



NORTHERN
ARIZONA
UNIVERSITY



Cookstove Performance & Emissions

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EGR 486C Students, Fall 2016

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December 3rd , 2016



BACKGROUND

TWO STOVES



Three stones stove [2]



Jiko Stove [3]

WOOD

TWO FUELS

CHARCOAL

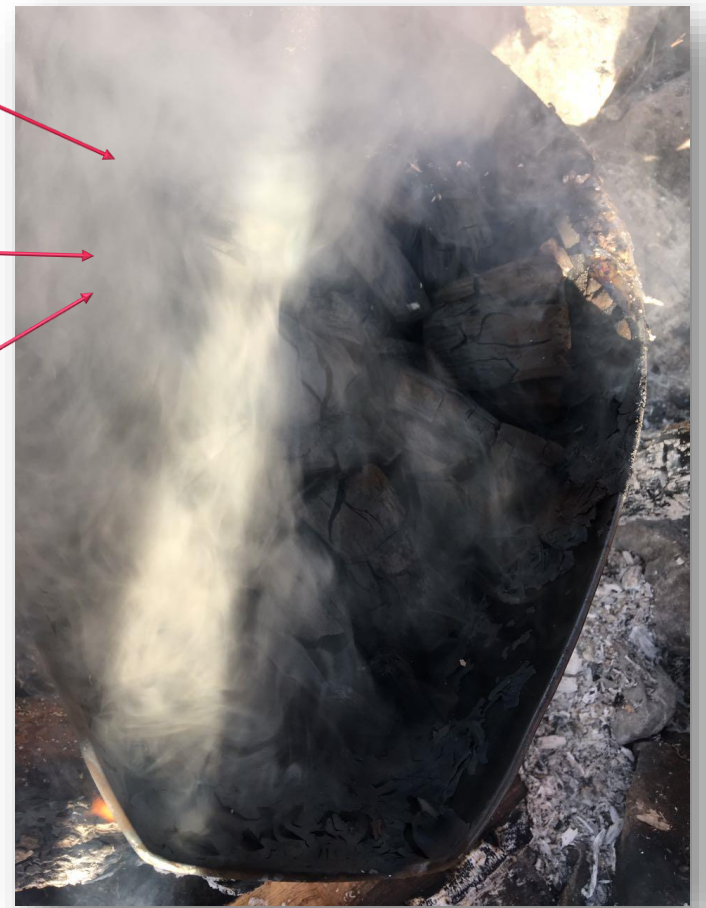


- Hard Wood (Maple)
- Higher Energy
- More heat

Enclosed Container

Low Oxygen

Exothermic



THE PLAN



Mechanical Engineers

Environmental Engineers

Predictions

Particulate Matter (PM) Testing & Analysis

Performance Testing & Analysis

HEAT TRANSFER

- $Q_{Delivered} = Q_{conv,total} + Q_{rad,total} + Q_{cond,total}$

CONVECTION

- $Q_{conv} = h * Area * (Temp_{hot} - Temp_{cold})$

RADIATION

- $Q_{radiation} = \epsilon * \sigma * Area * (Temp_{hot}^4 - Temp_{cold}^4)$

CONDUCTION

- $Q_{Conduction} = \frac{k * Area * (Temp_{hot} - Temp_{cold})}{Length}$

	Efficiency	
fuel type	jiko	3- stone
wood	21%	10%
charcoal	25%	12%

	Power (w)	
fuel type	jiko	3- stone
wood	750	360
charcoal	460	220



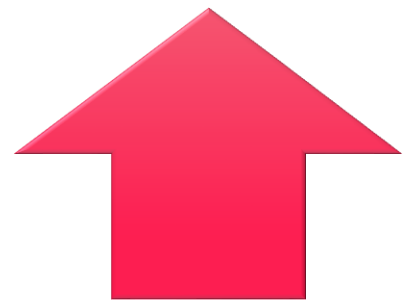
TESTING MATERIALS

Materials used are:

- Maple Wood
- Thermometer
- Steel Bin
- Aluminum Foil
- Scale
- Lighting fluid
- Lighter
- Water
- Pot
- Stop watch

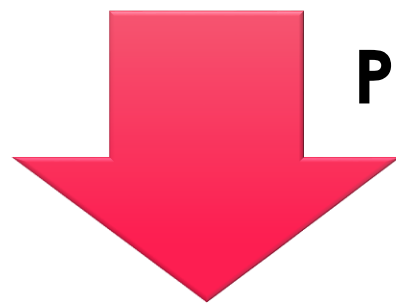


WATER BOILING TEST PROTOCOL VERSION 4.2.3*



Flagstaff

ALT=7100ft



Phoenix

ALT=1159ft



*By U.S. Environmental Protection Agency, Partnership for Clean Indoor Air (PCIA), with updates coordinated by PCIA and the Global Alliance for Clean Cook stoves (Alliance).

