Multidisciplinary Senior Design
Project Readiness Package

Project Title:	Biochar Kiln Heat Recovery 2.0
Project Number: (MSD will assign this)	P17487
Primary Customer: (provide name, phone number, and email)	Kathleen Draper, 585 737 7282, kdraper2@rochester.rr.com Ithaka Institute: http://www.ithaka-institut.org/en/home
Sponsor(s): (provide name, phone number, email, and amount of support)	MSD, $500
Preferred Start Term:	Fall 2015
Faculty Champion: (provide name and email)	Brownell
Other Support:	Tom Trebold (GIS), tatasp@rit.edu Steve Barber (GIS PhD student), stb4703@rit.edu Paul Taylor (Australia), Hans Peter Schmidt (Switzerland)
Project Guide: (MSD will assign this)	

Sarah Brownell 7/19/16

Prepared By Date

Received By Date

Items marked with a * are required, items marked with a † are preferred if available, but we can work with the proposer on these.

Project Information

*Overview:

The Ithaka Institute in a non-profit foundation leading research collaboration on carbon sequestration through biological methods. They focus specifically on research enhancing the production, treatment and use of biochar materials. Biochar is created by the thermochemical decomposition of organic materials at elevated temperatures in the absence of oxygen, a process known as pyrolysis. Biochar can be made from many types of biomass including agricultural wastes and has interesting characteristics due to its composition and physical structure including low density, high porosity, and elevated pH. It can be used as a soil amendment, an animal dietary supplement, a sustainable charcoal replacement, a filter material, and as a component in composite building materials. Because of its stability, it also has potential for sequestering carbon taken from the atmosphere by biomass as a remediation for climate change.

The Ithaka Institute has been experimenting with a Kon Tiki cone style kiln for making biochar from agricultural wastes such as cherry pits and coffee pulp.   The Kon Tiki Kiln (figure 1) is designed for small scale use by farmers and home owners in the United States. It has been used to destroy invasive species and to turn them and other agricultural wastes into a biochar soil amendment which, when inoculated with nutrients from compost tea or urine, can greatly improve agricultural output. Due to its simplicity, the kiln also has potential for use in the developing world. It can help deal with organic wastes while generating useful soil amendments and components for building materials, all the while sequestering carbon from the atmosphere. The carbon sequestering feature of this technology may make it possible to finance distribution in low income areas using carbon credits.

Figure 1: The Kon Tiki with and without its heat shield

The Ithaka Institute recently had a Kon Tiki kiln constructed locally for $500 (parts and labor--welding). This kiln works best for thin branches and stalks which allow for air movement during start up rather than more compressed feedstocks. The feedstock material is stacked on a grate in the middle of the kiln, making a tower which helps draw in air for combustion (figure 2), and is set on fire.

Figure 2: Starting the Kon Tiki

Once flames are visible all through the tower, the tower is knocked down. When the embers start to produce ash, the feedstock material is added little by little (timing for this is a bit of an art). The Kon Tiki kiln burns at approximately 650-750 ^{o}C, producing a char material with properties similar to activated carbon. When all the feedstock has been added or the top of the kiln has been reached, water flows in from a hose at the bottom of the kiln, quenching the fire. This highly alkaline quench water is later removed and can be used for cleaning or white washing purposes, similar to lye. The biochar (figure 3) can be used for various purposes described above. The full process takes 1-2 hours. See for more details: http://www.ithaka-institut.org/en/kon-tiki

Figure 3: Biochar

Some researchers have looked into recovering heat from biochar kilns to heat buildings using overhead hoods, but heat recovery has not proven to be very efficient. Others have looked at adding coils around the cone of the kiln, but data on the results has not yet been published. There is some risk of removing too much heat from the system and stopping the pyrolysis process inside. However, since biochar used for soil amendment is usually produced at a lower temperature—450-550 ^{o}C—than the current operating temperature of the Kon Tiki, there appears to be some opportunity to recover heat from the system during operation as well as during the quench period.

Last year the Ithaka Institute sponsored MSD team P16487 to develop a system to recover waste heat from this process. The team worked with researchers in Nepal and decided to recover heat for two additional processes—water pasteurization and tea leaf drying. Their final prototype is shown in figure 4. The team's leaf drying system worked relatively well, but they struggled to maintain constant temperatures within the water pasteurization system. The design was intended for rural Nepal, so simple, low-cost automotive thermostats were used to control temperature and flow. Water temperatures were influenced greatly by the unpredictable nature of the fire and alternated quickly between steam and luke-warm water rather than producing water consistently at pasteurization temperature. The thermostat did not respond quickly enough in response to changing temperatures. The team calculated that overall, the system produced enough heat for water pasteurization, but design changes would be needed to make the system safer--keeping users safe from burns as well as drinking water that might not be fully pasteurized.

