Fostering innovative solutions to Alaska's energy challenges through applied energy research at the University of Alaska

RSA 0925: TASK ONE FINAL REPORT

PREPARED FOR THE ALASKA ENERGY AUTHORITY
BY
THE ALASKA CENTER FOR ENERGY & POWER

PROJECT TITLE: Test Evaluation of Organic Rankine Cycle Engines Operating on Recovered Heat from Diesel Engine Exhaust

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PROJECT OBJECTIVE: The objective of this project is to perform laboratory and field tests on a system to capture waste heat from diesel generators for rural applications.

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PROJECT INTRODUCTION

The objective of this project is to investigate and demonstrate the economics and reliability of applying diesel engine waste heat for power generation for rural Alaskan villages. The project includes three stages: the preparation, initial testing, and field demonstration. Preparation includes procurement experiment and system selection. The initial testing conducts system performance test under controlled environment for system parameters study on optimization and preliminary evaluation on reliability and economic issues. Field demonstration, which deals with real world reliability and economic issues, includes system performance, economic and reliability analyses pertaining to the waste heat power system operating on a village diesel generator set. Currently, the work is in the second stage of the project.

TASK ONE OVERVIEW: THE PROCUREMENT EXPERIMENT

With the completion of this report, the preparation stage has been completed. The result of Task 1: Assessing Product Availability is provided here, which was completed by Jared Kruzek with the Alaska Center for Energy and Power in the fall of 2008. The procurement experiment report includes a survey of all companies which manufacture low temperature heat for power generators which are known and accessible through internet and telephone systems. The survey covered three types of thermal system; Organic Rankine Cycle (ORC), Kalina Cycle (i.e. ammonia/water absorption system), and Stirling Engine.

In the Procurement Experiment, operation principles and technology development history of ORC system, Kalina system, and Stirling engine and their current industrial applications have been briefly introduced. The survey covered general product information of nine ORC system companies, seven Kalina system companies, and two modified Kalina system companies.

A synthesized review of findings, considering the products which best fit the diesel engines used in rural Alaskan villages, is provided in a table (Table AI) included in the report. Nine ORC companies, two modified Kalina cycle companies, and a Stirling engine company and their products information are listed in details in the table. Information listed in the table is based on the categories of company name, power generation capacity, power generation unit cost or per kW cost, lead time, contact points, and comments. Comments are mostly related to current status of the particular units mentioned in the table.

The Stirling engine is a closed cycle thermal system, which is flexible in fuel source, quiet in operation, and efficient in theory. In practical application, the Stirling engine is known to be hampered by high cost and low power density. Therefore, it is not considered as a candidate for this project.

Next Steps – Verifying the Performance

After detailed discussions with some of the potential low temperature power system manufacturers, the waste heat unit selected was an absorption power system from Energy Concepts due to its potential for increased efficiency and ability to secure a physical system in a timely fashion compared to other products. In addition, Energy Concepts earned credentials from cooperative demonstration projects with some Alaskan villages in ammonia-water absorption refrigeration systems, of which the system design and components needed are similar to the ammonia-water absorption power system. Preparation of the test site and plan for the laboratory verification is now underway.

Task 1 Report: Assessing Product Availability
Fall 2008

Introduction

With today's energy environment, people are looking at various means to lower their energy bill. Some of these technologies exist in the market as cost effective options and others require further development before they are economically and technically viable. Waste heat recovery at an industrial level is a proven technology with many examples currently deployed to successfully increase the efficiency of power plant operations.

Recovering the waste heat from diesel engines, on the other hand, is not a mature field. While the technology exists, there are limitations in developing a product that produces a positive net energy. Because the waste heat is a low energy source it is easy for parasitic power from the recovery unit to be higher than what is being produced. There are companies currently investing in solutions, but more work needs to be done to provide cost effective solutions in both small and large scale applications.

For purposes of this report, three main technologies were examined, the Organic Rankine Cycle, the Kalina Cycle and the Stirling Engine. The basics of these technologies will be examined along with a more detailed look at the companies involved in producing each and the status of their product.

Organic Rankine Cycle

Diesel engines lose about 30-40% of their energy through exhaust. Organic Rankine Cycles (ORC) look to utilize this low temperature heat source to improve the overall efficiency of the engine or produce electricity directly. Some experts estimate the efficiency of an ORC unit to be approximately 10-20%, which would improve the overall engine efficiency by about 3-5%.