TESTING DATA ANALYSIS

- Efficiency $\eta_{th} = \frac{Q_{Delivered}}{Q_{Fuel}}$ **Eq. 1**

- $Q_{Delivered} = \Delta E_{H2O} + \Delta E_{vap} + \Delta E_{Lf}$ **Eq. 2**

- $\Delta E_{H2O} = c_{H2O} * (T_{final} - T_{initial}) * Mass_{H2O}$ **Eq. 3**

- $Q_{Fuel} = Mass_{Fuel} * HeatingValue_{Fuel}$ **Eq. 4**

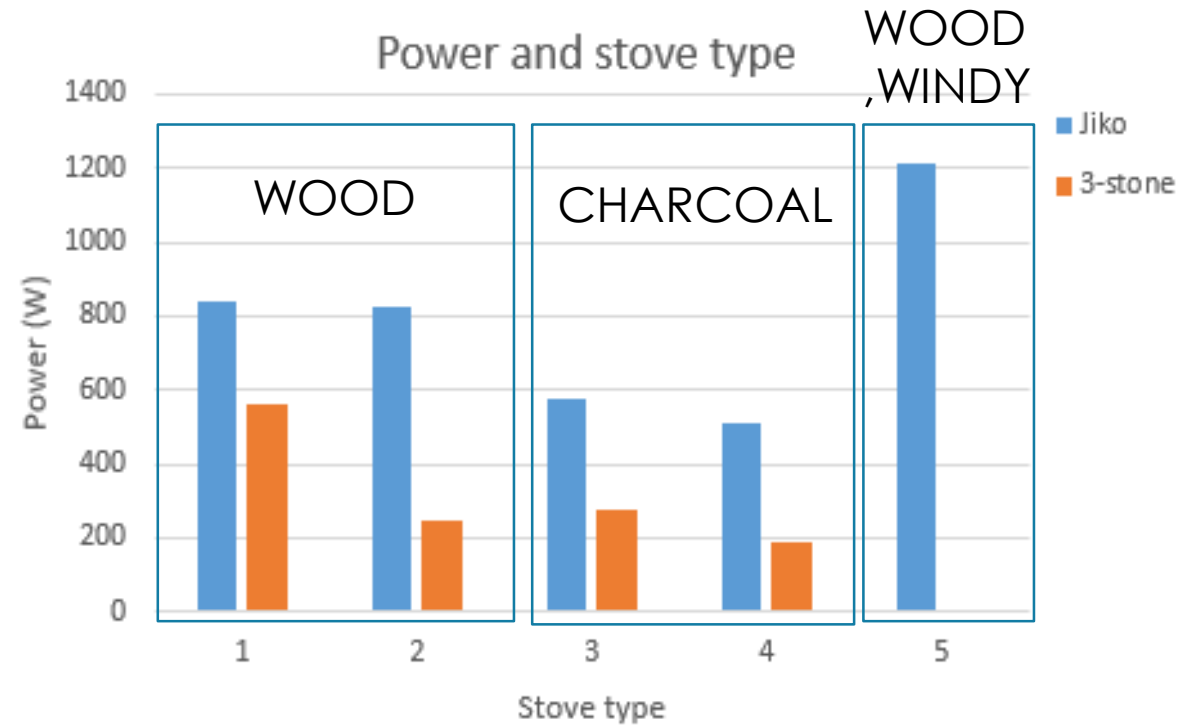
- $Power = \frac{Q_{delivered}}{time}$ **Eq. 5**

Maple						Charcoal
Weight dry cord,Maple	Weight dry cord,Maple	Recoverable heat value (dry wood)	Recoverable heat value (dry wood)	Recoverable heat value (dry wood)	Recoverable heat value (dry wood)	Recoverable heat value
(lb/cord)	(kg/cord)	(millions Btu/cord)	Mj/cord	Mj/kg	j/g	j/g
3655	1658	22	22789	14	13747	25700



