Delta-T Wood Stove Generator™ Project

AEA Emerging Energy Technology Fund Grant Application AEA-2014-007

1. Project Title: Delta-T Wood Stove Generator™ Project

2. Applicant Contact Information:

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3. Partners: No partners

4. Total Project Cost; $442,100
Grant Funds Requested: $293,700
Match Committed: $148,400

5. Previous project/application title(s)

2012
Delta T Wood Stove Generator Project
AEA-12-047 Emerging Energy Technology Fund
Did not receive grant

I. Project Summary

A. Project Description

The Delta-T Wood Stove Generator™ is a thermoelectric generator for use on wood burning stoves. It harnesses the temperature differential between the hot flue gas in the stove pipe and the cooler air of the room to generate electricity whenever the stove is burning.

The Delta-T Wood Stove Generator™ is designed to replace the first section of stovepipe on a woodstove. It is a simple plug and play style device requiring minimal maintenance. Operation is automatic once the device is installed. By placing thermoelectric generator modules in a position of maximum thermal differential within the device between a specialized heat exchanger in the flue gas stream and high efficiency air cooled heat pipe coolers above, the device efficiently generates about 100W of power continuously and over 1 kWh per day. In order to increase the temperature of the flue gas and thus the power output of the device an automatically damped catalytic converter is fitted in the generator below the heat exchanger. The position of the heat exchanger directly above the hot catalytic combustor allows it to stay free of thermal transfer inhibiting soot buildup which hampered previous attempts at wood stove thermoelectric power generation. The smart catalytic converter or SmartCAT™ provides the added benefit of improving stove efficiency and reducing stove emissions as it re-burns the smoke exiting the stove. By automatically diverting the flue gas into or around the catalytic element based on the temperature of the flue gas the SmartCAT™ also eliminates user error induced catalytic element failures caused by fouling or thermal shock previously associated with catalytic converters on wood stoves.

The project will build and extensively test two generations of prototypes of the Delta-T Wood Stove Generator™. The first prototype is currently under construction at Alaska Dynamics. During the project second generation prototypes will be built and tested in-house at Alaska Dynamics. The data collected during testing will be used to refine the design. Third generation prototypes incorporating the design changes from the second generation will be built by Alaska Dynamics and tested in the field in a variety of environments in Alaska. The data collected during field testing will be used to further refine the final design. The goal of this project is to bring the product to market at the end of the two year project. The Delta-T Wood Stove Generator™ will supply wood heated homes in Alaska with a clean supplemental energy source increasing energy independence and reducing power consumption from non-renewable fuel resources.

The Delta-T Wood Stove Generator™ Project satisfies all three criteria of AS 42.45.375(c). The proven core technology of the product, thermoelectric generator modules, have existed for many years but will be deployed in this device in a new and novel manner increasing wood stove combustion efficiency and generating power thereby *testing an emerging energy technology* as well as being a *method of conserving energy* (1). It *improves an existing energy technology* (2), the wood stove, by increasing wood combustion efficiency, reducing emissions, and generating power. And finally the Delta-T Wood Stove Generator™ project will *deploy an existing technology that has not previously been demonstrated in the state* (3), thermoelectric power generation applied to wood stoves.

The Delta-T Wood Stove Generator™ satisfies 3AAC 107.715 (1), above. It qualifies as an *"energy technology"* under AS42.45.375(j)(2) as it *enhances an available energy supply source*, wood, by generating power during wood stove combustion. The device *increases energy efficiency* by generating power during combustion as well as taking advantage of an advanced catalytic converter that increases combustion efficiency and *reduces negative energy-related environmental effects* by reducing combustion emissions. The Delta-T Wood Stove Generator™ is an *"energy technology"* that *relates to renewable sources of energy*, wood, and promotes the *conservation of energy* by reducing power consumption from non-renewable energy sources.

The Delta-T Wood Stove Generator™ is currently at a TRL level of 5 with the first prototype construction almost complete. With the exception of the device shell and heat exchanger all of the parts that compose the Delta-T Wood Stove Generator™ are off the shelf components. These individual components are all well established and tested technologies. The Delta-T Wood Stove Generator™ project will integrate these components into a system. During the course of the project the Delta-T Wood Stove Generator™ will progress to a TRL level of 9 with a well tested and refined design, ready for market.

B. Project Innovation

The Delta-T Wood Stove Generator™ is a novel approach to utilizing thermoelectric power generation on wood stoves. The pitfalls that hampered previous attempts to apply both thermoelectric power generation and catalytic combustors to wood stoves are addressed in this design. The Delta-T Wood Stove Generator™ is innovative in providing a source of power generation from a heat source present in many Alaskan homes that is currently not being utilized for this purpose. Power generation that is particularly valuable to rural Alaskan homes that use wood as a primary heat source. An added benefit from the catalytic combustor it utilizes to increase its power output is the improved combustion efficiency, and reduced emissions a catalytic combustor offers. The cooling system on the device also serves to transfer heat normally lost in the flue gas to the air of the room while circulating it at the same time. By generating power, improving stove efficiency, and reducing stove emissions the Delta-T Wood Stove Generator™ offers an innovative improvement to existing wood stove installations.

