The Electric EcoFogao

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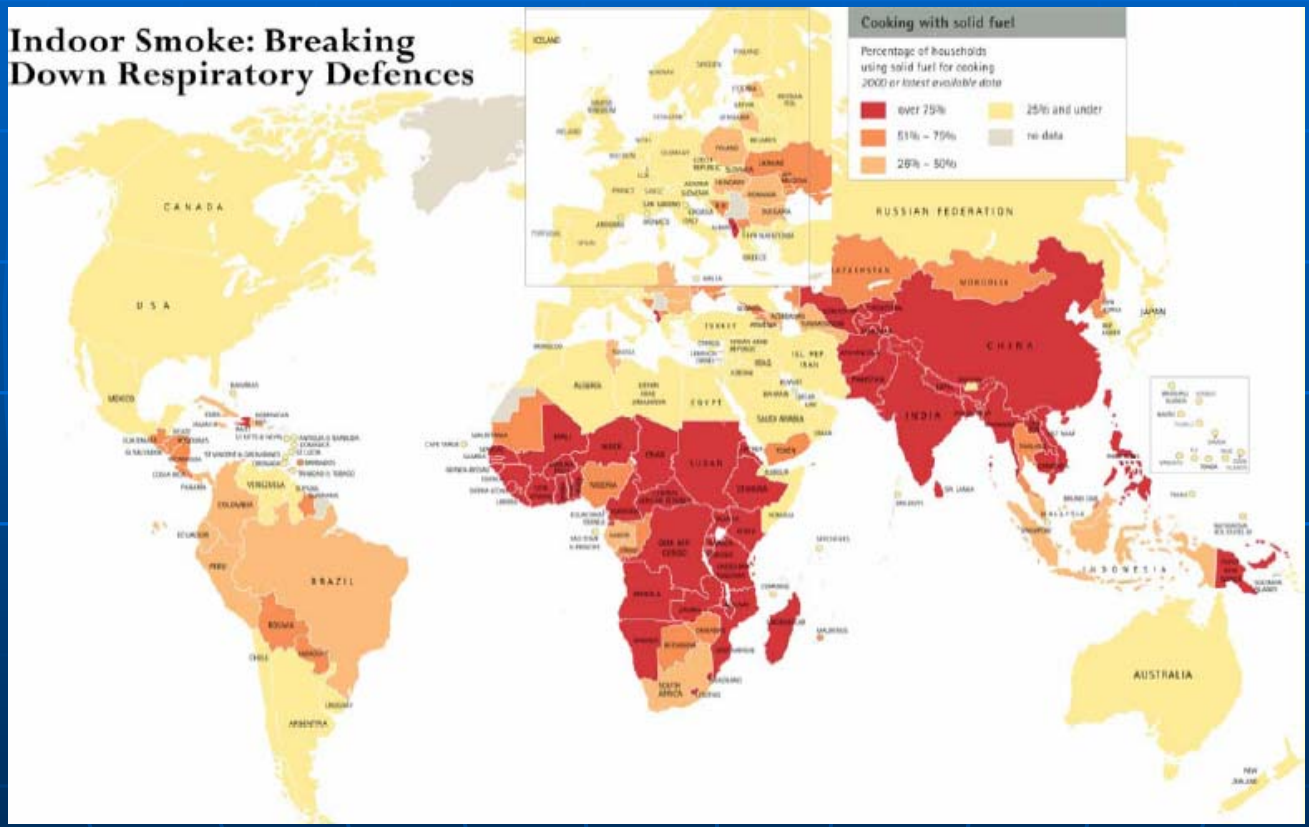
The Problem

2.4 Billion people use biomass for cooking and heating



1.6 Billion people have no access to electricity

The Problem

- Most people using stoves do not have modern lighting

Using . . . .