An ORC unit works similar to a traditional steam Rankine Cycle. A working fluid is pumped through a heat exchanger where it is vaporized and passed through a turbine and re-condensed. The process is then repeated. The major difference is in the working fluid. The traditional Rankine Cycle uses H_2O as its working fluid which has a high boiling point. Since the waste heat from the engine is a low temperature source, water will not work, so an ORC unit uses an

organic fluid as its working fluid. The choice of the working fluid will depend on the heat source. Many companies produce their own special blend that allows them to capture heat at low temperatures.

ORC units have been installed in various places around the world. Ormat, a leader in the ORC technology, has units in North America, Europe and Asia[1]. These units, however, have been installed on industrial scale application, ranging from 200 kW to 22 MW. For use on smaller diesel generators which are relevant to Alaskan applications, a unit less than 100 kW should be assessed. Not many units have been built at this size, although there are a few companies making progress to manufacture devices that can operate on a smaller scale.

In order to understand the current state of this technology this report reviews each company individually. The purpose of this report is to focus on a review of the facts provided through each company's website and personal contact with company representatives and includes no assessment of those facts.

ORC Companies

After a thorough web search, nine companies were reviewed that use ORC technology in their products. Some of these companies specifically target waste heat from diesel engines while others were broader in their application. The companies reviewed were Global Energy, Barber-Nichols, ElectraTherm, TransPacific Energy, Deluge Inc., Ormat, Turboden, UTC Power and GMK.

Global Energy
Global Energy, a Madison, WI company under the leadership of Greg Giese, has developed the Infinity Turbine®, an ORC turbine built for waste heat and geothermal applications. While there are numerous potential uses for this turbine, one that is specifically being targeted uses diesel engine exhaust. According to the website, the Infinity Turbine consists of a single skid-mounted assembly that fits in the standard 20 or 40 foot ISO standard shipping container. All the equipment required for the power skid to be operated (i.e. heat exchangers, piping, working fluid feed pump, turbine, electric generator, control and switch-gear) fit into the container.

In mid-July 2008 a 30 kW unit and an 80 kW unit were being built in Toronto. By July 29, 2008 the 30kw unit had been sold to a geothermal project in Casper, WY. Data analysis of this device was anticipated in fall 2008. While the website lists some performance specifications, these were only theoretical calculations to be verified by the test site in Casper, WY. A price of $60,000 was quoted over the phone for the 30 kW unit although it is not known how much the device sold for to the geothermal plant in WY. A delivery time of 11 weeks was quoted, presumably from day of purchase.

Barber-Nichols
Barber-Nichols is a leader in the field of turbomachinery. Thermodynamic Cycle Systems including the Organic Rankine Cycle and the Steam Rankine Cycle are part of their core competency. They have experience building waste heat applications but on an industrial scale. These units are too large to be used with diesel engines but they demonstrate that Barber-Nichols is competent in the technology.

They are currently working with some Canadian companies to develop smaller units that could be used with diesel engines. However, since these are custom designed units based on the size of the generators, an interested buyer would need to send in specifications regarding their application before construction could begin. During a phone conversation with a company representative a price range from few hundred-thousand dollars up to $1M was put forward as an estimate of the total cost, including initial research, NRE, and unit itself.

ElectraTherm

Nevada based ElectraTherm launched an ORC unit that captures waste on a smaller scale and have plans to produce units ranging from 30-500 kW. It is not clear how many units have been sold and field tested, but one unit at Southern Methodist University in Dallas, TX was known to be undergoing field tests. It is likely that this is their only operational unit. This device was demonstrated at the Geothermal Conference at SMU in June of 2008. A researcher from the Alaska Center for Energy and Power at the University of Alaska, Fairbanks traveled to the conference to view the unit. Concerns about the readiness of the product were raised during this visit. Currently, SMU is not planning to purchase the unit after the testing phase ends. The latest price that was available was $2400-$2700 per kW.

TransPacific Energy

This Nevada based company is developing a heat recovery/energy conversion system using ORC technology. The company's website indicates their system can use heat sources at temperatures as low as 80°F and up to 900°F. This is a larger range than most other ORC units which are typically limited to a low temperature of around 200°F. TransPacific Energy states their unit can operate at lower temperatures because of their own specially designed refrigerant which they believe is their key advantage over competitors.