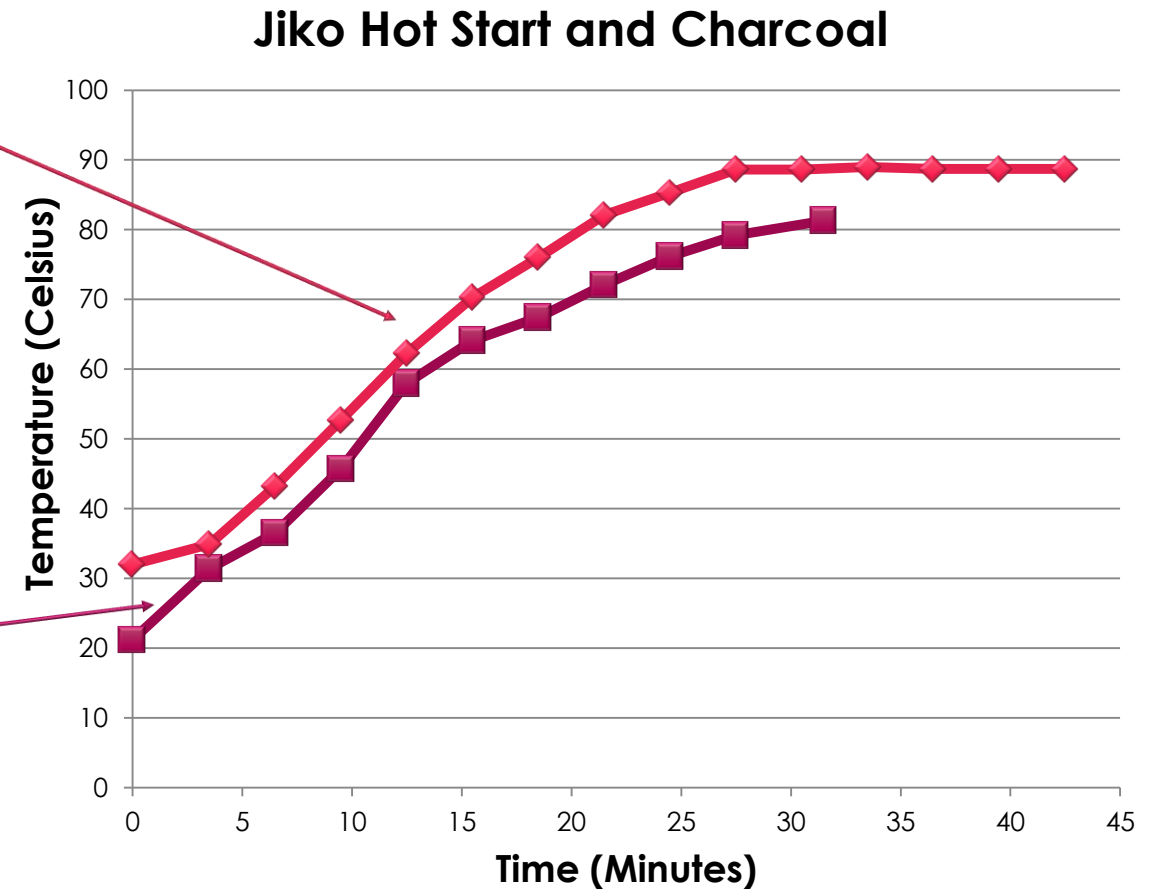
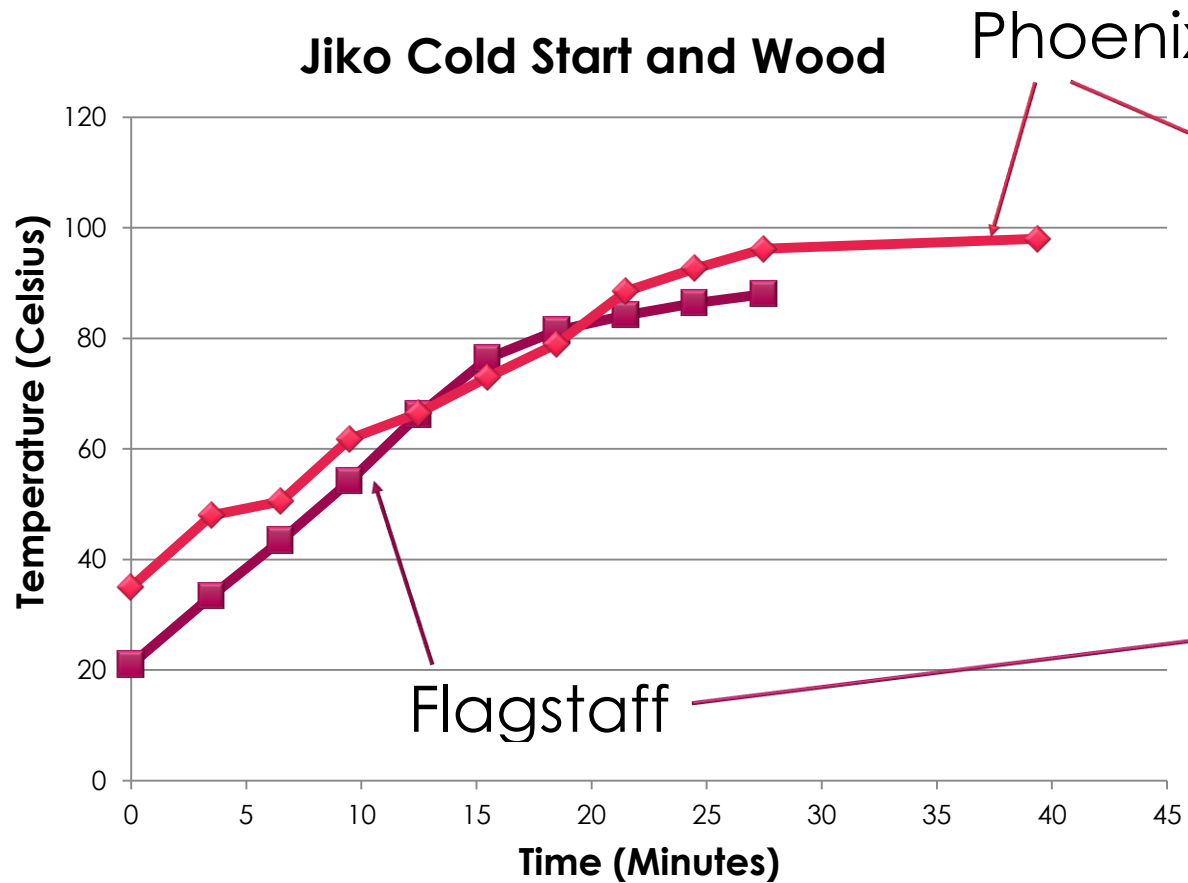
RESULTS