- Light from open fire
- Burning sticks
- Kerosene Lantern

The Solution

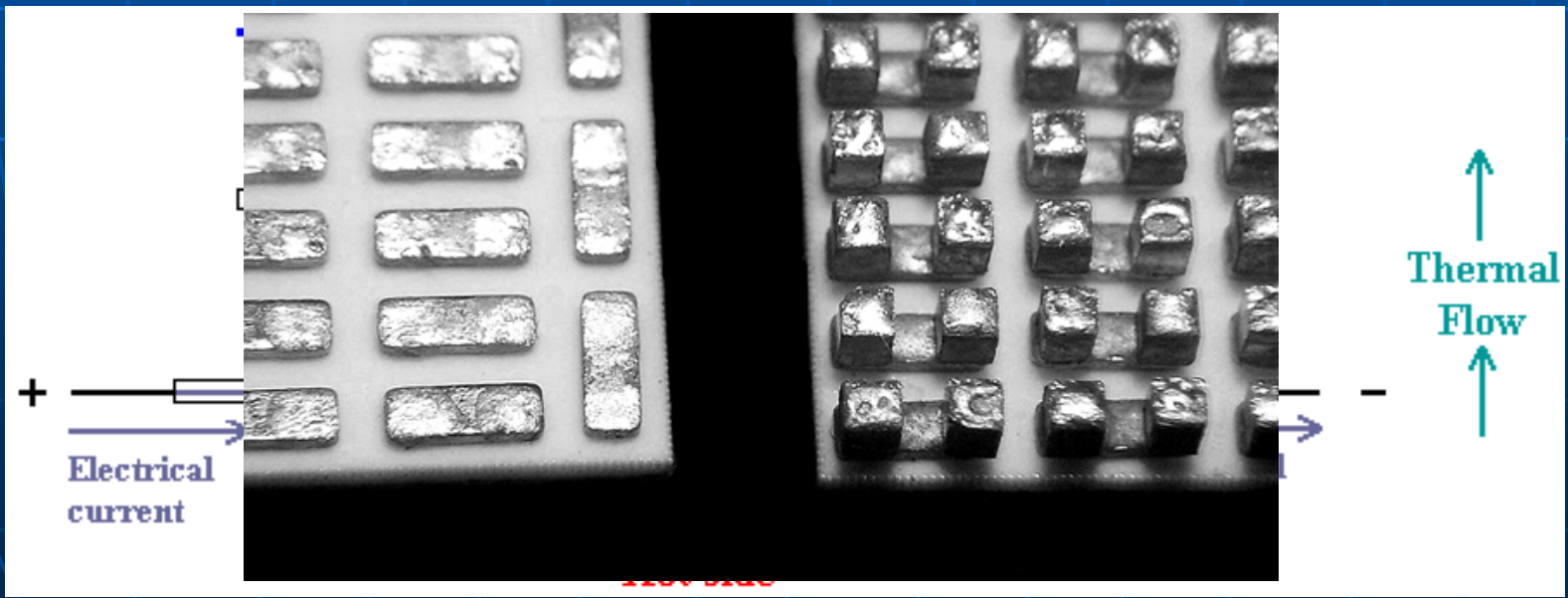
- Most stoves generate a very large amount of thermal energy ~ 1-5 kW
- Much of this energy goes right out the chimney
- Our goal was to create a device to turn a small fraction of this energy into electricity
- The most promising design is a thermoelectric generator (TEG)

Lighting Options

- Candle → 12 Lumen
- Kerosene Wick Lantern → 40 Lumens
- 1 W LED → 40 Lumens
- 3 W Cold Cathode Fluorescent Light (CCFL) → 120 Lumens
- 13 W Compact Fluorescent (CFL) → 800 Lumens
- 60 W Incandescent → 730 Lumens

Thermoelectric Generator

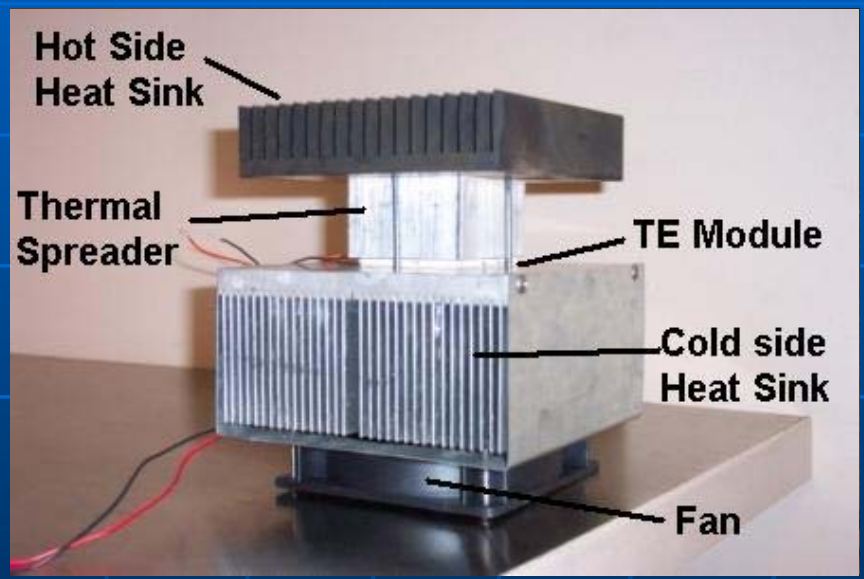
- Develop a Thermoelectric generator to convert waste heat to light
- Thermal energy is converted into electricity by the Seebeck effect



Thermoelectric Generator

Consists of

- Thermoelectric Module
- Cooling Fan
- Hot heat Sink
- Cold heat sink



The Ecoforno Stove

The TEG was incorporated onto the Ecoforno Stove

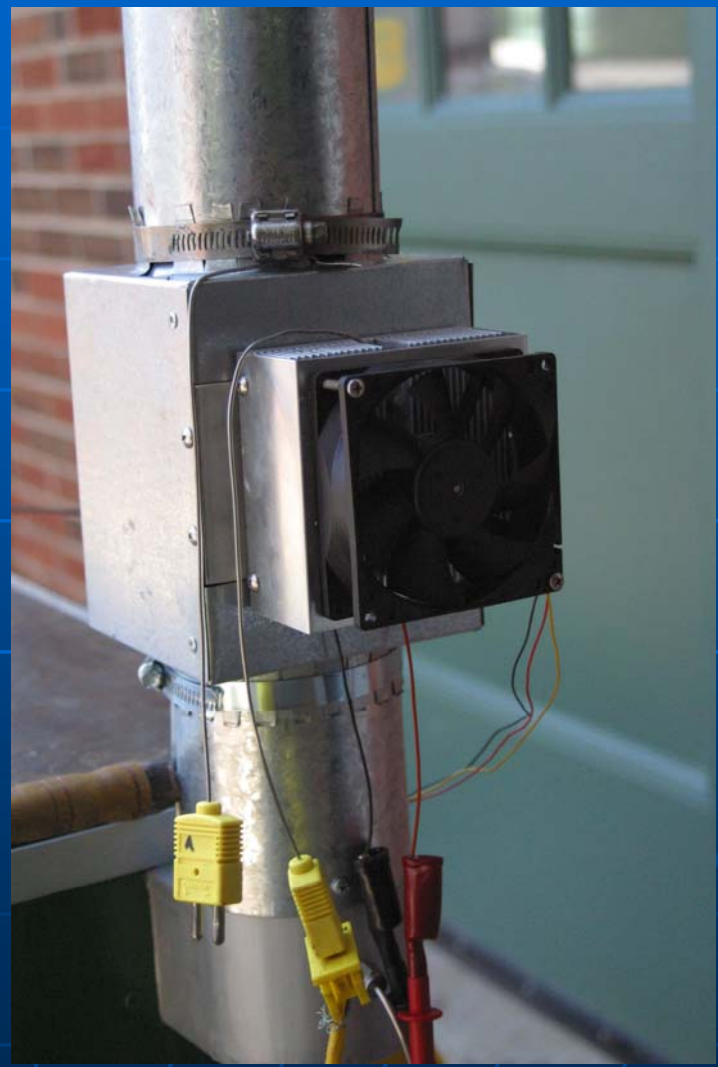
The goal was to produce enough energy to run a 15W compact fluorescent light for 3 hours