Figure 4. Last year's Kontiki heat recovery system

This year's team is tasked with taking the insights from the previous MSD team and developing a system for recovering waste heat from the Kontiki to produce hot water for showers and/or radiant heating. Reaching pasteurization temperatures in this system would be an added bonus.

Additional versions of the Kon Tiki kiln can be seen here:
https://www.pinterest.com/ithakainstitute/kon-tiki-kiln/

[*]Customer Requirements (CR):

- Attaches to the existing Kon Tiki kiln
- Adaptable to various KonTiki models
- Recovers heat during the biochar production process
- Uses heat recovered to heat water
- Costs less than $250 to add to the system
- Operated by a farmer or homeowner
- Operates outdoors
- Minimizes materials that would have to be imported to developing countries
- Safe
- Prevents unintended steam discharges

[†]Engineering Requirements (ER):

Metric	Units	Ideal Specification	Marginal Specification
Temperature of water output (range)	ºC	70-85	60-90
Heat recovered to working fluid/hour	kJ	>8000	>4000
Time elapsed until operating temperatures are reached	Min	<15	<25
Time to assemble on kiln	Min	<30	<45
Steps for operation	#	<2	<4
Time for new user to assemble	Min	<45	<85
Grade reading level of instructions	Grade	No reading required	<=2nd
Operation duration time	Min	>120	>90
Max weight of individual parts	Kg	<20	<25
Operates in various ambient temperatures	ºC	10-45	20-40
Part life time	Kiln life	>1	1
Adapts to different kontiki kiln styles	#	>3	>2
Kiln temperature maintained while heat capture is in place	ºC	>650	>550
Total cost of additions	$	<300	<500
Percent of materials by cost available within 100 miles	%	100	>95
Percent of materials by cost available within 100 miles	%	100	>90
People needed to install the system	#	2 or less	3
Interferes with kiln loading (operator evaluation on likert scale 1 = no to 5 = impossible to load)		>4	>3
Potential burn hazards not protected	#	0	<3
Materials resist degradation from weather			

*Constraints:

- Works as an add-on to the existing Kon Tiki kiln
- Operated by farmer or homeowner
- Costs less than $250 to add to the kiln
- Minimizes materials that must be imported in developing world (discuss with guide and customer as the design proceeds)
- Doesn't impede kiln loading or pyrolysis process

*Project Deliverables:

Minimum requirements:

- All design documents (e.g., concepts, analysis, detailed drawings/schematics, BOM, test results)
- working prototype
- technical paper
- poster
- Complete edge site
- All teams finishing during the spring term are expected to participate in ImagineRIT

Additional required deliverables:

- Test results

†Budget Information:

Some items from last team can possibly be reused

Item	Cost
Heat exchanger	$150
Structure	$ 75
Insulation	$ 50
Working fluid storage	$100
Total	$375

*Intellectual Property:

Maybe if a novel design is used, but probably not.

Project Resources

†Required Resources (besides student staffing):
Describe the resources necessary for successful project completion. When the resource is secured, the responsible person should initial and date to acknowledge that they have agreed to provide this support. We assume that all teams with ME/ISE students will have access to the ME Machine Shop and all teams with EE students will have access to the EE Senior Design Lab, so it is not necessary to list these! Limit this list to specialized expertise, space, equipment, and materials

Faculty list individuals and their area of expertise (people who can provide specialized knowledge unique to your project, e.g., faculty you will need to consult for more than a basic technical question during office hours)	**Initial/ date**
Dr. Rob Stevens	
Environment (e.g., a specific lab with specialized equipment/facilities, space for very large or oily/greasy projects, space for projects that generate airborne debris or hazardous gases, specific electrical requirements such as 3-phase power)	**Initial/ date**
Outdoor space for using the Kon Tiki /EHS approval	
Equipment (specific computing, test, measurement, or construction equipment that the team will need to borrow, e.g., CMM, SEM,)	**Initial/ date**
Temperature monitoring gages	
Materials (materials that will be consumed during the course of the project, e.g., test samples from customer, specialized raw material for construction, chemicals that must be purchased and stored)	**Initial/ date**
Material to char	
Access to a Kon Tiki	
Other	**Initial/ date**