EFFICIENCY AND POWER



- **Wood** produced more power than **charcoal**.
- **Charcoal** was more efficient in the **Jiko**.
- The **Jiko** was more efficient and produced more power than the **3-stone**.

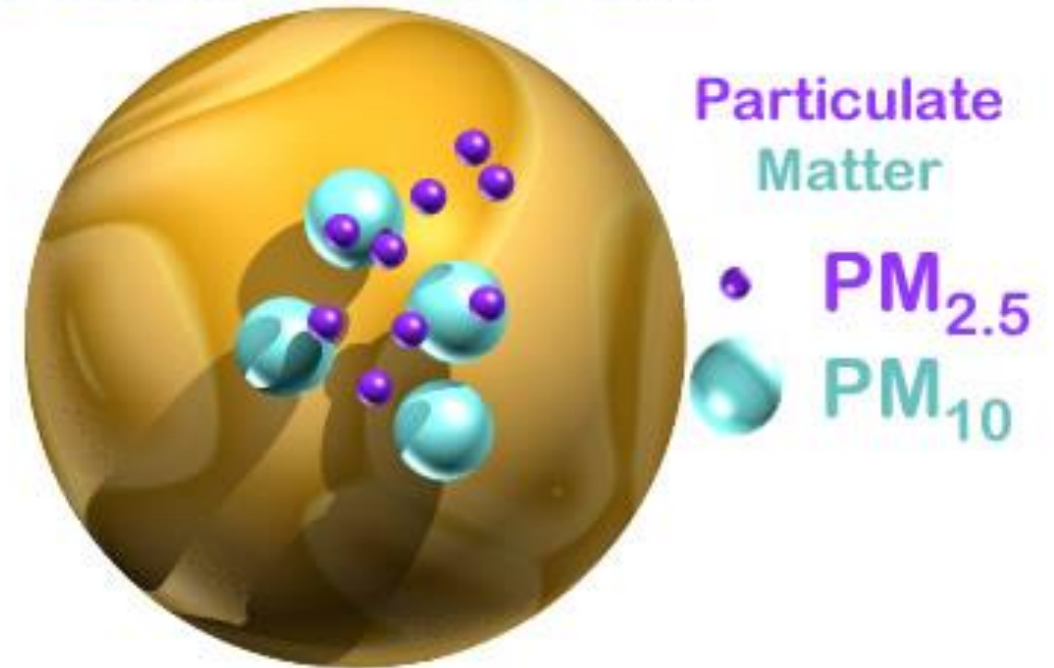
FLAGSTAFF VS. PHOENIX



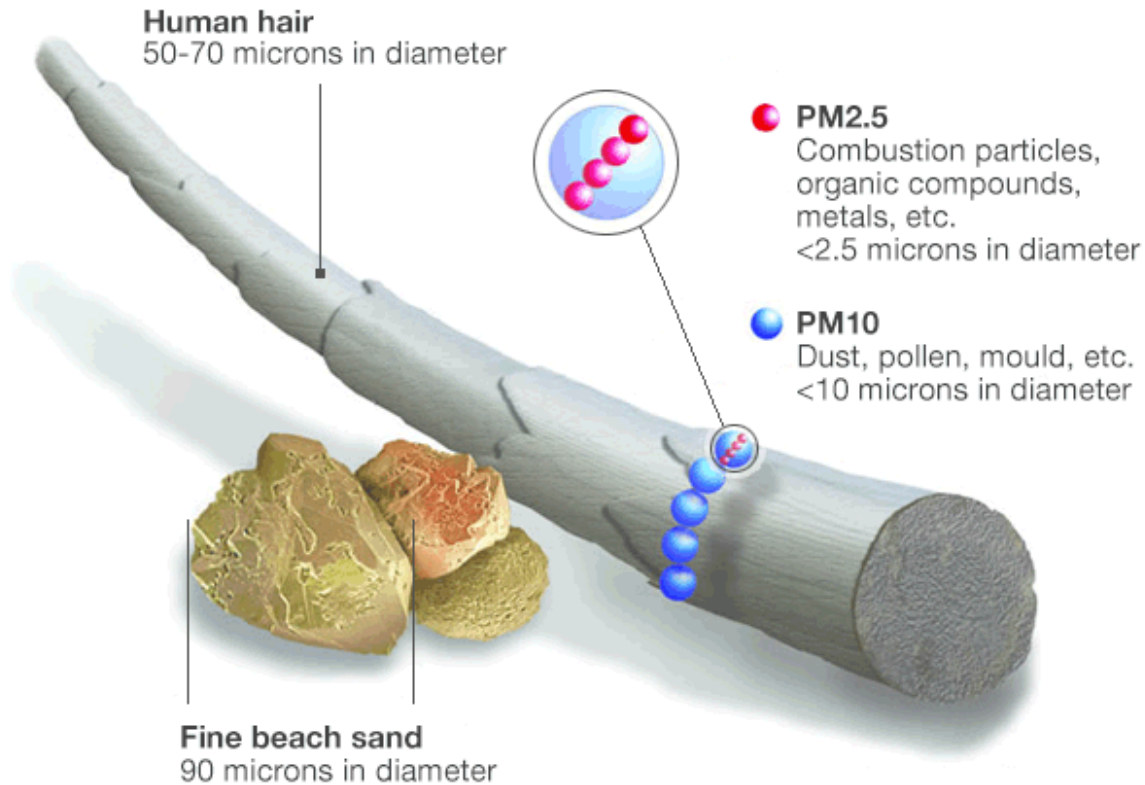
WHAT IS PARTICULATE MATTER?