45 W-hrs per day

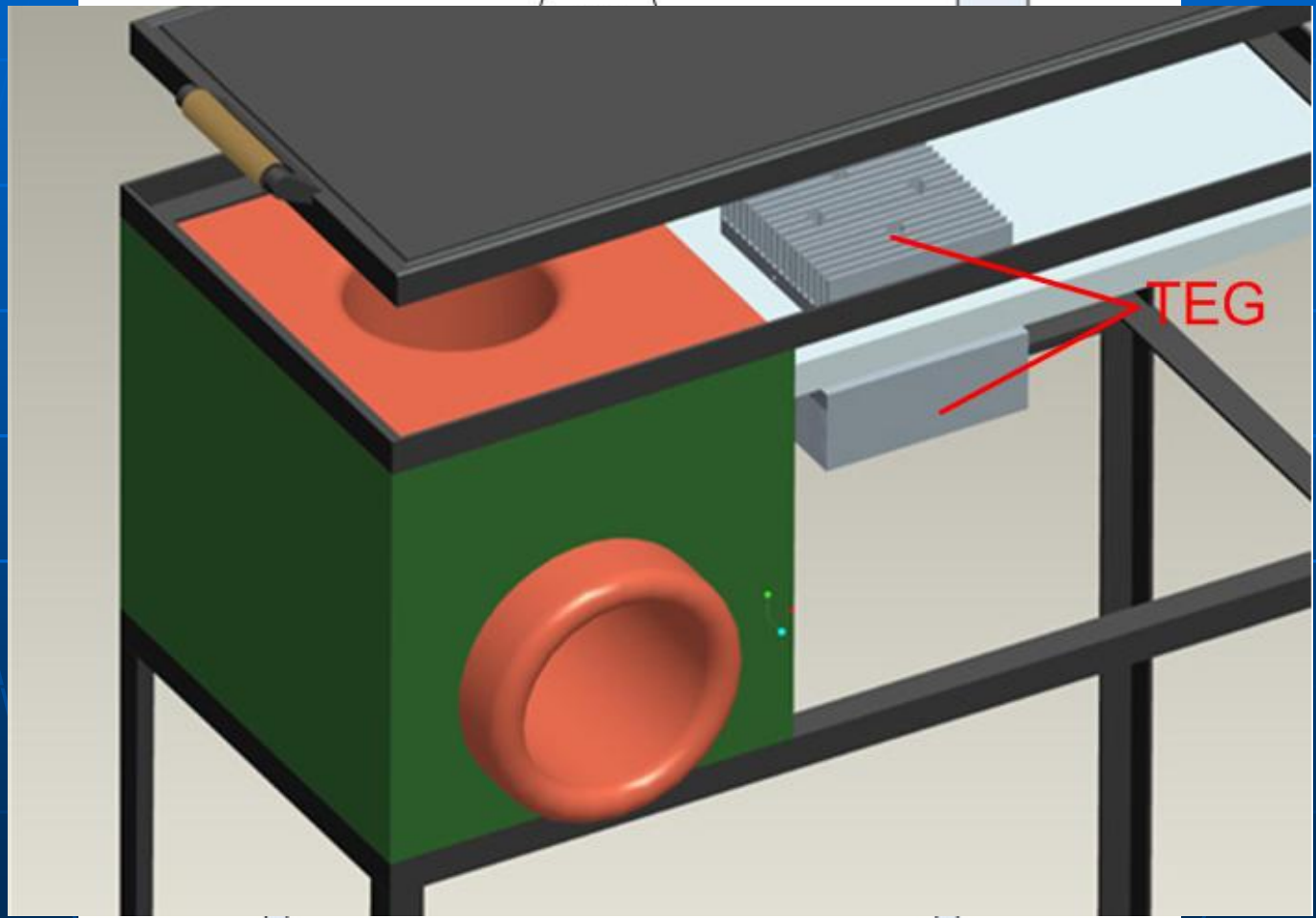
15 W-hrs per meal

Incorporating the TEG

- Initial chimney located TEG
- Produced just over 1 W
- Temperatures were too low (150 – 200 C)
- Need (300 – 400 C)

