Thermoelectric-Enhanced Cookstove Add-on (TECA) for Clean Biomass Cookstoves

Enhanced M-5000 Stove

M-5000 Stove

DOE BETO Cookstoves Program Review

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Outline

• Program Overview
• Emissions Reduction Approach and Results
• Integrated Prototype Development
• Reliability Testing
• Field Emissions Testing
• Summary
Program Goals

• Develop an affordable ($20 target) add-on device to enhance biomass cookstove performance.

• Demonstrate significant emissions reductions from the Envirofit M-5000 stove with the add-on in both the laboratory (USA) and the field (India) to approach Tier 4 standards for CO and PM$_{2.5}$.

• Demonstrate field reliability and safety of the add-on.

• Demonstrate the ability to crosswalk lab and field measurements to within 15%.

• Develop an effective approach to bring the solution to market through a manufacturing and scale-up plan – leverage RTI’s field office and Envirofit’s manufacturing facility in Nairobi, Kenya.

• Demonstrate auxiliary power production from the TECA device to power a light or recharge a cell phone to make the enhanced cookstove more attractive for long-term user acceptance and use.
Current Status

- Demonstrated PM emissions reduction from 275 (M-5000 baseline) to 58 mg/MJ delivered with an optimized air injection method
- Completed component level reliability testing to 5000 hrs
- Designed and built an integrated prototype with the optimized air injection nozzles, TE device, blower, and heatsink
- Developed a field testing methodology with portable gravimetric sampling
Measurement Capabilities

- **PM 2.5**
  - Gravimetric System
  - Isokinetic, isothermal sampling
  - Active control of volumetric flow through cyclone
  - Cumulative PM mass on filter using pressure drop across filter

- **CO and CO2 emissions**
  - 5 gas analyzer
  - CO and CO2 mass flow rates with 1 second resolution

- **Thermal Efficiency**
  - Measurements and calculations reflect current GACC procedures
Goal: Tier 4 emissions in a biomass cookstove

- < 41 mg/MJ of PM 2.5
- < 8 g/MJ CO
Emissions Results

• **Testing Methodology:**
  – Direct comparison between optimized PM emissions EGR and forced air using the same nozzle configuration
  – Completed flow rate optimization for both EGR and Air

• **PM Emissions Results**
  – M-5000 stove baseline PM emissions = 275 mg/MJd
  – EGR reduced PM to **125 mg/MJd** (55% reduction)
  – Air reduced PM to **91 mg/MJd** (67% reduction)
  – Optimized air flow reduced PM further to **59 mg/MJd** (79% reduction)
Stove Emissions Comparison

Current lab emissions:

• CO
  – 1.5-2 g/MJd
  – Tier 4
• PM
  – 59 mg/MJd
  – Tier 3.9
PM Emission Reduction Lessons Learned

• Mechanisms that reduce PM:
  – Chemical effect of injecting optimized O2 concentration
  – Increased residence time of particles via recirculation
  – Enhanced Mixing

• Parameter optimization:
  – Air injection location
  – Air flow rate
  – Velocity
Fully Integrated Prototype Design
Component Level Reliability Testing

• Thermoelectric device thermal cycling:
  – Accelerated test
  – 5000 cycle target

• Environmental chamber durability:
  – 32°C and 60% RH
  – 5000 hrs
Field Durability Testing

• 24/7 Durability lab in India
• 1 hour cycle – 45 minute burn/15 minute cool down
• Data Acquisition System will be used
  – Monitor TEG Performance
  – Monitor motor current and temperatures of key components
• Data recorded on a dedicated laptop with an uninterruptible power supply
• Laptop will be connected to the internet and data will be automatically uploaded to a shared Dropbox folder
• This allows near real time monitoring of performance from the U.S.
PM and CO monitor placement (Test #1 and #2)

Lower layer (30 cm above the ground)

- **L1** • MicroPEM PM • CO
- **L2** • MicroPEM PM
- **L3** • MicroPEM PM • CO
- **L4** • MicroPEM PM
- **Stove**
- **Entrance**

Higher layer (1.5 m above the ground)

- **H1** • MicroPEM PM • CO
- **H2** • MicroPEM PM
- **H3** • MicroPEM PM • CO
- **H4** • MicroPEM PM
- **H5** • MicroPEM PM
- **Opening**
- **Stove**
- **Opening**
- **Entrance**

*Openings made only for the Test #2*
PM and CO monitor placement (Test #1 and #2)
Next Steps

• Integrated prototype refinement

• Field reliability and safety testing:
  – Test prototype in the Envirofit 24/7 burn lab in India
  – 5,000 burn cycles to simulate 5 years of operation

• Field emissions testing:
  – Perform emissions test in US in portable tent
  – Perform emissions tests in India
  – Evaluate agreement between lab and field measurements

• Develop commercialization plan:
  – Manufacturing and scale-up plan
  – Marketing approach and analysis
  – Leverage RTI’s and Envirofit’s facilities in India and Kenya.