C. Project Site and Demonstration Environment

The project site will be a shop space rented by Alaska Dynamics in Anchorage, Alaska. Alaska Dynamics will provide the grant administrators with appropriate documentation demonstrating legal access and control of the facility as required in 3 AAC 107.710. Theo Graber also owns the intellectual property rights to the Delta-T Wood Stove Generator™. The site will have all of the necessary equipment and tools for the design, construction, testing, and development of the Delta-T Wood Stove Generator™. Design work will be handled in house with Autodesk Inventor CAD software allowing for advanced 3D modeling and simulation reducing the amount of time spent on physical prototyping. Parts to construct the prototypes will be fabricated from these digital designs. With the exception of the shell, central heat exchanger, and catalytic combustor diverter all of the parts for the Delta-T Wood Stove Generator™ are off the shelf parts. The prototypes will then be assembled in the Alaska Dynamics facility. The assembly of the electronic components for the control system and the wiring for the device will be accomplished in house at Alaska Dynamics as well. Once assembled the prototypes will be installed on the test bed wood stove in the Alaska Dynamics shop, fitted with an operational sensor array, and extensively tested and analyzed. Operational data collected will be analyzed by Alaska Dynamics and used to refine and improve the design. During the field testing phase third generation prototypes will be tested on wood stoves in homes and cabins in Fairbanks, Anchorage, and Juneau Alaska to provide three representative testing environments.

D. Priority

The Delta T Wood Stove Generator™ Project addresses the priority considerations in the following ways.

1.) Alaska Dynamics, LLC is an Alaskan owned and operated company.

2.) The project does not currently have any kind of partnership with the University of Alaska or another Alaska post-secondary institution.

3.) The project is supported by matching funds. Alaska Dynamics, LLC is contributing $30,000 in cash and $118,400 of in-kind labor.

4.) The potential market within the state is widespread. The Delta-T Wood Stove Generator™ will be desirable for both on and off-grid installations. According to 2010 US Census data an estimated 8,632 homes in Alaska use wood as their primary source of heat. Many thousand more use wood as a secondary heat source and would benefit from the supplemental power output of the Delta-T Wood Stove Generator™. The market for the Delta-T is much wider than just Alaska however.
As of 2010, 2.1 percent of US homes, or about 2.40 million households, use wood as a primary heat source, up from 1.6 percent in 2000. About 10 to 12 percent of American households use wood as a secondary heat source according to the Census Bureau and the EIA.

5.) The Delta-T Wood Stove Generator™ project qualifies as both a Co-generation and a heating efficiency project as the device will generate power and additional heat as well as improve the efficiency of the wood stove it is installed on.

II. Technology Validation and Data Collection

A. Objectives

Design specification parameters for the catalytic converter:

1.) *The catalytic converter temperature must be high enough during operation for the secondary combustion reaction to light off, between 400°F and 500°F.*
Flue gas temperatures will be monitored above and below the catalytic converter to verify efficient operation. The design will be modified if necessary to insure the catalytic converter is supplied with sufficiently hot exhaust gas to initiate and maintain the secondary combustion reaction.

2.) *The catalytic combustor must receive enough oxygen to maintain secondary combustion.* A fresh air injector may be added to the device if the temperature of the flue gas is sufficient to initiate secondary combustion but the reaction fails to sustain itself.

3.) *The diverter system must reliably divert flue gas around the catalytic converter below the light off threshold, between 400°F and 500°F, and into it above that threshold.*
The set points at which the diverter opens and closes will be established for the device until optimum conditions are maintained. The reliable mechanical operation of the diverter will be tested by repeated cycling under a variety of conditions. The diverter system will then be examined for wear or malfunction. Any inadequacies in the design will be adjusted or strengthened.

Design specification parameters for the thermoelectric modules:

4.) *The temperature differential between the two sides of the thermoelectric module must be as great as possible without exceeding the design tolerance of the module, about 600°F on the hot side.*
Effective thermal transfer must be achieved between the hot side of the thermoelectric modules and the flue gasses. Temperatures above the catalytic combustor and the on the hot side of the thermoelectric modules will be measured. The shape and design of the central heat sink coupling the hot side of the thermoelectric modules with the hot gas exiting the catalytic combustor will be modified if necessary to insure efficient heat transfer to the module without exceeding its temperature tolerance.

5.) *Efficient cooling must occur on the outer, cold side, of the thermoelectric module.* The temperature of the cooling air and the cold side of the thermoelectric modules will be measured. The cooling air circulation will be increased and or the heat pipe cooler design modified if more efficient cooling is required. Fitting the unit with a liquid cooling system is an option if heat pipe air cooling proves inadequate.