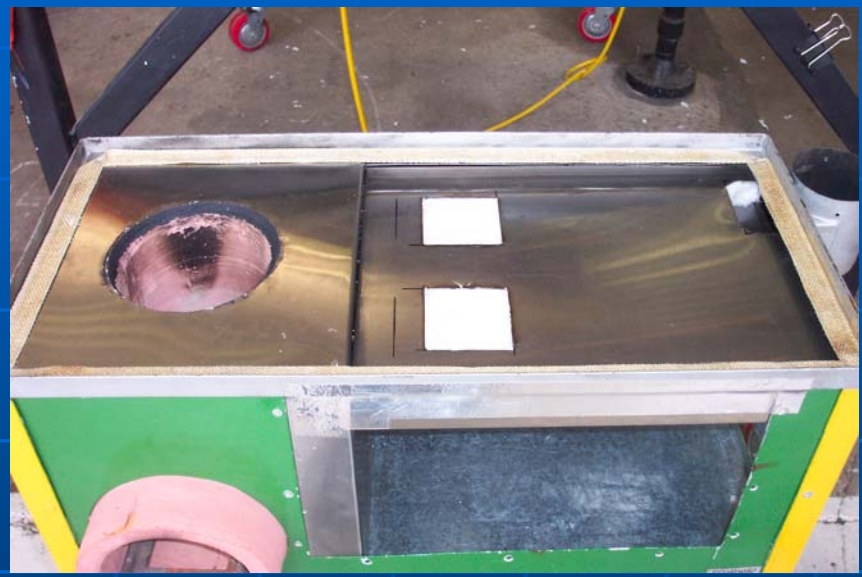


Incorporating the TEG



Modifying stove for TEG

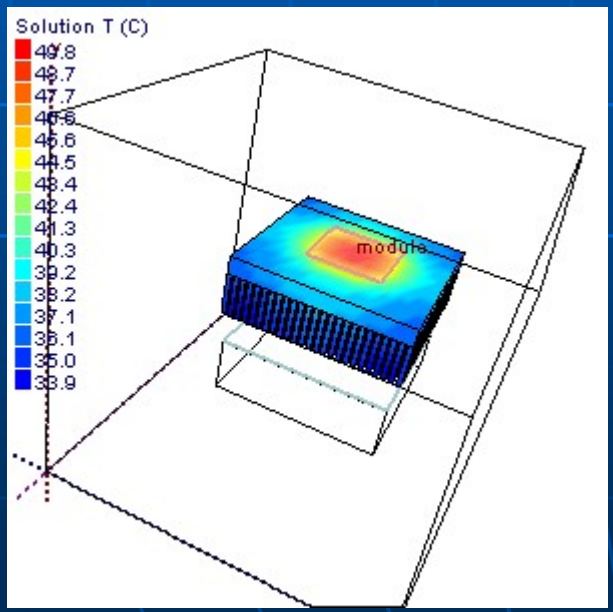
Ecoforno with oven removed



Reconstructed for use with TEG

TEG Design – Module and Heat Sink Selection

- Heat sinks were modeled using a heat sink modeling software program
- Various heat sink – module combinations were modeled in a spreadsheet



0.2	14.7	180	430	257.86	82.60	20	312.98	8.16745	1.2	13.89734
0.18	14.7	180	430	255.19	77.21	20	317.83	8.294078	1.2	14.33161
0.16	14.7	180	430	252.44	71.65	20	322.83	8.424693	1.2	14.78655
0.14	14.7	180	430	249.60	65.92	20	328.00	8.559488	1.2	15.26351
0.12	14.7	180	430	246.67	60.00	20	333.33	8.698667	1.2	15.76392
0.1	14.7	180	430	243.64	53.88	20	338.84	8.842446	1.2	16.28935
Cold Heat Sink Resistance (C/W)	Reference Power (W)	Reference DT (C)	T hot air (C)	T hot mod (C)	T Cold Mod (C)	T amb (C)	Heat Flow (W)	Voc	Module elec resistance	Power
0.2	10.2	180	430	284.52	59.68	20	264.52	10.47748	1.7	16.14377
0.18	10.2	180	430	282.61	54.84	20	267.97	10.61444	1.7	16.56859
0.16	10.2	180	430	280.66	49.87	20	271.52	10.75503	1.7	17.0104
0.14	10.2	180	430	278.66	44.77	20	275.17	10.8994	1.7	17.47012
0.12	10.2	180	430	276.60	39.52	20	278.91	11.04769	1.7	17.94873
0.1	10.2	180	430	274.48	34.14	20	282.76	11.20007	1.7	18.44729
0.1	20	180	430	233.91	55.65	20	356.52	8.556522		