In an email response from Jim Olsen, a company representative, it was revealed that they do not actually have any units installed yet as they are a new company. It is not known if the specifications listed are based on theoretical calculations or measured results. The company website provides additional data about the sizing of their units:

Systems are sized from 20 kW up to 20 MW+ modules, containing all the equipment required for the units to be operated (i.e. heat exchangers, piping, working fluid feed pump, turbine, electric generator, controls and switch-gear). Larger units are composed of multiple modules, pre-assembled at the factory.

The price for a 115 kW unit was quoted up to $250,000 for the complete unit. Delivery time is expected to be 6-9 months depending on their fabricator, Concepts NREC, based in Massachusetts.

Deluge

The Deluge Natural Energy Engine is not an ORC unit but rather a thermo hydraulic engine that produces mechanical energy by heating a fluid so that it expands and moves a piston. The heat source can be solar, geothermal, or waste heat. The main components of the engine are the piston/cylinder and the heat transfer system. The cylinder contains the piston and the working fluid, usually $C0_2$. The heat transfer system is made up of heat exchangers and corresponding system to circulate the heat exchange fluid, usually H_2O. A three step process creates a back and forth movement of the piston to generate mechanical energy.

The technology has been independently verified by university and government studies. In an email from company representatives in July 2008, they report completion of their first 250 kW

unit which was being shipped to a location in Hawaii for installation. They believe 250 kW can be produced from a 150 gpm flow of water at 190°F and that the cooler temperatures needed with their unit eliminates the need for the radiator cooling. The price for a 250 kW engine/generator set is $400,000 when purchasing a single unit. The delivery timeframe given was 90 days from purchase order.

Ormat

Ormat is the world leader in ORC technology. They have successfully installed ORC units around the world. They specialize in Geothermal Power, Recovered Energy Generation, and Remote Power Units. Their units range from 200 kW to 22 MW for the Recovered Energy Generations units for waste heat recovery. Their remote power units range in size from 200-4500 watts. When given the specifications for a 125 kW diesel generator, the company indicated that the application was too small for their Recovered Energy Generation units. Currently, Ormat is assessing the development of a smaller unit that could be used with diesel generators, but as of this report, none are available.

Turboden

Turboden is an Italian company that specializes in ORC technology. They have combined heat and power systems in established sizes ranging from 200 kW to 2000 kW. They also have heat recovery systems that range from 500 kW to 1500 kW. The company can also build custom sizes but currently do not manufacture any under 500 kW for applications requiring a single unit. They have installed many units, mostly in Europe and in the biomass industry. The company did not respond to emails so there are few cost and delivery details. However, the company was recently purchased by United Technologies Corporation and may be available in the U.S. soon.

UTC Power

UTC Power is a division of United Technologies Corporation based in Connecticut. They provide environmentally responsible power solutions and have recently developed an ORC unit. The PureCycle® Power System is an electric power generating system which runs off any hot water resource at temperatures as low as 195°F. The hot water can be derived from a geothermal source or other waste heat source.

Currently this ORC unit is sized at 280 kW (gross) of electrical power. One of these is commercially running at Chena Hot Springs Resort in Alaska and they have sold 75 units to date. The average price per kW is $1250 with a delivery time of 8 weeks. They are currently working on a 1 MW unit to be completed in the early part of 2009. There are also plans underway for a possible smaller unit with the size to be determined.

GMK

Gesellschaft für Motoren und Kraftanlagen (GMK) is a leading ORC-module developer and producer in Europe. They have three different product applications. Their INDUCAL is an ORC

unit used in power plants to recover waste heat. The electrical output of these units varies from 0.5-5.0 MW. The two other products are GEOCAL and ECOCAL which use geothermal energy and biomass respectively to produce electrical power in similar amounts as that of the INDUCAL. GMK has various installations of all three products currently underway in Germany. The company appears to be focused on larger, industrial power plants rather than on units that would be useful in heat recovery from small diesel generators.

Table AI has a summary of each of these companies with some notes of interest.

