# Biomass Combustion Devices

International Training Programme
March 20-31, 2006

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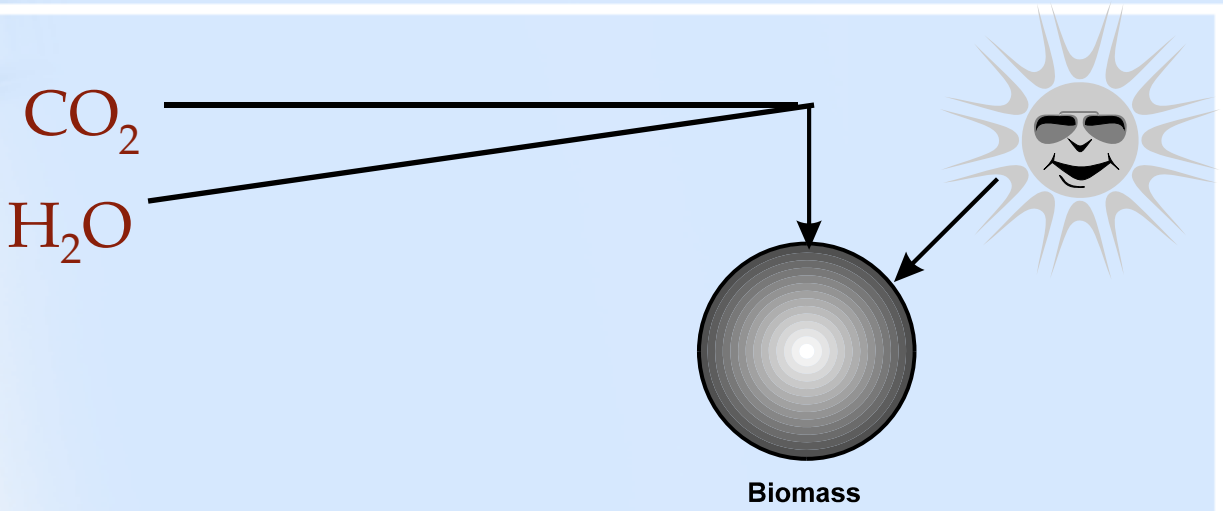
# Structure of Presentation

- Biomass
- Combustion – Air-to-Fuel Ratio
- Devices –
  - Sawdust Stove
  - Gasifier Stove
    - Cooking
    - Bath Water Heating
  - Puffed Rice Stove
  - Ejector Stove
  - Cardamom Dryer

