

## **Small modular biopower product development at External Power, LLC: Residential and small commercial Stirling cogeneration systems**

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With matching funding from the U.S. Department of Energy's Small Modular Biopower Program, and in collaboration with corporate strategic partners, External Power, LLC. is commercializing a line of residential and small commercial cogeneration systems. External Power's small modular biopower products will employ advanced biomass combustion systems coupled to free-piston Stirling engines for converting the resulting heat to electricity.

The objective of the three-phase Small Modular Biopower Program is to develop a number of small, modular biopower systems that are fuel-flexible, efficient, simple to operate, whose operation has minimum negative impacts on the environment, and which will provide power in the range of electrical generation sizes of 5 kW to 5 MW for domestic and international markets. The Phase 1 objective was a feasibility study that included a market assessment; resource assessment; preliminary system design; an assessment of relevant environmental and safety considerations; an evaluation of financial and cost issues; and a preliminary business plan and commercialization strategy. Phase 1 of this project was completed in 1999. The Phase 2 objective is to demonstrate operation of a prototype small-scale biopower system, complete a detailed business plan including feed stock resource assessment, and establish strategic partnerships with distribution/service entities. Phase 2 is currently nearing completion. The Phase 3 objective is to develop and demonstrate an integrated small scale biopower system with the operation and performance required to successfully compete in the target market. This will include establishing the automated nature of feeding and operating the system, operating the system to establish operations and maintenance cost projections, and performing detailed emissions and measurements and certification of the system performance. External Power plans to conduct Phase 3 over the next two years.

Invented in 1816, Stirling engines were extensively commercialized during the 19<sup>th</sup> Century for applications as diverse as ventilation and ship propulsion. Along with steam engines, these externally heated engines were displaced from the marketplace early in the 20<sup>th</sup> Century by the mass production of internal combustion engines and liquid petroleum fuels for vehicular transportation, for which application internal production engines and these fuels were particularly well-suited. Eventually, the cost reductions derived from mass production enabled internal combustion engines to capture virtually the entire engine market. However, emerging 21<sup>st</sup> Century mass markets for small modular stationary power sources, environmental objections to liquid petroleum fuels, and technological innovations are re-opening market opportunities for Stirling engines. These opportunities are being driven by increasing worldwide demands for electricity, increasing costs of transmission and distribution, deregulation of the electricity generation industry, heightened environmental priorities, and the economics of cogeneration.

Invented in 1964, the modern "free-piston" Stirling engine overcomes inherent technical barriers to the commercialization of the original "kinematic" Stirling engine in long-life, high-reliability, low-maintenance applications. With internal moving parts levitated on gas bearings to eliminate mechanical contact, friction, and wear inside a hermetically sealed casing, free-piston Stirling engines are expected to require no maintenance during an operating lifetime of up to 10 years. The technical advantages of free-piston Stirling engines include input versatility, output versatility, quiet operation, zero wear, zero maintenance, long-life, continuous full-power operation, simple interfacing to electric utility distribution systems, and high efficiency at the residential scale that presents largest market opportunities.

External Power has adopted the 3kW(e) twin-opposed pair of free-piston Stirling engines as the unit of engine production. By serving larger electrical loads up to 24kW(e) with multiple engine-pairs, External Power expects to enjoy economies of scale in manufacturing while reducing the capital cost of new product development.

For heating these Stirling engines, External Power and its corporate strategic partners are developing custom engineered, close-coupled biomass gasification-combustion systems for serving particular target markets, including burners for both densified and undensified fuels. For example, External Power and Wood-Mizer Products, Inc. (<http://www.wood-mizer.com>) are developing a burner for multiple, undensified, green (and wet) biomass fuels with water contents up to 65%. Systems comprised of this burner and up to eight engine-pairs are targeted primarily at small, rural businesses (such as Wood-Mizer customers) that produce biomass fuel on-site as a waste or byproduct. With other strategic partners, External Power is developing novel, pellet burners for residential markets.

During Phase 2, External Power has built and tested a generation of pre-production prototypes, re-engineered them for manufacturing in volumes of 10,000 units/year, sourced parts for the first 100 production prototypes, established an initial pilot production facility for up to 1,000 units/year, and has begun to assemble the first 100 units of the production design for in-house testing and field trials in conjunction with strategic partners. In Phase 3, External Power anticipates an intensive program of field trials in the target markets of our strategic partners culminating in the introduction of products for retail sale. Thereafter, we hope to expand production beyond 10,000 units/year to serve the growing demands of our strategic partners.