The Kalina Cycle

The Kalina Cycle was developed by the Russian engineer Aleksandr Kalina in the early 1980s. It is a thermodynamic cycle that allows thermal energy to be converted to mechanical power which can then be used to create electrical power. Its functionality is similar to the ORC with one major difference: the Kalina Cycle uses a mixed binary working fluid. Usually the fluid is a mixture of ammonia and water which allows for a broader range of boiling points since ammonia has a much lower boiling point than water. Studies show that the Kalina Cycle performs better than the Organic Rankine Cycle at moderate pressures. Some scientists believe it is more efficient than the Organic Rankine Cycle in general, but more testing needs to be done to support this claim.

Commercially tested Kalina Cycle units are not common, with only a few having ever been built. One of those units is being used in a geothermal power plant in Iceland. In addition, there are two plants in Japan, one a waste heat plant and the other a waste-to-energy demonstration plant where the Kalina Cycle was used.

The first demonstration of the technology was in California, which proved successful. Currently the geothermal plant in Iceland and the steel mill waste heat power plant in Japan are still in operation.

TDX Power recently received a grant from the Alaska Energy Authority to install a geothermal power plant at Manley, Alaska using a Kalina cycle unit developed in Japan.

Kalina Cycle Companies

The companies involved previously in this technology have gone through various mergers and acquisitions and today there is currently only one company with technological rights to the Kalina Cycle. Global Geothermal was created in 2007 and now owns all those rights as well as

the over 200 international patents associated with the proprietary technology. They are a licensing company and sell the rights to the technology to companies for use in power plants or other applications. The following is a more detailed look at the companies that made up Global Geothermal and some of the companies currently licensing the technology.

Original Company: Exergy

In 1992, Exergy, the company founded by the inventor of the Kalina Cycle, Aleksandr Kalina, saw the first Kalina Combined Cycle power plant go online at Canoga Park, CA. The 6.5 MW Canoga Park power plant was built as a demonstration plant to prove the technology was commercially viable. The plant ran until 1997 and was deemed a success. Useful data was gathered demonstrating that the Kalina Cycle is an efficient way of generating power. Generating as both a waste heat power plant and a combined cycle power plant, it was designed to be tested at extreme conditions. In total the plant logged about 9,000 hours of operation over its five year life span, which corresponds to about 21% availability. [2]

In 1997 Exergy teamed up with Ebara Corporation, a Japanese company that specialized in advanced industrial systems, to build another demonstration plant in Fukuoka, Japan. [3] This demonstration was a 4.5 MW waste-to-energy plant that ran from 1998-1999 and was again seen as a success. [4]

In 1998 another project started at the Sumitomo Metals Kashima Steelworks in Kashima, Japan as a waste heat recovery application. This was the first commercially installed Kalina Cycle power plant and is currently still running. The 3.4 MW plant has exhibited a high rate of availability and utilizes 208°F (98°C) hot water.

Combining of Licensees

It is not clear how all the mergers and acquisitions occurred regarding the rights to the Kalina Cycle, but there is basic data on how this industry has evolved.

Recurrent Engineering

Recurrent Engineering became a global licensee in 2002. They are owned by Wasabi Energy. No data is available as to what they did with the technology from 2002 to 2007, but in 2007 Global Geothermal was created to buy up Recurrent Engineering and Exergy and to consolidate other companies licensed to use the Kalina Cycle worldwide. Wasabi had been in some disagreements with their co-venturer, AMP Capital Partners LLC as to how to handle the Kalina Cycle technology and the solution was to incorporate Global Geothermal, which is owned 70% by Wasabi and 30% by AMP

Global Geothermal

Due to these changes in the industry, Global Energy now owns all the rights to the Kalina Cycle as well as the over 200 international patents associated with it. The company's primary business

model is to license the technology for up-front fees as well as follow-on fees bases on size and use of the licensee's power plant. They also provide engineering services, equipment procurement, and project management services through their subsidiary Recurrent Engineering

Current Licensed Companies

A number of companies have received licenses from Global Geothermal or the previous companies with licensing power, and are working with Global Geothermal to make the best use of the Kalina Cycle technology.

Exorka

A geothermal energy company in Iceland, Exorka specializes in low temperature geothermal sources. In 1999 they built the first geothermal power plant using the Kalina Cycle in Husavik, northern Iceland. According to their website the plant produces 2MW of power from a flow of 90 kg/s at 248°F (120°C) geothermal brine. Exorka acquired the rights to the Kalina Cycle in 1999, with these rights extending to Iceland and most of Western Europe. They are currently in the late development and finance stages of five projects in Germany. Each project is about a 5 MW binary geothermal power plant. It is expected that these projects will come online in 2010.

