ADVANCED RECIPROCATING ENGINE SYSTEMS (ARES)

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ABSTRACT

Reciprocating engines have evolved technically more in the past decade than at any other time in the past 100 year history. Reciprocating engines are the fastest-selling, lowest-cost distributed generation technology in the world today. It is a well known wide spread technology having superior reliability, low maintenance, and good durability, that can be used to load follow, and are approaching efficiency that is better than its nearest competitor. Primarily driven by emissions regulations, the modern piston engine has secured its future as a primary driver for multiple markets. The mission of the ARES Program is to lead a national effort to design, develop, test, and demonstrate a new generation of reciprocating engine systems applications that are cleaner, more affordable, reliable and efficient than products that are commercially available today.

ADVANCED RECIPROCATING ENGINE SYSTEMS

Launched in September 2001, ARES consists of three phases, each with specific targets to reach the program's overall goals while maintaining current engine reliability. ARES goals for advanced gas engines are substantial, including 45% thermal efficiency (HHV), NO_x emissions of 0.1 g/bhp-hr, installed capital costs of $400+ per kW_e with a maintenance cost of $0.01 per kW_e-h/year by the year 2010. Despite aggressive goals and a relatively short timeline in which to achieve them, the degrees of support for the ARES program are relatively large and increasing.

The ARES program is working with three major engine manufacturers: Caterpillar, Cummins and Waukesha in a competitively funded cost shared program to produce advanced engines approaching an efficiency of 45% (HHV). Engine manufacturers, national laboratories and universities are working together as a team to develop and commercial-

ize advanced engines running on natural gas as the primary fuel; however alternate fuels are being looked at for various power generation applications. Primary emphasis is on large 500 to 6500 kW systems for commercial power generation use. Special attention has been given to technologies that compare to current and future competing distributed generation technologies such as micro-turbines, and fuel cells.

The ARES program is supported by national laboratories, including the Oak Ridge National Laboratory, Argonne National laboratory, Pacific Northwest National Laboratory, Brookhaven National Laboratory, and the Sandia National Laboratory. Each laboratory is working on technologies that will enhance the operation of the ARES engines. The laboratories work very closely with the manufacturers such that when a solution to a problem is found, that technology is transferred to the manufacturers, incorporated into an engine and tested in the laboratory. If satisfactory, the technology is transferred to the manufacturers for incorporation in to the latest engine design.

The manufacturers and suppliers, teamed with several universities and national laboratories, to research advanced materials, unique fuel and air handling systems, advanced ignition and combustion, catalyst, lubricants, and technologies that are compatible with existing transmission and distribution systems. Technologies being addressed are: spark plugs, controls, emissions, lubrication, and friction, catalysts, materials and other technologies needed to meet the ARES goals.

Looking at some technologies for power generation:

Product	*Size (kW)*	*Efficiency (HHV)*	*Installed Cost $/kW*	*Status*
IC Engine	10-5,000	28-45%	$300-$600 $1,000-$1,500 CHP	Now
Micro-turbines	30-100 today 100-400 future	24-32%	$1,000-$1,500 $1,500-$2,000 CHP	Now
Small Fuel Cells	3-10 Lab Units 10-50 future	23-32%	Play the lottery	2010?
Large Fuel Cells	200-1,000	35-40 %	$4,000-$5,000	?
Turbine	30-10,000	25-40%	$600-$1,000	Now
Photovoltaic	0.1-10	?	$8,000 +	Now

Engine systems being addressed in the ARES program are: the Miller cycle, HCCI cycle, Stirling cycle, and Otto cycle.

The objective of the ARES program is to provide a new generation of advanced internal combustions engines for power generation from light to large commercial applications. Operating on natural gas fuel, this new technology will maximize energy efficiency consistent with economic competitiveness, and minimize emissions of global environmental pollutants.

The ARES program can have significant penetration into the power generation market and make an impact on the installation of distributed energy (DE) and the use of fossil fuels. In all three markets (residential, small commercial, and large commercial), the greatest potential impact is for power generation. The production of waste, or recoverable energy, is the second largest application for the IC engines; it is of primary interest for the program.