†Anticipated Staffing By Discipline:
Indicate the requested staffing for each discipline, along with a brief explanation of the associated activities. “Other” includes students from any department on campus besides those explicitly listed. For example, we have done projects with students from Industrial Design, Business, Software Engineering, Civil Engineering Technology, and Information Technology. **If you have recruited students to work on this project (including student-initiated projects), include their names here, as well!**

Disc.	**# Req.**	**Expected Activities**
BME		
CE		
EE		

ISE	0-1	Not required, but always helpful: systems thinking, engineering economy, safety, sustainability knowledge, materials, experimental design, optimization, project management
ME	4	Thermodynamics, heat transfer, fluid dynamics, modeling of fluid systems, 3D CAD. Modelling and optimization of complex systems.
Other		

†Skills Checklist:

Indicate the sills or knowledge that will be needed by students working on this project. Please use the following scale:

1=must have
2=helpful, but not essential
3=either a very small part of the project, or relates to a "bonus" feature
blank = not applicable to this project

Mechanical Engineering

	ME Core Knowledge		ME Elective Knowledge
1	3D CAD	2	Finite element analysis
	Matlab programming	1	Heat transfer
1	Basic machining	1	Modeling of electromechanical & fluid systems
	2D stress analysis		Fatigue and static failure criteria
	2D static/dynamic analysis		Machine elements
1	Thermodynamics		Aerodynamics
1	Fluid dynamics (CV)	2	Computational fluid dynamics
	LabView		Biomaterials
	Statistics		Vibrations
			IC Engines
			GD&T
			Linear Controls
			Composites
			Robotics
			Other (specify)

Electrical Engineering

	EE Core Knowledge		EE Elective Knowledge
	Circuit Design (AC/DC converters, regulators, amplifies, analog filter design, FPGA logic design, sensor bias/support circuitry)		Digital filter design and implementation
	Power systems: selection, analysis, power budget		Digital signal processing
	System analysis: frequency analysis (Fourier, Laplace), stability, PID controllers, modulation schemes, VCO's & mixers, ADC selection		Microcontroller selection/application
	Circuit build, test, debug (scope, DMM, function generator		Wireless: communication protocol, component selection
	Board layout		Antenna selection (simple design)
	Matlab		Communication system front end design
	PSpice		Algorithm design/simulation
	Programming: C, Assembly		Embedded software design/implementation
	Electromagnetics: shielding, interference		Other (specify)

Industrial & Systems Engineering

	ISE Core Knowledge		**ISE Elective Knowledge**
	Statistical analysis of data: regression		Design of Experiment
	Materials science		Systems design – product/process design
	Materials processing, machining lab		Data analysis, data mining
	Facilities planning: layout, mat'l handling		Manufacturing engineering
	Production systems design: cycle time, throughput, assembly line design, manufacturing process design		DFx: manufacturing, assembly, environment, sustainability
	Ergonomics: interface of people and equipment (procedures, training, maintenance)		Rapid prototyping
	Math modeling: OR (linear programming, simulation)		Safety engineering
	Project management		Other (specify)
	Engineering economy: Return on Investment		
	Quality tools: SPC		
	Production control: scheduling		
	Shop floor IE: methods, time studies		
	Computer tools: Excel, Access, AutoCAD		
	Programming (C++)		

Biomedical Engineering

	BME Core Knowledge		**BME Elective Knowledge**
	Matlab		Medical image processing
	Aseptic lab techniques		COMSOL software modeling
	Gel electrophoresis		Medical visualization software
	Linear signal analysis and processing		Biomaterial testing/evaluation
	Fluid mechanics		Tissue culture
	Biomaterials		Advanced microscopy
	Labview		Microfluidic device fabrication and measurement
	Simulation (Simulink)		Other (specify)
	System physiology		
	Biosystems process analysis (mass, energy balance)		
	Cell culture		
	Computer-based data acquisition		
	Probability & statistics		
	Numerical & statistical analysis		
	Biomechanics		
	Design of biomedical devices		

Computer Engineering

	CE Core Knowledge		**CE Elective Knowledge**
	Digital design (including HDL and FPGA)		Networking & network protocols
	Software for microcontrollers (including Linux and Windows)		Wireless networks
	Device programming (Assembly, C)		Robotics (guidance, navigation, vision, machine learning, control)
	Programming: Python, Java, C++		Concurrent and embedded software
	Basic analog design		Embedded and real-time systems
	Scientific computing (including C and Matlab)		Digital image processing

	CE Core Knowledge		CE Elective Knowledge
	Signal processing		Computer vision
	Interfacing transducers and actuators to microcontrollers		Network security
			Other (specify)