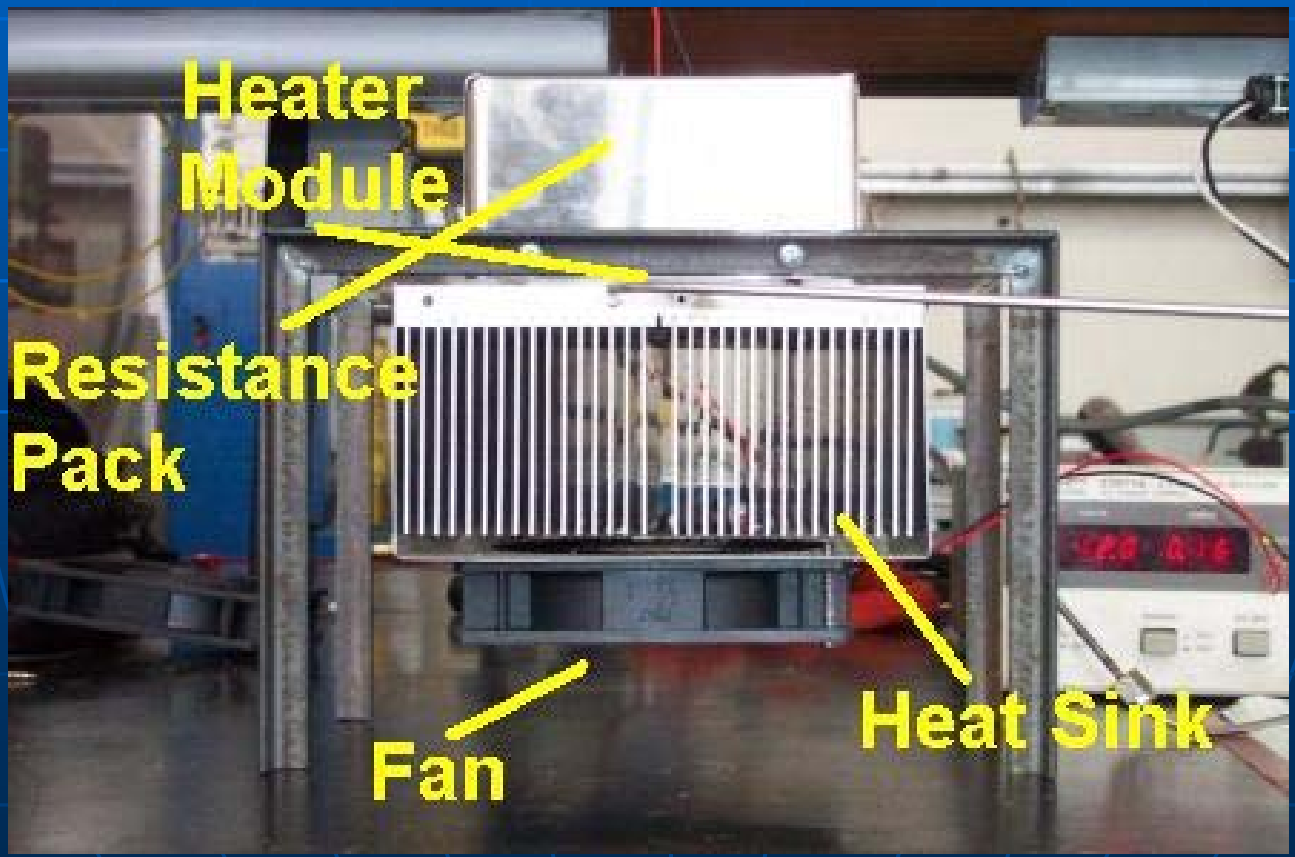
Heat Sink Selection

The following heat sinks were identified as candidates

Bonded Fin Heat Sink Pin Fin Heat Sink Extruded Heat Sink

Bench Top Testing

Heat sink thermal resistance and Module power were determined from a series of bench top tests

