of North Dakota and the US Department of Energy:
    • Allam Cycle Lignite Study
    • R&D to address key coal cycle technical challenges