- The sum of all solid and liquid particles suspended in air many of which are hazardous
- Organic and inorganic
- Dust and smoke

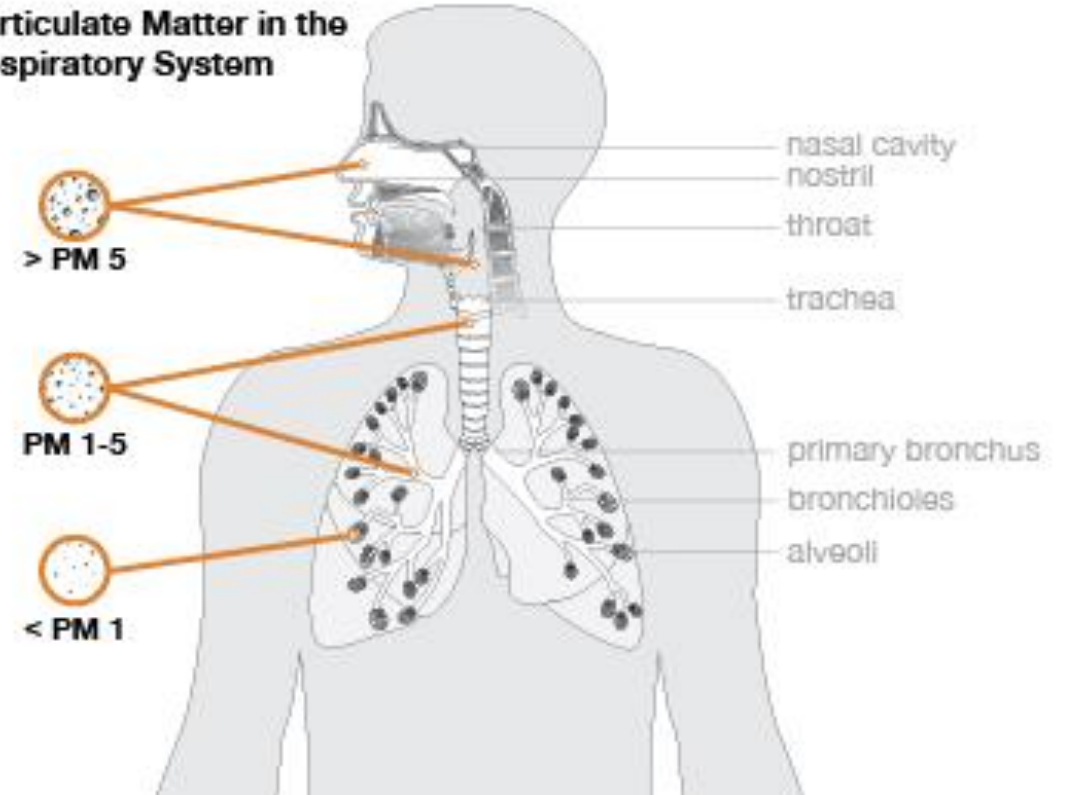
Beach Sand Grain



WHY IT IS HARMFUL?



Particulate Matter in the Respiratory System



WHAT IS PARTICULATE COUNTER?

In General

- Used in detecting and sizing physical particles emitted.
- Used in counting the particles emitted.

Met One Instrument Model 212

- Laser diode based optical sensor.
- Uses light scatter technology.
- Measure 0.3 μm to 10 μm (eight selectable sizes).