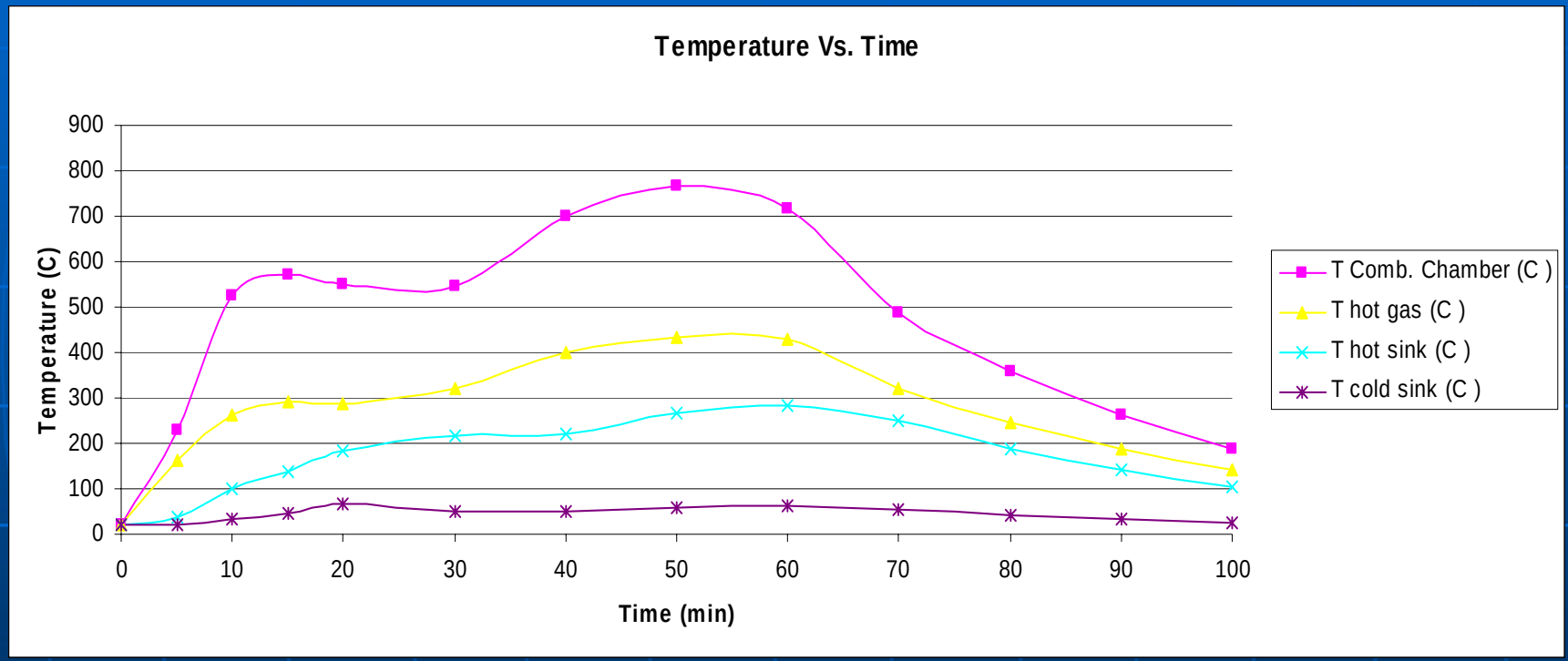


Preliminary Testing

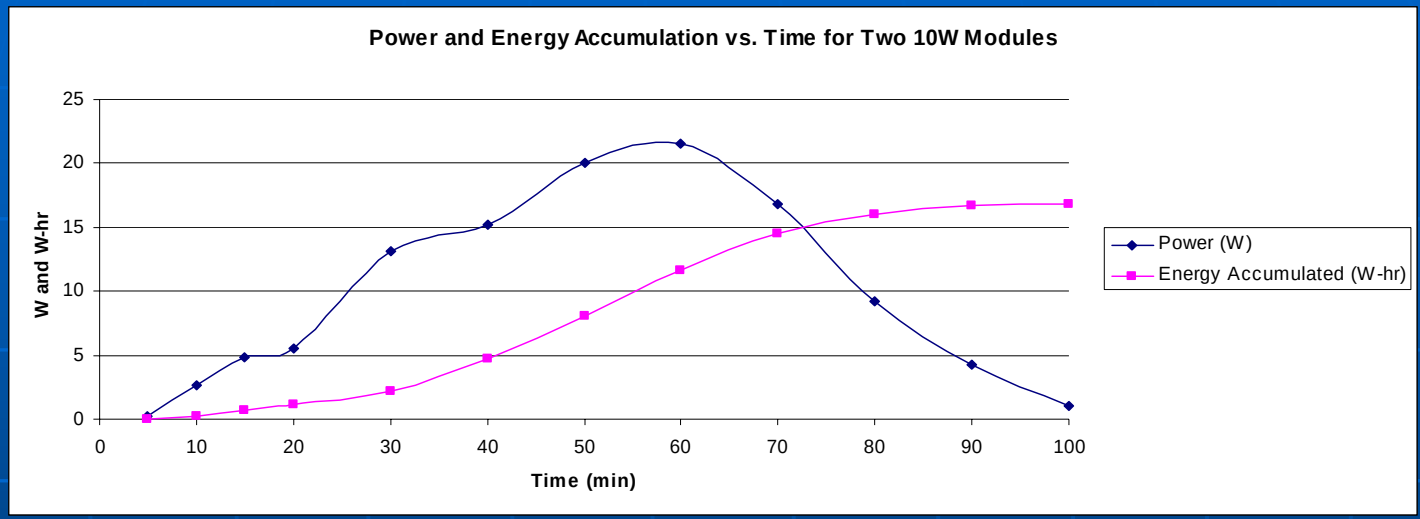
Preliminary testing was performed to asses:

