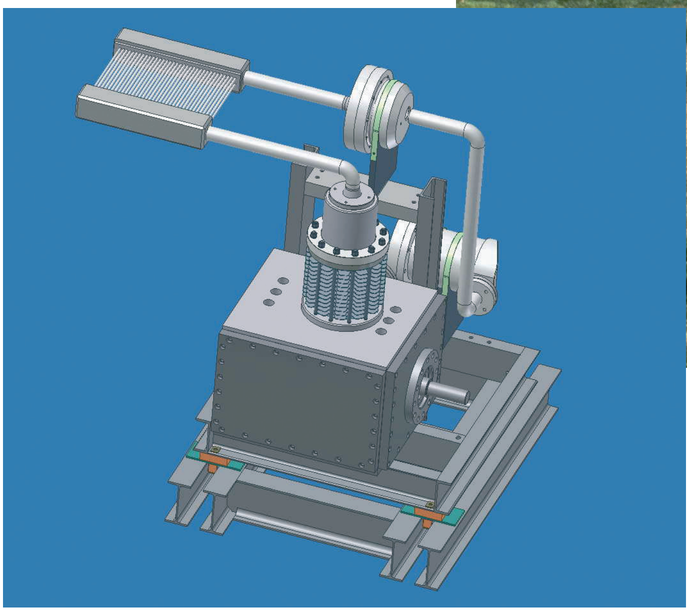
The Stirling Engine: An Alternative For Energy Production From Biomass



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Enernova Stirling : a profile

Enernova Stirling Srl is a privately held, limited liability company founded in 2003. in Verona, Italy.

Its mission: to create highly optimized Stirling-cycle engines geared to the economical production of electric power from biomasses (predominantly wood).

Its founders are Beniamino Benato, a physicist with a longstanding curriculum in the management of territorial energy agencies, and Alessandro Zuccato, CEO of Sanitaria Scaligera Spa, holder of more than a dozen patents ranging from biological research to device identification.

Above : the Managing Staff of Enernova Stirling. L to R : Alessandro Zuccato, General Manager; Beniamino Benato, Technical Director.

Beside the two founders, it employs Dr. Francisco Yepes Barrera, a computer programmer specializing in scientific computational software, and is assisted by external consultants, including Engineer Gianantonio Cestari (mechanical designer), Engineer Dr. Carlo Sordelli (agricultural agent). Engineer Simonetti, (special materials expert).

The Stirling-Cycle Engine

First patented in 1816 by Robert Stirling, the Stirling-cycle engine is an external-combustion engine, made of two parts, with different temperatures : a hot part, in which the working fluid expands, and a cold part, where the working fluid is compressed. Both expansion and compression are isothermal (i.e. the temperature remains constant).

The mechanical work done equals the net difference between the heat absorbed in the hot part during expansion and the heat released to the cold part during compression.

The Stirling-cycle engine presents several advantages with regard to internal combustion (e.g. Otto or Diesel cycle) engines or gas turbines:

- High efficiency: an ideal Stirling Cycle has the maximum theoretical efficiency.
- Low emissions.
- External combustion means no dependency upon particular fuel characteristics or particular fuel quality.
- Silent.
- Reversible.

In short, the Stirling-cycle engine can be one of the few possibilities for the economically convenient production of electric power from biomass.

That is, when several of the engineering challenges that make its practical efficiency far from its theoretical efficiency have been won.

Enernova Stirling's Project

Enernova Stirling has taken an aggressive, high-tech approach to design, using advanced optimization techniques (genetic algorithms) for dimensioning.

Engine configuration was studied for maximum thermodynamic efficiency, and designed explicitly to use biomasses as fuel.

Extensive research was done regarding operating condition and high-temperature materials, and resulted in advanced technical and design solutions.

A Genetic Algorithm(GA) is a search method used in computer science that uses techniques inspired by evolutionary biology such as inheritance, mutation, selection, and crossover (also called recombination) to gain solutions to optimization and search problems.

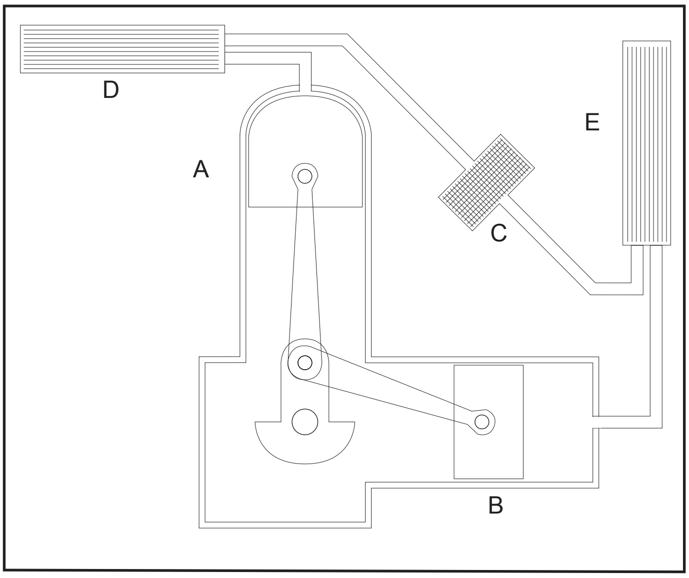
Evolution is guided by evaluating how well the results fit the simulation scenarios - in our case, how close the results were to the maximum theoretical performance values.