When the use of recoverable energy is linked to the lithium bromide/water (LiBr/H2O) chiller for cooling, and desiccants for indoor air quality, the overall efficiency of the system can reach 70 to 80% in climates where building cooling and indoor air quality are needed as a primary way of providing clean, comfortable environments for employ-

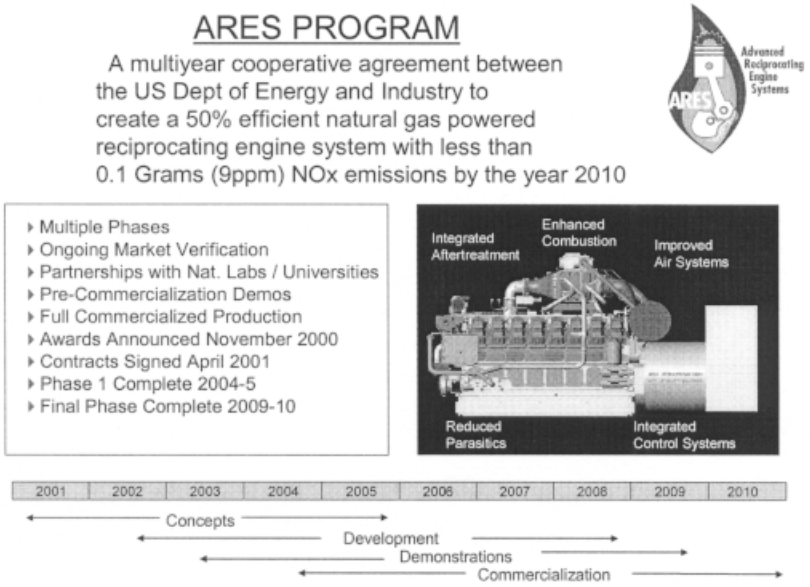

Figure 1. ARES Program

ees. Supporting research is carried out in key technical areas to enable current concept developments to proceed and to form the basis for future advanced concepts with even higher energy saving potential.

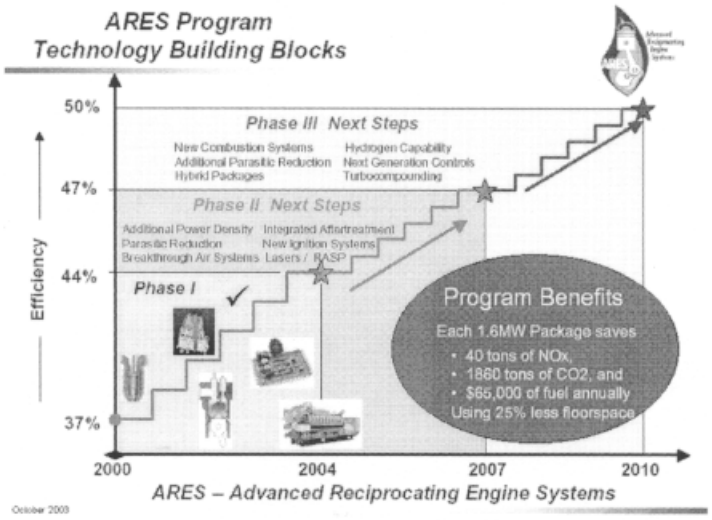

Figure 2. ARES Program Phases

Major Accomplishments to date:

1. **Laser–Ignition System for Reciprocating Engines**
   Colorado State University researchers, under contract from the ARES program, achieved an important milestone in operating one cylinder of a Waukesha engine with laser ignition energy delivered through a fiber optic coupling. This is part of the first ever consortium including Argonne National Laboratory (ANL), Colorado State University (CSU) and National Energy Technology Laboratory (NETL). This is also the first ever project co-funded by the U.S. Department of Energy, Office of Distributed Energy Resources (DOE-DER) and California Energy Commission. This successful milestone, even though it is less than ideal in the sense that it used the head and piston top as targets for laser energy, nevertheless provides encouragement regarding successful commercialization of this technology.

2. **Rapid Compression Machine for Ignition Research**
   With a view to determine the true limits of ignition and knock, and

thereby the full envelope of operation for gas engines, Argonne National Laboratory has designed and developed a unique rapid compression machine (RCM). This RCM has recently been commissioned and operated successfully. Controlled experiments conducted in the RCM will enable the engine manufacturers to push the envelope of the lean limits of future ARES engines to obtain very high thermal efficiencies while maintaining very low NO_x emissions.

3. **Operation of Visioscope**
This optical imaging instrument was operated successfully on a diesel engine to obtain high resolution combustion process. This instrument will be used to obtain combustion images in an ARES engine to study the flame propagation in the natural-gas-fueled, spark-ignited engine. This will be the first of its kind to assist in the development of high efficiency ARES engines.

CONCLUSION

Beyond the technical challenges, each of the engine builders acknowledges that there are some pitfalls on the road to Phase 3 completion in 2010. One, the market for distributed generation is not fully developed, and there remain barriers and policy inconsistencies. Two, emissions regulation could possibly outpace the ARES program goals. Finally, continued funding of various research programs is essential to achieving ARES milestones. It's also imperative to reiterate, however that ARES has already been successful in bringing together the divergent agenda of the various participants, including those of DOE, laboratories, universities, and industry.

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