- Generator power
- Stove Temperatures
- Transient behavior

Stove and Generator Temperatures



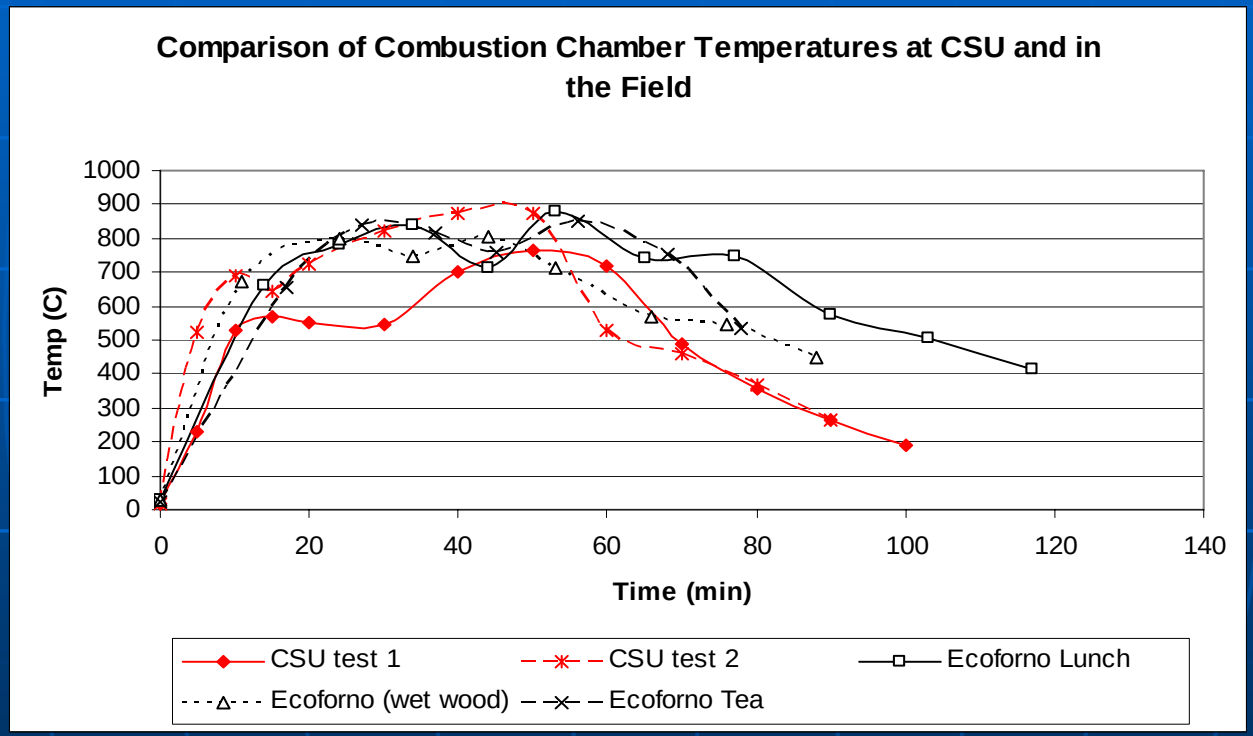
Preliminary Test Results



- 17 W-hr per meal with 3 meals per day generates 51 W-hr of energy per day
- Desired amount: 45 W-hr

Stove set-up with two 10-Watt modules produce enough energy to power a 15-Watt CFL for 3 hours

CSU vs. Field Testing



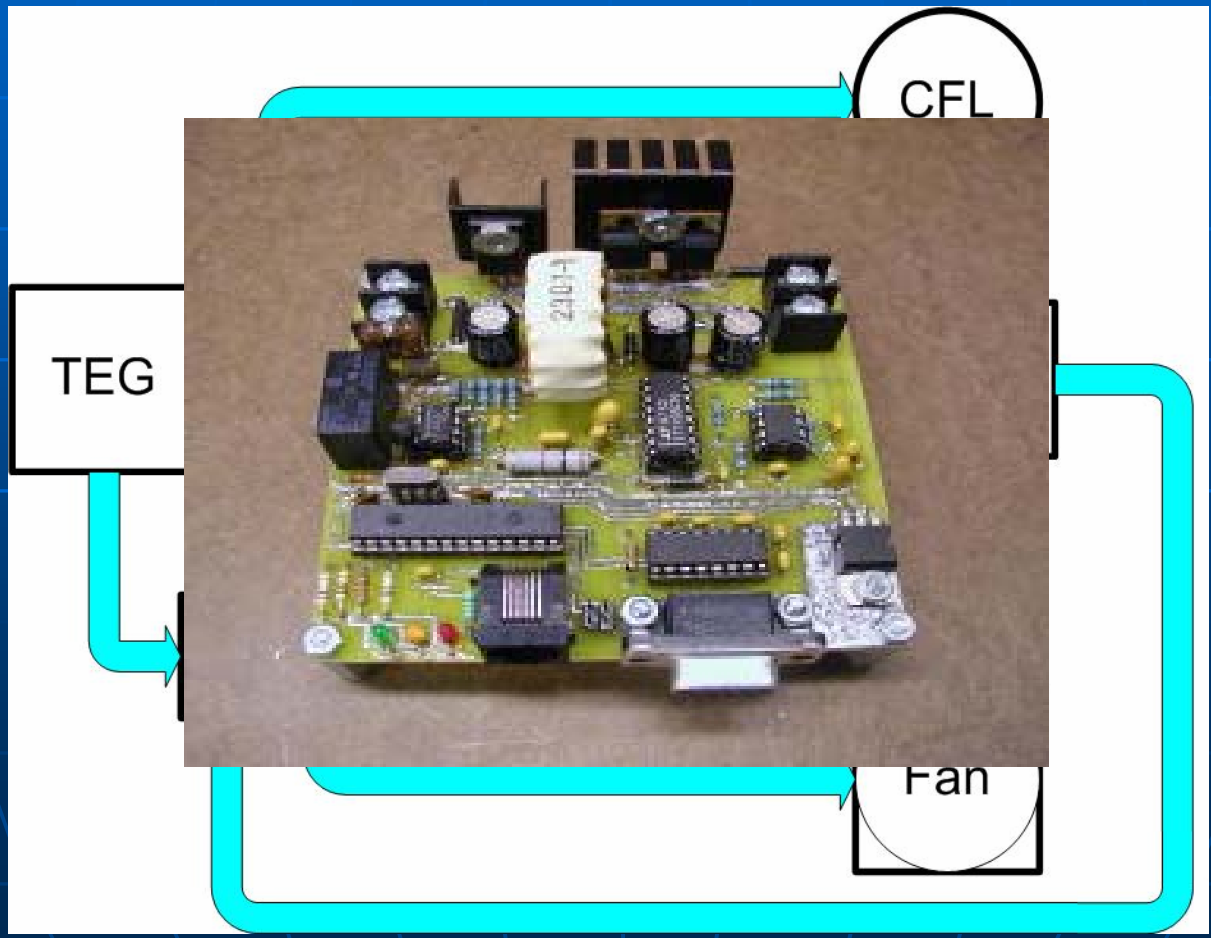
- CSU testing followed similar path as on-site field testing

Electrical Power Management

- Needs to boost voltage to charge 12 V battery
- Needs to regulate charging and discharging of battery
- Needs to turn DC-DC converter and fan on and off

