P1B RESIDENTIAL MICRO-COGENERATION USING STIRLING ENGINES

Description of Technology

Distributed power refers to small-scale generation connected to the electricity grid and to generation on the customer side of the meter. It promises low cost, reliable, and efficient power and heat. Stirling Engines are promising distributed power technologies for residential micro-cogeneration. They are heat engines driven by thermal expansion and contraction of a working gas, usually hydrogen. Stirling engines use an external heat source, which simplifies design, minimizes noise and vibration, and allows multi-fuel use. These features make the Stirling engine a promising alternative to the internal combustion engine. The Stirling engine concept originated in the 1800s; however, they were unsuccessful until recently due to the high precision manufacturing processes required. Two types of Stirling engines show potential for residential cogeneration—kinematic Stirling and free-piston Stirling. The free-piston Stirling does away with mechanical linkages, resulting in fewer moving parts, no need for a lubricant, low maintenance costs, and a longer life. Kinematic Stirling engines are typically larger than their free-piston counterparts. Electric capacities for kinematic Stirling units are between 5–500 kW, while the capacities for free-piston units are between 0.01 and 25 kW.

Current Status of Measure

Internationally, several developers and manufacturers have targeted the residential sector for Stirling engine applications, supported in part by government and utility programs. Commercialization is expected in the 2003–2006 period. The emphasis to date has been on engine capacities designed to meet all or a portion of the typical electricity and heating loads required of grid-connected single detached homes. Some European companies involved in Stirling engine research include Gasunie, Gastec, Zantingh, EnergieNed, and ENECO Energie. WhisperGen is a New Zealand company promoting a natural gas 850 W kinematic Stirling unit. In the United States, two firms, Stirling Thermal Motors (STM) and Stirling Technology Co. (STC), are developing Stirling technology onsite generators in sizes upwards of 1 kW. STC offers 5 sizes from 100W to 3kW. Sunpower has developed a prototype biomass-fired 1 kW free-piston Stirling engine and expects to have a commercial model ready by 2006.

Energy Savings and Costs

The Stirling engines are 15–30% efficient in converting heat energy to electricity, with many reporting a range of 25 to 30%. The goal is to increase the performance to the mid-30% range (Krepchin 2002). Early prototypes for the kinematic Stirling cost $10,000/kW, but are expected to reach a mature price of approximately $1,000/kW by 2006. Free-piston Stirling engines are currently more expensive (Sunpower's 1 kW prototype cost $35,000); however, the mature market price is expected to be between $500–1,000 per kW. Stirling engines are expected to run 50,000 hours between overhauls, and free-piston Stirling engines may last up to 100,000 hours (Krepchin 2002).

Key Assumptions Used in Analysis

This analysis assumes 25% electricity conversion efficiency and a 40% waste heat recovery efficiency for space heating and DHW. The analysis assumes an average 1,800 ft^2 house with an annual electricity consumption of 12,338 kWh/year and total space heating and DHW consumption of 89 MMBtu/year. This analysis also assumes a mature cost of $1,000/kW plus overhaul and maintenance costs of 3 cents/kWh.

Recommended Next Steps

Both technical and institutional issues need to be addressed for Stirling engines to be accepted in the residential market. Governments and utilities need to collaborate in dealing with barriers pertaining to connection and integration with the distribution system. Standardized building codes, permit procedures, and electrical interconnection standards are necessary to boost end-user acceptance. Technically, there is a need for continued support to help developers work to lower first costs through a combination of design refinements and material substitution.

P1b Residential Micro-CHP Using Stirling Engines

Description	non-renewable, <10 kw CHP using Stirling Engines		

Market Information:

Market sector	RES		
End-use(s)	OTH		
Energy types	GAS		
Market segment	RET, NEW		

Basecase Information:

Description	2,000 sqft average new house		
Efficiency			
Electric use	12,338	kWh/year	avg EUI
Summer peak demand	2.8	kW	50% load factor
Winter peak demand	1.4	kW	base load
Gas/fuel use	89		avg EUI

New Measure Information:

Description	2 kW Stirling engine with waste heat recovery with a 60% time availability		
Efficiency	65%	overall; 25% elect. + 40% heat recovery	
Electric use	950	kWh/year	net purchased household electricity
Summer peak demand	1.0	kW	90% availability on peak
Winter peak demand	-0.4	kW	90% availability on peak
Gas/Fuel use	115.9		Net gas consumption for power genration plus heating
Current status	PROTO		
Date of commercialization	2006		
Life	10	years	

Savings Information:

Electricity	13,288	kWh/year	avoided purchased electricity
Summer peak demand	1.5	kW	
Winter peak demand	1.5	kW	
Gas/Fuel	-27	MMBTU/year	Increased gas purchases
Percent savings	50%		Savings in primary energy
Feasible applications	1.3%		2% of new construction and 1% of existing stock
2020 Savings potential	22,249	GWh	
2020 Savings potential	201	TBtu (source)	
Industrial savings > 25%	YES		

Cost Information:

Projected Incre. Retail Cost	$3,000	2003 $	$1,500/kW
Other cost/(savings)	$266	$/year	maintenance and overhaul cost of 2 cents/kWh
Cost of saved energy	$0.06	$/kWh	
Cost of saved energy	$5.53	$/MMBtu	
Data quality assessment	C	(A-D)	

Likelihood of Success:

Major market barriers	New way of doing business, incremental costs, reliability, dwindling natural gas suppleis		
Effect on utility	Increased equipment maintenance		
Current promotion activity	Initial field protype trials		
Rating	2	(1-5)	
Rationale	Increased natural gas costs make economics less attractive		

Priority / Next Steps

Priority	Low		Unless economics improve
Recommended next steps	Reduce product costs, new electrical rate structure to encourage residential co-generation		

Sources:

Savings	Reiss, Krepchin et al, 2002
Peak demand	Brown & Koomey 2002
Cost	Reiss, Krepchin et al, 2002
Feasible applications	Marbek estimate
Measure life	Marbek estimate
Other key sources	Hedman 2002
Principal contacts	
Notes	