We used a Steady-State, Multi-Objective Genetic Algorithm with two objectives:

1) Minimizing the difference between the power generated by candidate solutions and the desired solution given as an input;
2) Maximizing thermodynamic efficiency.

The target function used by our Genetic Algorithm was the one given by well-known isothermal sizing procedures

The results were outstanding:, our GA obtained efficiency improvements 6% higher than engines designed using isothermal sizing procedures, for a given output power and working fluid.



Above : A schematic of the Enernova Stirling proposed Alpha configuration. A. Hot Cylinder. B.Cold Cylinder C. Regenerator D. Hot heat exchanger E. Cold Heat exchanger

From Paper to Steel & Beyond

Enernova Stirling proposes an Alpha configuration which ensures, in principle, a high thermodynamic efficiency.

For this purpose, two separate cylinders are used, a hot one and a cold one, to reduce as much as possible the inefficiencies due to the proximity of hot and cold parts.

As said before, the Enernova Stirling engine structure has been expressly designed to use biomass as fuel. For this purpose the combustion chamber and heat exchanger configuration have been expressly designed to work with biomass combustion exhaust fumes.

Regarding the engine power output, we find three engione configurations worth researching:

- 3-5 kWe: Home use ;
- 20 kWe: Residential / Condominial use
- 160 kWe: Industrial applications.

Enernova decided to go for the middle-sized system for its first prototype. Its working specifications are the following:

Working temperatures:	650-800°C
Mean pressure:	19.7 atm @ 800°C
Extreme pressures:	13.8 atm-28.8 atm
Speed:	600 rpm
Electrical power:	> 20 kWe
Fluid temperature in the hot part:	782 °C
Fluid temperature in the cold part:	85 °C
Carnot's Limit:	66%
Expected Engine Efficiency:	> 32%

Advantages

Enernova Stirling's engine has several advantages over the competition:

- High fuel-to-electricity transformation efficiency (>22%).
- Unsupervisioned, automated working mode possible
- Transportability (fits into two 40' containers).
- Low maintenance costs.
- Does not require expensive and complex auxiliary systems.
- Limited system cost (ca. 1800 Euro/ installed kWe)
- Long service life thanks to low rpm working regimes and high quality, high-tech materials.
- Can use other combustibles such as biogas, painting plant residual fumes, RDF (Refuse Derived Fuels), oils
- No significant environmental impact:
  - exhaust abides to low atmospheric emission laws;
  - efficient combustion creates low quantities of inert ashes;
  - silent running eliminates noise pollution
  - compact design does not waste space.

These characteristics, most notably its extremely low environmental impact, compact size and independency prom auxiliary systems make Enernova Stirling plants ideal to be located near the biomass production sites (small and medium agricultural industries, wood industry, etc.) themselves, thus avoiding heavy traffic and related pollution for the transportation of biomasses.

Added Social Value

An efficient Stirling-Cycle engine as the one proposed by Enernova Stirling has several social benefits, among which are the following :

- Transforming food farming in non-food farming, it raises farmer income.
- Producing energy locally, it favors the development of local resources and makes territory less dependent on non-renewable energies.
- It can be used in underdeveloped countries.
- It creates diffused occupation for production, sale and assistance of the systems.

What is its Market ?

We expect a market for the migration of farming from food cultures food to energetic cultures.

The short-term market is composed of medium agricultural industries that want to convert part of their productions to energetic cultures, thus raising their incomes.

A migration of 35% of food cultures in the province of Verona to energetic cultures, would open the market to about 700 160-Kwe plants in 10 years. Said plants would produce about 110 MWe, corresponding to the power used in all of the residential district of Verona.

It is reasonable to believe that the same proportion would be valid on a national and European scale.

The long-term market remains related to the conversion of biomasses to energy, (e.g. residues of agro-industrial productions and wood industry).

An important part of the market will be composed of other industries (such as painting plants, and ceramic tile industry) which want to recycle their high temperature gas residues, valorizing them.

