Generators for Small Electrical and Thermal Systems (GENSETS)

GENSETS project teams will design, build, and test improved electric-power generators for use as residential combined heat and power (CHP) systems, which capture the generator's heat output for space and water heating. These CHP systems will be powered with natural gas and can supply the majority of a household's electricity and water heating needs as well as helping to heat the residence. In order to make small-scale CHP systems more affordable and stimulate their adoption, the GENSETS program aims to develop 1 kW (electric) sized generators that are highly efficient (40% or greater), long lasting (10 years or more), low cost ($3,000 or less), and clean. The projects are grouped into four areas of technology focus: Stirling engines, internal combustion engines, microturbines, and solid state devices (thermal to electrical converters with no moving parts).

PROJECT DESCRIPTIONS

Stirling engines

Infinia Technology Corporation – Richland, WA

Sustainable Economic mCHP Stirling (SEmS) Generator - $3,708,019

Infinia Technology Corporation (ITC) and its affiliate, Qnergy, Inc., will work with their partners to develop a generator that features a free piston Stirling engine powered by an ultra-low emissions natural gas burner. This technology incorporates flexure bearings so that there are no rubbing parts, thereby eliminating the need for maintenance and greatly increasing lifetime. The team will also develop novel materials that enable high-temperature engine operation, further increasing the efficiency of the system. Manufacturing costs will be reduced through use of additive manufacturing and/or investment casting technologies.

Sunpower, Inc. – Athens, OH

Free Piston Stirling Engine Based 1kW Generator - $3,500,000

Sunpower, Inc. and its research partners will design and build a generator based on a free piston Stirling engine with a high-temperature heater head and gas bearings for non-contact operation. Team member Aerojet Rocketdyne will develop new materials to increase the efficiency of the system by allowing it to operate at high temperatures, and partner Precision Combustion, Inc. will develop an innovative, catalytically assisted recuperated burner to ensure low exhaust emissions and high efficiency operation.

Temple University – Philadelphia, PA

Advanced Stirling Power Generation System for Combined Heat and Power - $1,000,000

Temple University will lead a team in designing and demonstrating an advanced Stirling power generation system for combined heat and power. A highly effective and reliable involute foil regenerator will be developed and used to improve efficiency through enhanced heat transfer and reduced flow losses. The team will use additive manufacturing methods to produce a one-piece Stirling heater-head assembly consisting of a pressure vessel, heat accepter, involute foil regenerator and heat tube-and-shell heat rejecter. Additive manufacturing will also be utilized to produce a system that integrates the burner and Stirling engine heater head so that the burner thermal losses and combustion gas flow losses are minimized.

Internal Combustion Engines

Aerodyne Research, Inc. – Billerica, MA

Single-cylinder Two-stroke Free-Piston Internal Combustion Generator - $2,555,590

Aerodyne Research, Inc. and its team will design and build a generator for CHP systems based on a small, single-cylinder, two-stroke free-piston internal combustion engine. The free-piston engine, which does not employ a traditional slider-crank mechanism, reduces friction and improves efficiency. The system will also incorporate low temperature, glow plug-assisted homogenous charge compression ignition (HCCI) combustion, which reduces heat loss from the engine and increases efficiency. The team will also incorporate a double-helix spring for energy storage, which allows for high frequency operation – key to producing a system with compact size, low weight and low cost.

Mahle Powertrain – Farmington Hills, MI

Advanced Lean Burn Micro-CHP Genset - $2,500,000

Mahle Powertrain and its partners will develop and optimize a CHP generator that uses an internal combustion engine with a turbulent jet ignition (TJI) combustion system. TJI incorporates an auxiliary-fueled pre-chamber combustor, enabling the system to operate under ultra-lean conditions and therefore increasing thermal efficiency. The team will further increase the system's efficiency by using low friction engine components. Team member Oak Ridge National Laboratory will develop a novel low-temperature after-treatment system to reduce exhaust emissions.