Geodymanics

Geodynamics is an Australian geothermal energy company which focuses on enhanced geothermal energy. In 2004 they acquired the rights to use the Kalina Cycle technology in Australia and New Zealand. As of this report, they do not have a plant running that uses the technology. In 2007 they merged with Exorka to form Exorka International Limited.

Raser Technologies

A publically-traded technology licensing company, Raser, was formed in 2003 with a goal to improve the efficiency of rotating electromagnetic and heat transfer applications. They are also involved in the geothermal energy industry as well as waste heat recovery with the goal to make the technology as efficient as possible using their skill and technological knowledge in heat transfer and motors. To this end, they became a Kalina Cycle technology licensee in 2006. Raser controls large amounts of geothermal land in Nevada and Utah where they are developing a 20 MW binary geothermal plant. They also are working on a 10 MW geothermal plant in New Mexico. The plan is for these plants to go online in 2010. Raser not only has Kalina license rights to geothermal applications but also to industrial waste heat applications. They are working closely with Recurrent Engineering to use Kalina technology in waste heat projects in both the US and Europe, primarily in the cement industry. Most recently, however, Raser has invested in the UTC 280kW unit, purchasing 75 units for installation at a site in Nevada. This project has been completed, but there are rumors of some issues related to the resource at the site.

Siemens

A well known Germany engineering firm, Siemens purchased Kalina Cycle license rights in 2000 and is able to use them for geothermal power projects in Germany, up to a total of 10 MW in size. Even before it gained the rights to the technology, Siemens was involved in evaluating and testing it. They have been working with Recurrent Engineering to complete the construction of the first Kalina power plant in Europe. The 3 MW plant was completed in December 2007 as a binary geothermal project built as a turn-key project for the City of Unterhaching, Germany. Siemens will provide long term O&M for the plant. The plant was expected to go through commissioning and acceptance testing during the first quarter of 2008 and come online in mid-June 2008. It is expected to have a lifetime of 30-plus years. Siemens is looking to add more plants in the next decade and currently has two more contracts for turn-key power plants in Germany.

Other Companies Related to Kalina Cycle

There are a few companies that do not fit into the above breakdown but are either using Kalina Cycle Technology or something very similar. They are discussed below.

Energy Concepts

Energy Concepts is a Maryland based engineering company that focuses on heat-activated absorption systems and the associated fluid contact equipment. The Absorption Cycle was invented by Ferdinand Carre in 1846. The idea is to take heat out of a system by running a cycle that uses a heat input. When ammonia is absorbed in water the vapor pressure decreases, and so according to the laws of thermodynamics, the temperature will drop also, *ceterus paribus.* The absorption cycle has the benefits of requiring little electric input and using natural substances, ammonia and water, instead of halocarbons. Although this is not a true Kalina Cycle, it takes advantage of the properties of the binary fluid made of ammonia and water.

Energy Concepts has devised a way of using this cycle to convert exhaust heat from prime movers to electric power. The Heat Activated Dual Function Absorption Cycle is capable of taking a heat source ranging from 250°F to 750°F to and converting it to electric power, refrigeration and/or air conditioning. According to the company website, when using the Absorption Cycle a 1 MWe gas turbine with an exhaust temperature of 750°F can produce 400 kW. Company literature indicates this cycle works well with distributed power generators sized from 1 to 15 MWe.

Rexorce

An Ohio based thermal energy company, Rexorce is looking to find ways to better harness existing thermal resources and also to recover waste heat and use it efficiently. They have developed a thermal engine, Thermafficient, which is designed to recover thermal energy from a range of sources and convert it into electric power, cooling and heating. Rexorce's engine uses supercritical CO_2 and other working fluids for their power generating cycle. This binary fluid cycle has many of the same benefits as that of the Kalina Cycle. According to information from a

company contact, they are working on a 250 kW generator and claim 25-30% efficiency when working in diesel exhaust at 500°F. As of this report, they were still working on the expansion device and hope to have it completed by January 2009. The price for the unit is expected to cost less than $1500 per kW. With a higher volume of orders that price could drop significantly.