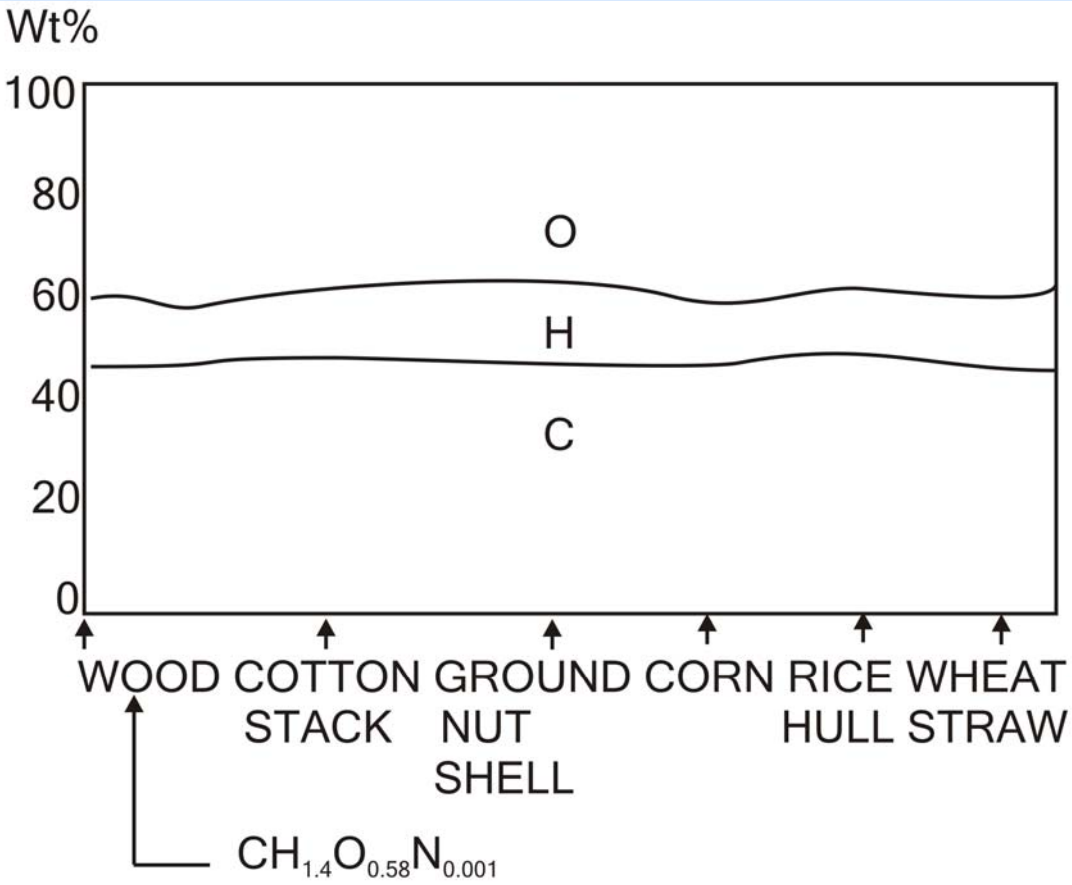



- Biomass is stored solar energy.
- Woody biomass  is dense and has little ash.
- Agricultural residues can be woody, like cotton stalk and mulberry stalk.
- Weeds like Juliflora Prosopis, Lantana camera, usually found in tropical climates can also be treated as woody biomass.

# Biomass - Classification

| WOODY | AGRO RESIDUES |
|---|---|
| Branches of wood | Rice husk, Rice straw |
| Some agricultural wastes | Saw dust |
| Cotton sticks | Sugarcane trash |
| Mulberry sticks | Bagasse |
| Lantana, Prosopis Julifora | Coir pith, Peanut shells |
| Density > 250 - 300 kg/$m^3$ | < 250 - 300 kg/$m^3$ |
| Ash < 2 % | ~ 6 - 20 % |

# Biomass - Composition



# Biomass - Energy Content

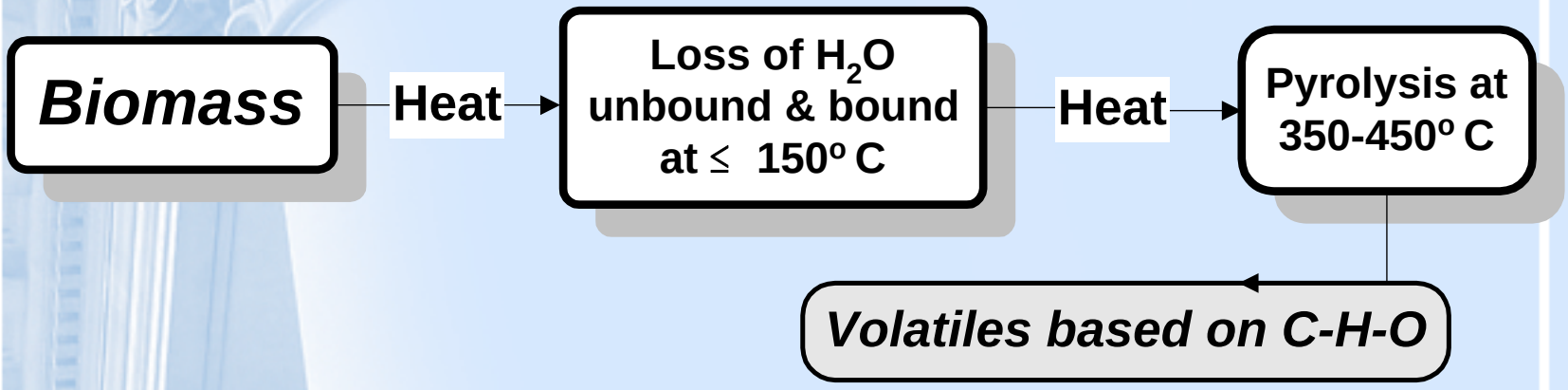
Lower Cal Value = $(18.0 - 20\ f_w)(1-f_{ash})$
(MJ/kg) (for $f_w < 50$ %)

$f_w$ = Moisture fraction in dry wood

$f_{ash}$ = Ash fraction in dry wood

- Typically sun dry wood has 10 % Moisture & Ash fraction are 0.5 %
- Thus the calorific value of sun dry wood is 15.8 MJ/kg.

# Combustion - Volatilization




| Biomass | Volatiles | Fixed Carbon | Ash |
|---|---|---|---|
| Bagasse | 75 | 17 | 08 |
| Rice husk | 60 | 20 | 20 |
| Corn cob | 80 | 16 | 04 |
| Wood | 75 | 24 | 01 |

# Combustion - Air-to-Fuel Ratio

$$CH_{1.4}O_{0.6}N_{0.002} + 1.05\,(O_2 + 3.76\,N_2) \longrightarrow CO_2 + 0.7\,H_2O + 3.952N_2$$