6.) *The insulation blanket around the second shell must efficiently block heat transfer to the outer cooling shell.* Temperatures will be monitored on either side of the insulation blanket. If the thermal bleed through is too high the insulation material thickness will be increased.

Design specification parameters for the device housing:

7.) *The device must be gas tight and well constructed.* The device will be monitored during operation to check for gas leaks and sound construction.

8.) *The device must not experience excessive carbon buildup.* Carbon deposits will be monitored throughout the testing process and design changes made if they become excessive.

B. Data Collection

The prototype generators will be installed on the test bed stove at Alaska Dynamics and fitted with a sensor array including temperature sensors before and after the catalytic combustor, on both sides of two of the thermoelectric generator modules, a combustion gas analyzer in the upper exhaust stream of the device, an ambient air temperature sensor, an internal stove temperature sensor, and a voltage and current sensor measuring the output of the thermoelectric generator modules. The prototypes will then be run on the test stove extensively. The sensor array will be connected to a data acquisition module connected in turn to a dedicated data collection computer via USB where the sensor input will be recorded into a spreadsheet. The data collection computer will be fitted with dual redundant hard drives and backed up to prevent data loss. During the third generation testing phase the prototypes will be fitted with a similar sensor array connected to a portable data acquisition module. The remote sensor data will be downloaded by the field tester and emailed to Alaska Dynamics where the data will be stored and backed up on the data collection computer. The stored operational data will be analyzed to determine whether or not the unit is operating within design parameters. Test analysis reports will be generated detailing where the device is or isn't operating within design parameters and what steps will be taken to correct any device operation outside of these parameters. All of the raw operational data as well as the testing analysis reports will be made available to AEA and the grant administrators.

III. Project Schedule and Project Budget

1st Quarter: Material and equipment purchase. Installation of equipment and test woodstove.
2nd Quarter: Second generation prototype construction.
3rd Quarter: Go/No Go point, 2nd Gen prototype operational. Testing, data collection, and analysis.
4th Quarter: Second generation data analysis, design changes identified and implemented.
5th Quarter: Third generation prototype construction.
6th Quarter: Go/No Go point, 3rd Gen prototypes operational. Field testing, data collection, and analysis.
7th Quarter: Third generation data analyzed, final design changes identified and implemented.
8th Quarter: Preparation for production.

Summary Project Budget:

	EETF Grant Funds	Grantee Matching Funds	Source of Matching Funds	Totals
Direct labor and benefits	$72,000	$118,400	In Kind Match	$190,400
Travel & Per Diem	$10,000			$10,000
Equipment	$70,500	$10,000	Cash Match	$80,500
Materials & Supplies	$66,300	$10,000	Cash Match	$76,300
Contractual Services	$10,000			$10,000
Other Direct Costs	$64,900	$10,000	Cash Match	$74,900
Totals	$293,700	$148,400		$442,100

IV. Project Team Qualifications

Theo Graber, Project Manager. Theo Graber will be responsible for project management as well as design and production. As the inventor of the Delta-T Wood Stove Generator™, Theo, will be responsible for the prototyping, testing, and design refinement of the device as well as managing the operation of the project under the grant. Theo has an extensive background in manufacturing spanning over twenty years. His relevant skills include previous product development management in Alaska, 3D CAD modeling and digital prototyping, precision machining and welding, and electronics design and fabrication. He has the experience and skills to successfully bring the Delta-T Wood Stove Generator™ to market and successfully accomplish the goals of this project.

Jonathan Bittner, Principal Investigator. Jon will be responsible for overseeing the collection and management of the operational data sets during testing as well as preparing monthly reports for the grant authority. He will ensure valid scientific methods are employed to maintain the accuracy and relevance of the data collected. Jon holds a Bachelor of Science in Geology. He has spent several years as a field geologist/GIS specialist and project geologist. He is currently the Vice President of the Anchorage Economic Development Corporation where he specializes in business development.

V. Discussion of Commercialization of Funded Technology.

The commercialization of the unique application of thermoelectric power generation the Delta-T™ represents is as yet undeveloped. Upon completion of this project Alaska Dynamics will manufacture the device in Anchorage, Alaska for distribution and sale to not only the Alaskan market but to wood heated homes in cold climates worldwide. A potential market of several million customers. Since the Alaska Dynamics website went live last year at www.alaskadynamics.com and with the media attention from our crowd funded Kiva Zip startup loan and an article in the Alaska Dispatch http://goo.gl/CWLJri Alaska Dynamics has received a huge amount of interest from potential customers all over Alaska and the world. Inquiries looking to purchase the device have come in from all over Alaska and the lower 48, the northern European countries, Canada, Russia, China, Japan, and even New Zealand.

The Delta-T Wood Stove Generator™ project will have a profound effect on the commercialization of thermoelectric power generation applied to wood stoves, it will **be** the commercialization of thermoelectric power generation applied to wood stoves.

VI. Signed Applicant Certification "By signature on this application, I certify that we are complying and will comply with the amount of matching funds being offered."