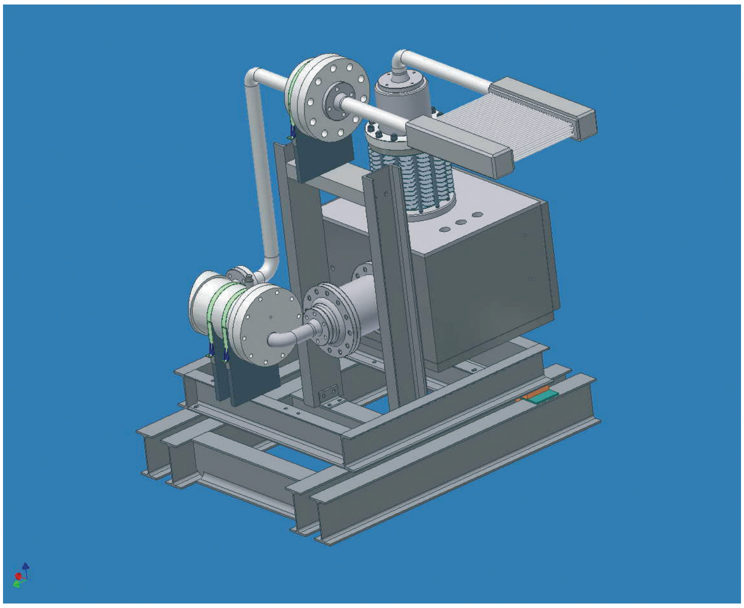
The Bottom Line

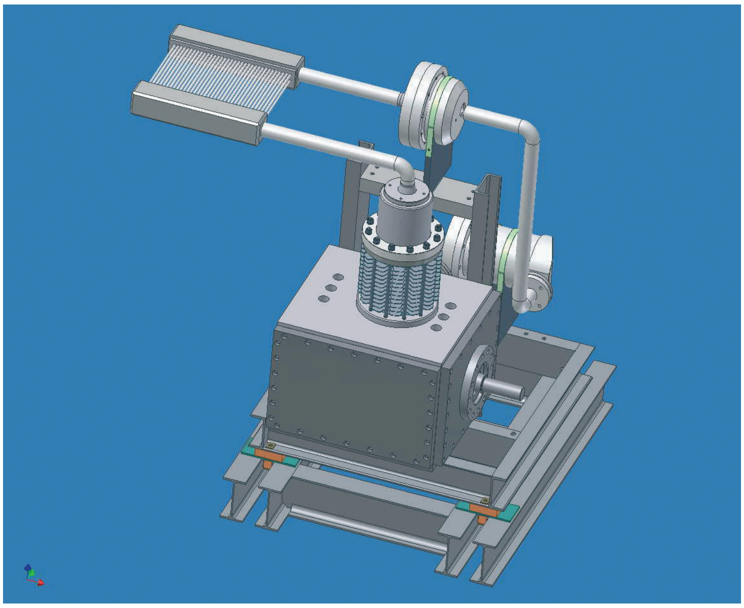
Enernova Stirling is now completing and testing a first 20 kWe prototype, and all tests and experimentation are expected to be completed by Spring 2007. An 80-kWe prototype, commissioned by the Province of Mantua, will also begin working by then.

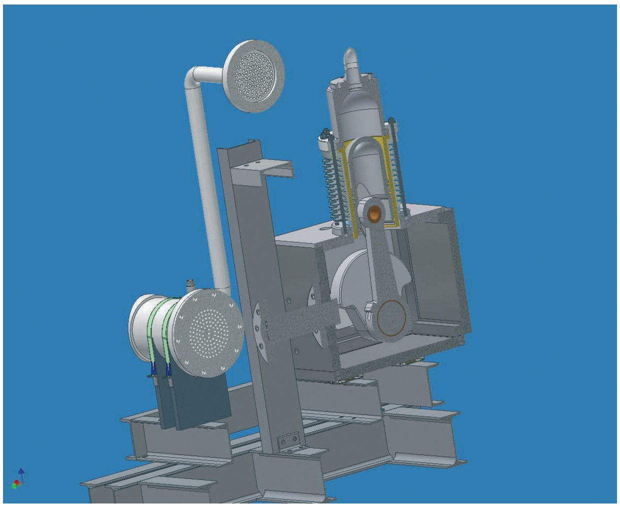
Mass production is scheduled to begin in Spring 2008, while patents are pending on several innovations introduced in designing the system.

Research needs however to be continued, as fine-tuning a Stirling engine is a very complex task, both scientifically and from an engineering standpoint. As an example, Stirling-cycle engine design is not linearly scalable. Initial funding, interely supplied by Enernova itself , is sufficient is sufficient only for forementioned proofs of concept

Enernova so requires an investor to provide additional funding to insure the momentum that's needed to bring it over the prototypal phase and on to the market.







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