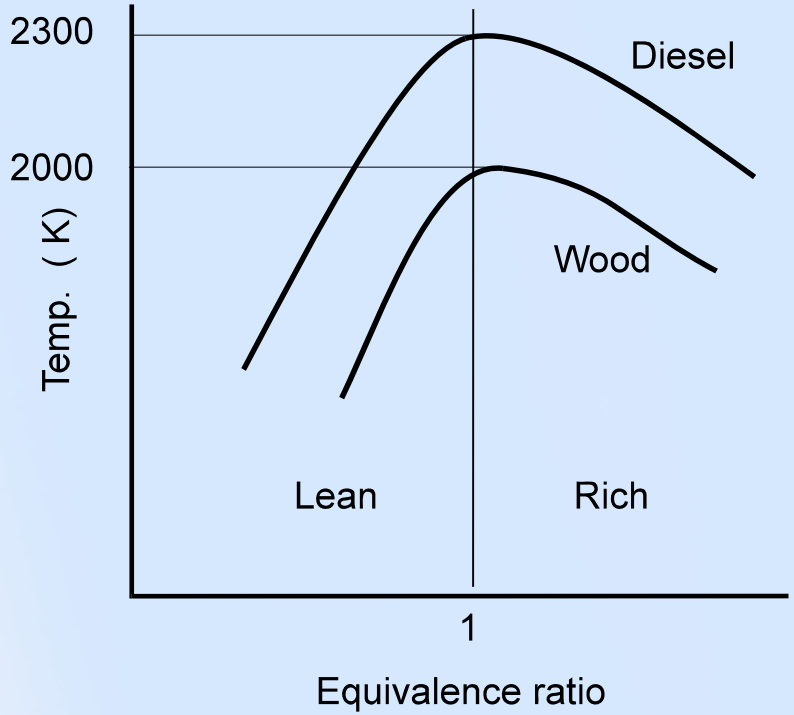
Thus, Stoichiometric Air to Fuel Ratio for Biomass is 6.3

# Combustion – Air-to-Fuel Ratio

$CH_nO_m$

| | n | m | Ash | A/F |
|---|---|---|---|---|
| Rice husk | 1.78 | 0.56 | 20.0 | 5.60 |
| Saw dust | 1.65 | 0.69 | 0.80 | 5.90 |
| Paper | 1.60 | 0.65 | 6.00 | 5.75 |
| Rice straw | 1.56 | 0.50 | 20.0 | 5.80 |
| Douglas fir | 1.45 | 0.60 | 0.80 | 6.30 |
| Beech | 1.33 | 0.60 | 0.20 | 6.00 |
| Pine bark | 1.33 | 0.60 | 2.90 | 5.85 |

# Combustion - Flame Temperature




Wood combustion achieves 1273 K -1673 K
Since air-to-fuel ratio matching with the stoichiometric value is difficult due to varying fuel wood size and operating procedure.

# Combustion – Comparison

| Fuel | Energy MJ/kg | Temperature K |
|---|---|---|
| Petroleum fuel | 40 - 44 | 1800 - 1900 |
| Wood | 14 - 17 | 1300 - 1700 |
| Rice husk, other shells with high ash | 10 - 13 | 1000 - 1300 |

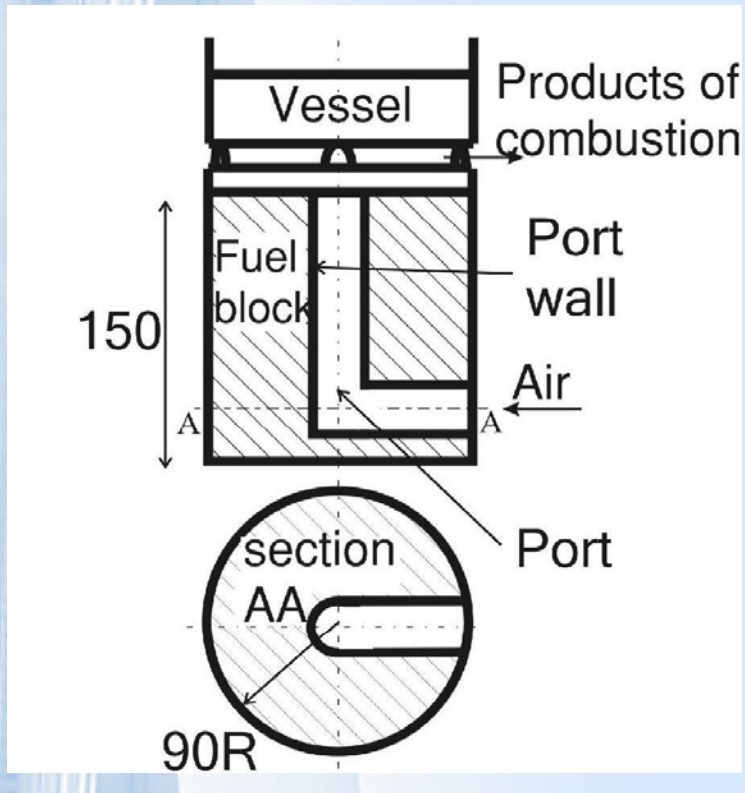
- Peak temperatures achieved in biomass combustion is not very inferior to petroleum fuels