Met one Model 212

PM TESTING METHOD¹⁵

Set up the device 2 feet from the emissions source

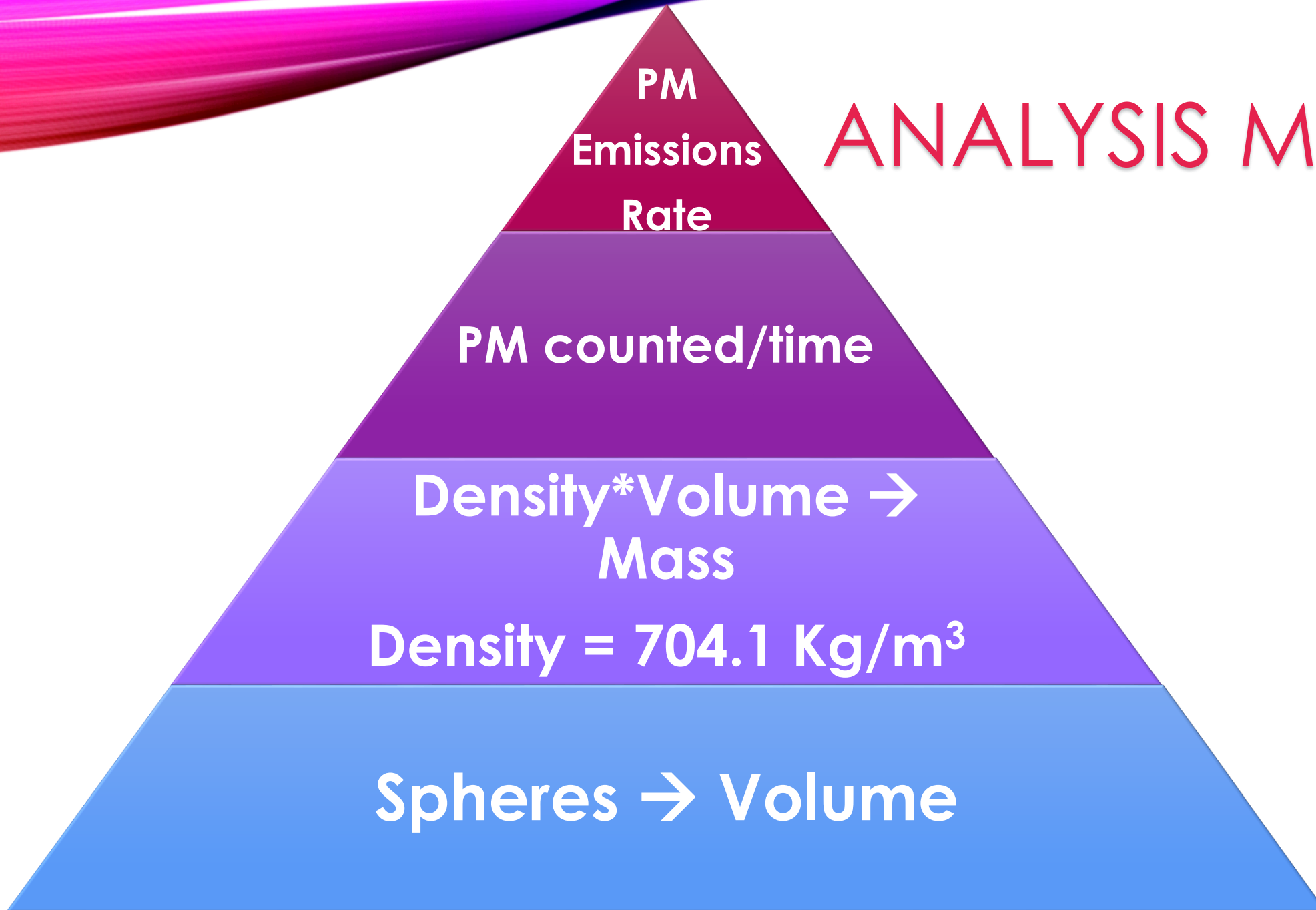
Attach it to the computer

Start recording the data from the device profiler software

Analyze the data in a spreadsheet

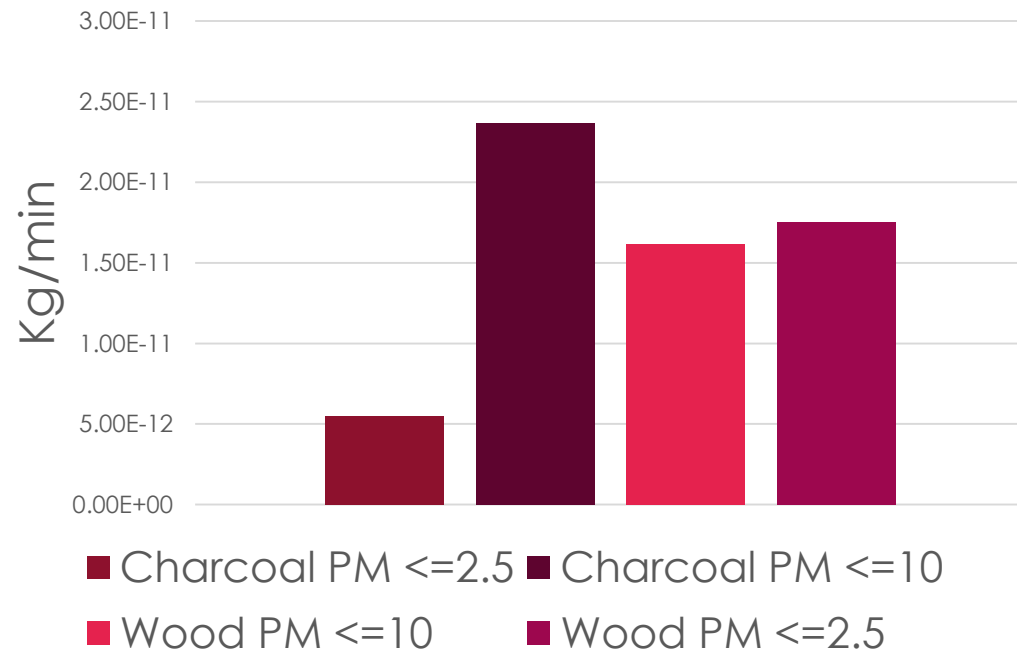


ANALYSIS METHOD

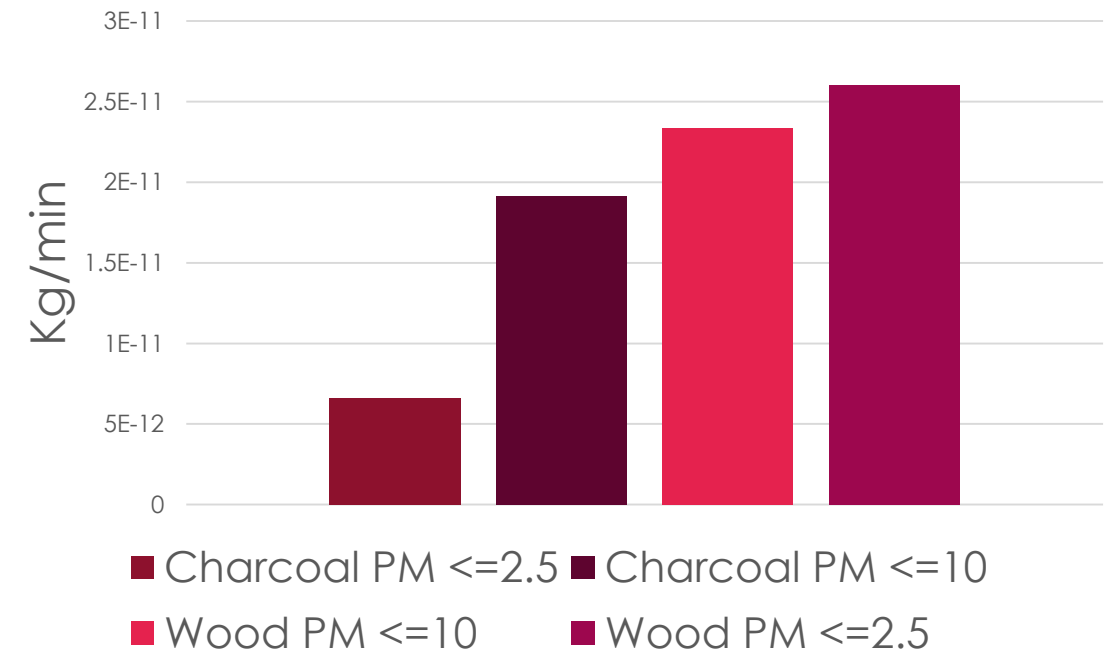


PM EMISSIONS RATE

Jiko stove with charcoal & wood



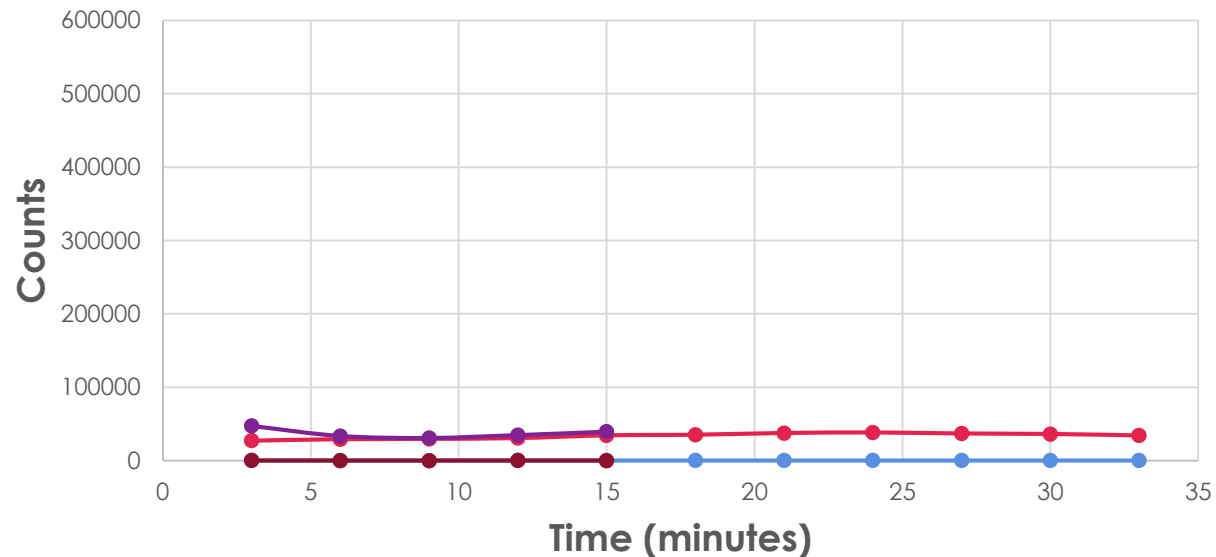
3-stones stove with charcoal & wood



PM TESTING RESULTS

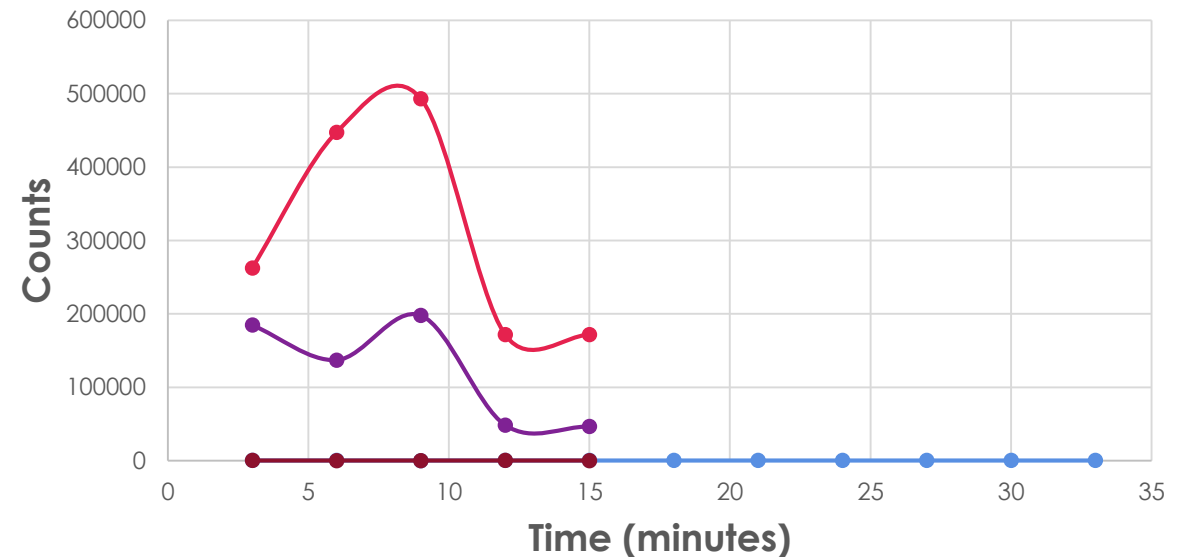
Charcoal

● Jiko PM \leq 2.5 ● 3-stones PM \leq 2.5
 ● Jiko PM \leq 10 ● 3-stones PM \leq 10



Wood

● Jiko PM \leq 2.5 ● 3-stones PM \leq 2.5
