Advanced Natural Gas Reciprocating Engines (ARES)
Contract: DE-FC26-01CH11080
GE Energy, Dresser Inc.
10/2010 – 12/2013

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U.S. DOE Industrial Distributed Energy Portfolio Review Meeting
Washington, D.C.
June 1-2, 2011
Project Overview

Develop a reciprocating natural gas engine with 50% Brake Thermal Efficiency (BTE) while:

\[ \begin{align*}
&1 \text{ producing } 0.1 \text{ g/bhp-hr } \text{NO}_x \\
&2 \text{ reducing the cost of electricity by 10\% and,} \\
&3 \text{ with no change in reliability, durability, or maintenance costs}
\end{align*} \]
Project Objective

1. Develop cost-effective technologies to improve efficiency
2. New technologies needed
Current state-of-the-art

2. BTE in the 42-44% range depending on engine size – up from 37%

2. Brake Mean Effective Pressure (BMEP) in the 16 – 17 bar range – up from 12 bar

2. NO\textsubscript{x} 0.5 g/bhp-hr – down from 1.25 g/bhp-hr
Technical approach

1. Full optimization of engine sub-systems
   - Design of Experiments approach
   - Intensive computational simulation

2. Looking for system synergies

2. Not neglecting customer focus
   - Secondary benefits of new technologies reduce total cost of ownership
Technical approach

1. Increase BMEP to drive initial cost down and efficiency up
2. Brings new technical challenges with
   - Spark plug life
   - Structural integrity
   - Turbocharger limitations
   - Knock margin
Transition and deployment

1. Developed technologies are generic and applicable to our complete engine portfolio.

2. Technologies work with straight PowerGen or CHP.
Transition and deployment

2 Reciprocating engines have the highest efficiency of any technology less than 100 MW.

2 Recips offer low 1st cost, fast start, excellent cycling, and high efficiency at part load.

2 New market of peaking power – backup for renewables.
Measure of success

2 47% BTE demonstrated without exhaust energy recovery, preserving the heat for CHP use

2 Initial cost increase minimal
Benefits

1. Further improves CHP economics by increasing electric/thermal ratio while preserving exhaust energy.

2. Secondary benefits add as much value for the customer as fuel savings.
Benefits

1. Additional benefits by avoidance of electric grid losses
2. Low water usage, no combustion residuals
3. Energy security with on-site generation
Commercialization approach

Commercializing ARES II technologies
### Project management & budget

**Expected Project Duration:** 3.25 years  
**Projected DOE Funding:** $7,538,127  
**Total Project Cost:** $16,038,826

<table>
<thead>
<tr>
<th></th>
<th>FY11</th>
<th>FY12</th>
<th>FY13</th>
<th>FY14</th>
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<tbody>
<tr>
<td>DOE Investment</td>
<td>$1,609,408</td>
<td>$2,640,272</td>
<td>$2,644,053</td>
<td>$644,754</td>
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<tr>
<td>Cost Share</td>
<td>$2,571,621</td>
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<td>Project Total</td>
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<td>$5,280,543</td>
<td>$5,288,106</td>
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## Project management & budget

<table>
<thead>
<tr>
<th>Task/Milestone Number</th>
<th>Title or Brief Description</th>
<th>Task/Milestone Completion Date</th>
<th>Progress Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Power Cylinder Optimization Confirmed Version 1</td>
<td>Mar-11 Jul-11 60% Testing in progress</td>
<td></td>
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<tr>
<td>2</td>
<td>Update Test Engine</td>
<td>Jul-11 Sep-11 30%</td>
<td>Components available, updates to start occurring during 3rd quarter</td>
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<td>3</td>
<td>Valve Event Analysis Complete</td>
<td>Nov-11</td>
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<td>4</td>
<td>Engine Installation / Baselined</td>
<td>Mar-12</td>
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<td>5</td>
<td>Pmax Study - Phase 1 Complete</td>
<td>Mar-12</td>
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<td>6</td>
<td>Flow Loss Analysis Complete</td>
<td>Apr-12</td>
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<td>7</td>
<td>Ignition / Combustion options tested</td>
<td>May-12</td>
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<tr>
<td>8</td>
<td>Power Cylinder Optimization Confirmed Version 2</td>
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<td>9</td>
<td>Friction Reduction options evaluated</td>
<td>Dec-12</td>
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<td>10</td>
<td>Exhaust Energy Recovery Systems Evaluated</td>
<td>Jan-13</td>
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<td>11</td>
<td>Engine Updated with Select Efficiency Options / Testing</td>
<td>Jun-13</td>
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<td>12</td>
<td>50%BTE Demonstration</td>
<td>Nov-13</td>
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Results and accomplishments

- ARES Phase I completed and commercial product released in 2006
- Commercially successful product with strong export sales
- 6 patents, 6 ASME technical papers, numerous trade publication articles
Results and accomplishments

2 ARES Phase II completed with 47% BTE lab demonstration – commercialization activities continuing

2 4 patents, one pending

2 Ultra low emissions combustion technology transferred to DOE CHP project

2 Many of the developed technologies have no or low initial cost increase
   – 25% lower engine friction
   – Wear rates down dramatically
   – Oil consumption cut in half
Results and accomplishments

- ARES Phase III started October, 2010
- Additional efficiency improvement technologies identified – testing in process
Path forward

1. Validation of ARES II technologies in process
2. Moving to production release of selected ARES II technologies
3. Continuing to investigate new technologies