Tour Engine, Inc. – San Diego, CA

High Efficiency Split-Cycle Engine for Residential Generators - $1,000,000

Tour Engine, Inc. will lead a team to develop an efficient internal combustion engine based on Tour's existing split-cycle engine technology. The split cycle divides the process into a cold cylinder (intake and compression) and a hot cylinder (expansion and exhaust) with improved thermal management. It also allows for independent optimization of the compression and expansion ratios, enabling a higher expansion ratio and therefore increased thermal efficiency. Tour Engine will also further develop its existing innovative crossover valve mechanism, known as the Spool Shuttle Crossover Valve and Combustion Chamber (SSCVCC), which enables efficient transfer of working fluid between the cold and hot cylinders.

West Virginia University Research Corporation – Morgantown, WV

Oscillating Linear Engine and Alternator - $2,000,000

West Virginia University Research Corporation, along with its research partners, will develop a generator for CHP systems based on a crankless, linear, free-piston internal combustion engine that drives a permanent magnet linear electric generator. The free-piston engine is a two-stroke, spark-ignited system. The team will improve the system's efficiency by using a low-friction free-piston design, managed exhaust gas recirculation operation and resonant tuning of the engine cylinder. The free-piston engine will employ a spring to increase the frequency and stabilize operation.

Wisconsin Engine Research Consultants (WERC), LLC – Madison, WI

Spark-Assisted HCCI Residential Generator - $2,613,287

Wisconsin Engine Research Consultants and its research partners – Briggs and Stratton, the University of Wisconsin-Madison's Engine Research Center and Adiabatics, Inc. – will develop a generator for CHP systems using a low-temperature, high-efficiency internal combustion engine that incorporates an advanced spark-assisted homogenous charge compression ignition (SA-HCCI) system. Novel thermal barrier coatings developed by Adiabatics, Inc. will be used to reduce heat losses. An optimized combustion chamber and low-friction power cylinder will also be employed to increase efficiency and reduce emissions. Further, a pressure wave supercharger, or novel crankcase-based boosting system, will be used to increase intake air pressure and increased efficiency.

Microturbines

Brayton Energy – Hampton, NH

1kW Recuperated Brayton-Cycle Engine Using Positive-Displacement Components - $2,400,000

Brayton Energy will lead a team in developing a high efficiency recuperated Brayton-cycle engine. Due to the very small scale of this engine, the system uses a screw compressor and expander, rather than traditional turbomachinery. Brayton will develop a ceramic screw expander, which enables high temperature operation. In addition, Brayton Energy will use its patented intake recuperator and existing ultra-low emissions combustor to increase generator efficiency.

Metis Design Corp – San Francisco, CA

Advanced Microturbine Engine for Residential Generation - $1,000,000

Metis Design Corp and its partners will develop a generator consisting of an efficient microturbine that incorporates an innovative compression system and a low emissions combustor. The compression system will use a braked rotating vaneless diffuser (RVD) to reduce viscous and frictional losses and thus improve efficiency. The team will use Mohawk Innovation Technology Inc.'s (MiTi) patented high-temperature foil bearings, a type of non-contact bearings that help enable a long system lifetime. The team will also use Lawrence Berkeley National Laboratory's ultra-lean low-swirl burner (LSB) technology to reduce emissions.

Solid State Devices

Georgia Institute of Technology – Atlanta, GA

High Efficiency Generator Based on Sodium Thermo-Electro-Chemical Conversion (Na-TEC) - $1,000,000

Researchers at Georgia Institute of Technology will lead a team in developing a modular CHP system using a reverse flow-type combustor to generate heat, and a thermo-electro-chemical converter to convert the heat to electricity. One of the team's key innovations is to use a two-stage heat exchanger that allows for improved heat utilization. In addition, this design results in more efficient energy conversion at lower temperatures and increases the lifetime of the system components.

NanoConversion Technologies, Inc. – San Jose, CA

High-efficiency Thermoelectric Generator- $1,500,000

NanoConversion Technologies, Inc., in conjunction with North Carolina State University and General Electric Appliances, will develop a Concentration-mode Thermoelectric converter (C-TEC) device, which converts heat directly into electricity. The C-TEC uses an array of electrochemical cells to produce electricity in a sodium ion expansion cycle driven by external combustion. The team will build and test a micro-generator combining the C-TEC with an efficient natural gas burner. The superadiabatic gas burner, developed by partner Gas Technology Institute, provides a low-emissions heat source.