 ● Jiko PM \leq 10 ● 3-stones PM \leq 10



- Wood produced significant amounts of PM \leq 2.5 microns
- Charcoal produced far less PM \leq 2.5 microns
- The Jiko with charcoal produced the fewest emissions of any combination

PM TESTING RESULTS



- Jiko with charcoal produces fewest PM<=2.5 to boil 3 liters of water.

EFFICIENCY AND PM RESULTS

EFFICIENCY

FUEL TYPE	Jiko	3-Stones
WOOD	23.9%	12.4%
	20.3%	8.2%
CHARCOAL	28.3%	8.9%
	24.8%	9.0%

EMISSIONS

PM SIZES (microns)	WOOD		CHARCOAL	
	Jiko	3-Stones	Jiko	3-Stones
PM_{≤2.5} *10 ³	1546	1790	151	186
PM_{≤10} *10 ³	1.02	1.98	1.2	1.12

RECOMMENDATIONS

Next Stove Capstone Group

- **Mechanical Engineering Students**

- I. More Cookstoves
- II. Proper scale
- III. More testing trials
- IV. Isolated facility
- V. Continual feed testing
- VI. Simmer testing
- VII. Animal waste testing

Women in Rural Areas of Africa

- **The Best Option in Terms of Efficiency:**

- ✓ Jiko with charcoal

- **The Best Option in Terms of Power:**

- ✓ Jiko with wood

RECOMMENDATIONS

Next Stove Capstone Group

- **Environmental Engineering Students**
 - I. Carbon Monoxide (CO)
 - II. Carbon Dioxide (CO₂)
 - III. Nitrogen Oxides (NO_x)

Women in Rural Areas of Africa

- The Best Option in Terms of **PM Emissions:**
 - ✓ Jiko with charcoal

ACKNOWLEDGEMENTS



Dr. Fethiye Ozis



Dr. Sagnik Mazumdar



Dr. Terry Baxter



Instructor Gary Slim

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QUESTIONS?