Electrical Power Management

The power circuit is still in development, estimated cost is $15



Total System Cost

In quantities of 1000, TEG system cost is $170 → 20W

$7.75/watt

In larger quantities, local manufacturing ~ $5-6/W

Solar power $5-8/watt

The next generation of thermoelectric modules will reach 3-4 times the power output of current modules → $2/watt

Item	Quanity	Cost per item (@ 1000 units)	Cost total
Hot heat sink (Thermaflo)	2	$7.00	$14.00
Cold heat sink (Thermaflo)	2	$20.00	$40.00
Module (Thermonamic)	2	$35.00	$70.00
Thermal spreader	2	$3.00	$6.00
Battery (Power Sonic)	1	$6.00	$6.00
Fan (Vantec)	2	$10.00	$20.00
Power Circuit (Maxim, Mouser)	1	$15.00	$15.00
TEG System Cost			$171.00
Cost per Watt @ 24 W			$7.13
Stove Cost	1	$100	$100
Total Cost for TEG system and Stove			$271

Conclusion

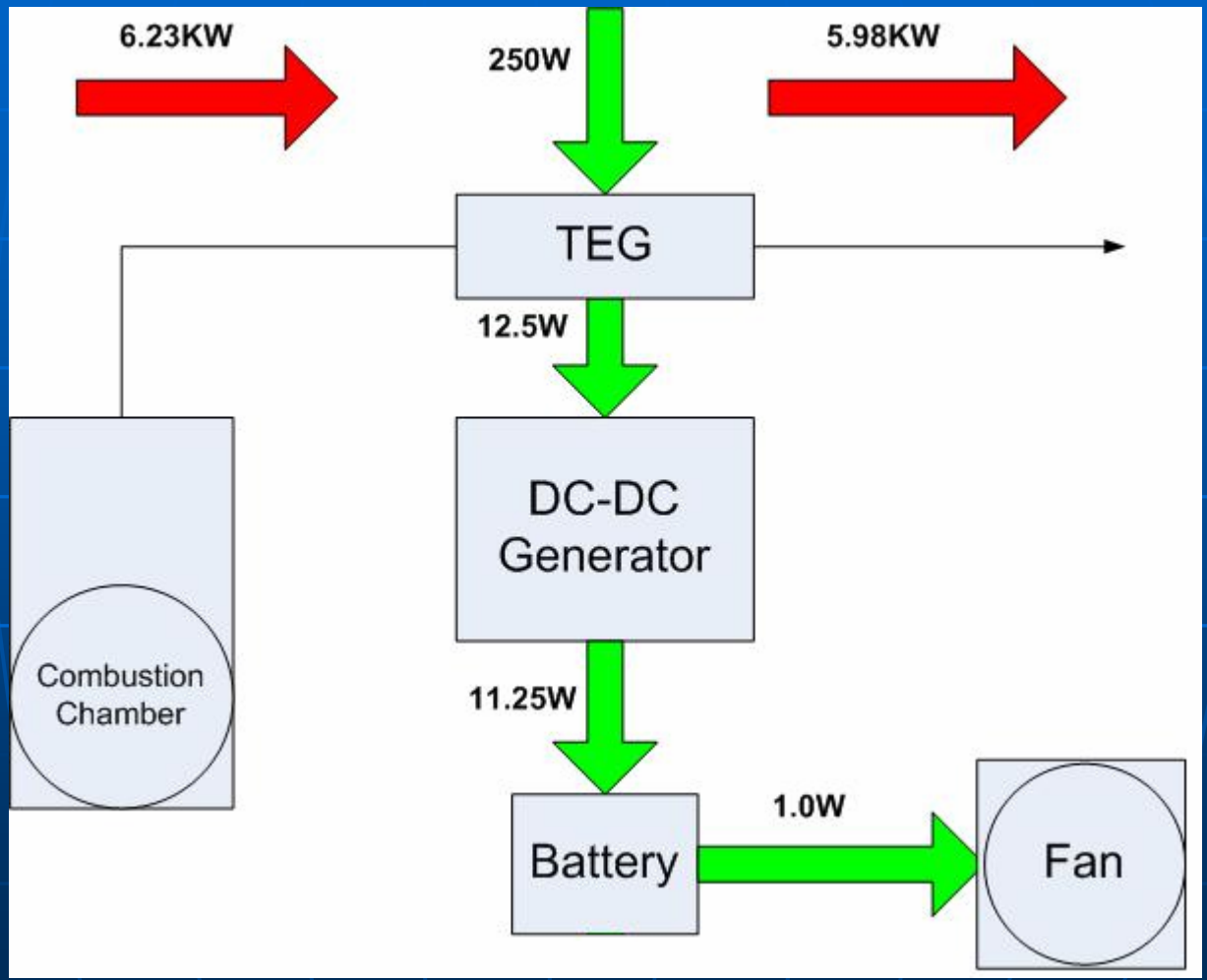
- A thermoelectric generator has been successfully incorporated into the Ecoforno stove
- In order to generate the power desired the TEG must be incorporated into the stove design
- The generator produces enough power to run a 15 watt CFL for three hours
- The system cost for 1000 units is $170 → $7.75/watt
- Costs will be further reduced through high volume/local manufacturing

Future Work

- Complete construction of power management circuit
- Develop a standardized test cycle
- Hot side heat sink redesign (less restrictive)
- Continue to incorporate the latest technology in modules, manufacturing, and electronics to reduce cost
- Field Testing – reliability, user interation, etc.

Questions?

Average Energy Flows



Net Battery Power: 11.25 - 1.0 = 10.25 W