Stirling Engines

The technology for Stirling engines dates back almost 200 years. First developed by Reverend Dr. Robert Stirling in 1816, they have recently made resurgence as a useful technology. These engines are a closed-cycle regenerative heat engine. The working fluid is in gaseous form which becomes heated by an external source. They have been used primarily in small, low power applications for the past two centuries. One of the things of note about this engine is its theoretical perfect efficiency. However, in practice this has been an allusive goal, and much work remains to achieve the theoretical results. The efficiency is limited because of non-ideal properties in the working fluid and as well as losses due to engine material properties. Sterling engines also have potential to run more quietly than a normal internal combustion engine and to require less O&M. They are best utilized in applications where the primary concern is to minimize the cost per unit of energy generated ($/kWh), instead of the capital cost per unit power ($/kW). Thus, they are competitive with other technologies when sized up to about 100 kW. Although they have higher capital costs and are often larger and heavier than an internal combustion engine with the same power rating. They require less maintenance and over the unit's lifetime the costs are about the same. Current uses of this technology vary from waste heat recovery to solar power generation. Stirling engines do not require significant external energy for operation which is advantageous for recovering waste heat.

Notes

1. *Ormat*. 2007 [cited 2008 July 11]; ORCs for geothermal and waste recovery.]. Available from: http://www.ormat.com/businesses.php?did=73.

2. *Kalina History*. 2007 [cited; Canoga Park power plant info]. Available from: http://www.geodynamics.com.au/irm/ShowStaticCategory.aspx?CategoryID=236&HideTopLine=True&shareprice=Hide.

3. *"Ebara and Exergy team to build first Kalina Cycle Power Plant; The Largest Japanese Environmental Engineering Company and California Energy Technology Company Begin Construction on First Kalina Cycle Power Plant in Japan".* Business Wire. Feb 4, 1997. FindArticles.com. 13 Aug. 2008. http://findarticles.com/p/articles/mi_m0EIN/is_1997_Feb_4/ai_19087052.

4. *Kalina History*

Table AI
Waste Heat Recovery Companies

Company	Unit	Price	$$/kW	Delivery	Contact Info	Current Status/Notes
ORC Units						
Global Energy	30 kW	$60,000	$2,000	11 weeks	Greg Giese; greg@infinityturbine.com	30 kW unit sold, expected to be online within by September 2008.
	80 kW	No price quote	N/A	11 weeks		As of July 14, 2008 being built in Toronto
Barber-Nicholes	custom	$200K - $1M	N/A	N/A	David K.; davidk@barber-nichols.com;	Would require a custom design. It is unclear how long this would take for a unit to be delivered
ElectraTherm	30-500 kW	Depends on size	$2,400-$2,700	N/A	Bill Olsen; bolson@electratherm.com	Unit must be proven before it becomes commercially viable
TransPacific Energy	115 kW	$250,000	$2,174	24-36 weeks	Jim Olsen; jolson@transpacenergy.Com	No units installed, only designs.
Deluge Inc.	250 kW	$400,000	$1,600	13 weeks	Brian Hageman; bhageman@delugeinc.Com	Not ORC but thermal hydraulic engine. Built first 250 kW unit and is being installed in HI.
Ormat	> 200 kW	No price quote	N/A	N/A	Colin Duncan; cduncan@ormat.com	As of now recovering heat from a diesel generator is not available. They are looking into it though for the future.
Turboden	>200 kW	No price quote	N/A	N/A	info@turboden.it	Unable to reach Turboden so details are limited.
GMK	0.5 - 5.0 MW	No price quote	N/A	N/A	info@gmk.info	Focus on industrial power plants
UTC Power	280 kW	350,000	$1,250	8 weeks	bierderbp@utc.com	Commercial unit of Chena Hot Springs unit. 75 units sold to date. Working on 1 MW unit to be complete in early '09 and plan on possible smaller unit.

Modified Kalina Cycle Units						
Energy Concepts	400 kW absorption cycle	No price quote	N/A	N/A	Don Erickson	Not clear if a specific unit is available or if their product would be custom designed per application
Rexorce	250 kW Thermal Engine	No price quote	$1,500	N/A	Michael Gurin 847-962-6180	Modified Kalina Cycle. Expect to be completed in a few months

Stirling Engine						
ReGen Power	500 kW	No price quote	$1000 - $2000	N/A	Dick Meloy: 203-328-3045	3 months into 18 months development cycle. Hope to have 10 kW prototype at end of 2008. Also hope to have 250 kW and 1MW units in furute.