# Combustion – Emission (Stoves) g/kg fuel

| Fuel | $CO_2$ | CO | $CH_4$ |
|---|---|---|---|
| Wood | 1450 | 58.7 | 2.7 |
| Crop Residues | 1130 | 86.3 | 4.6 |
| Coal | 2280 | 71.3 | 2.9 |
| Kerosene | 3130 | 7.4 | 0.03 |
| Gases | 2980 | 3.7 | 0.14 |

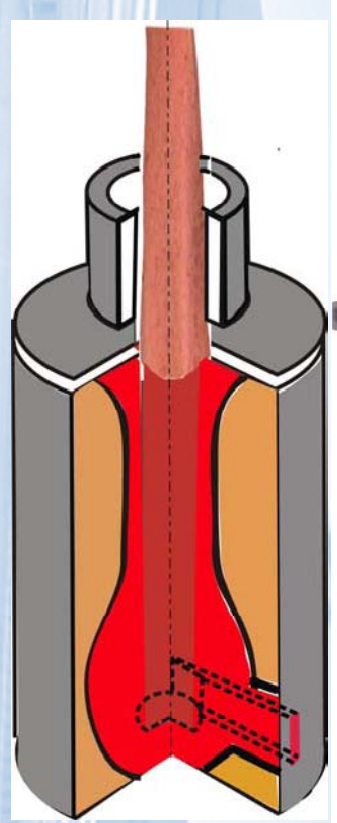
- Crop residues have CO emissions 1.5 times that of wood
- Pulverisation renders fuels more uniform

# Devices - Sawdust Stove




- Works with sawdust packed to ~ 250 kg/m$^3$
- The port size and height fix power level.
- Web thickness fixes Burn time
- CGPL has established these parameters
- Flame quality is less then optimum

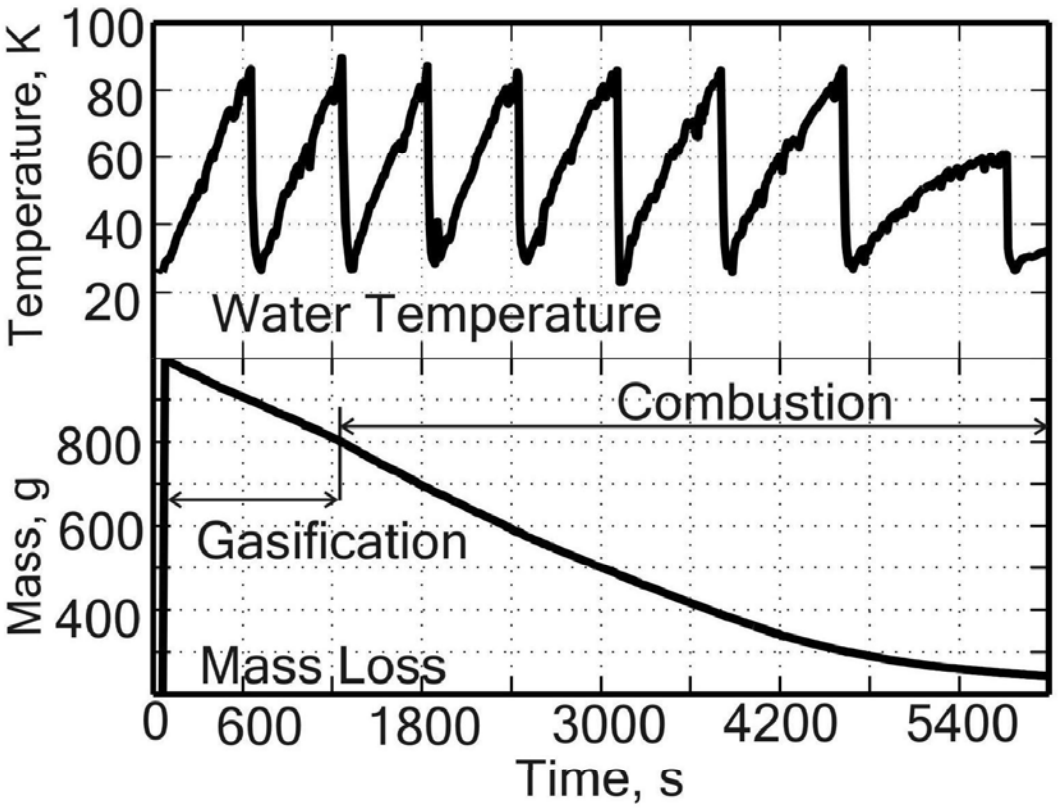
# Devices - Pulverised Fuel Stove

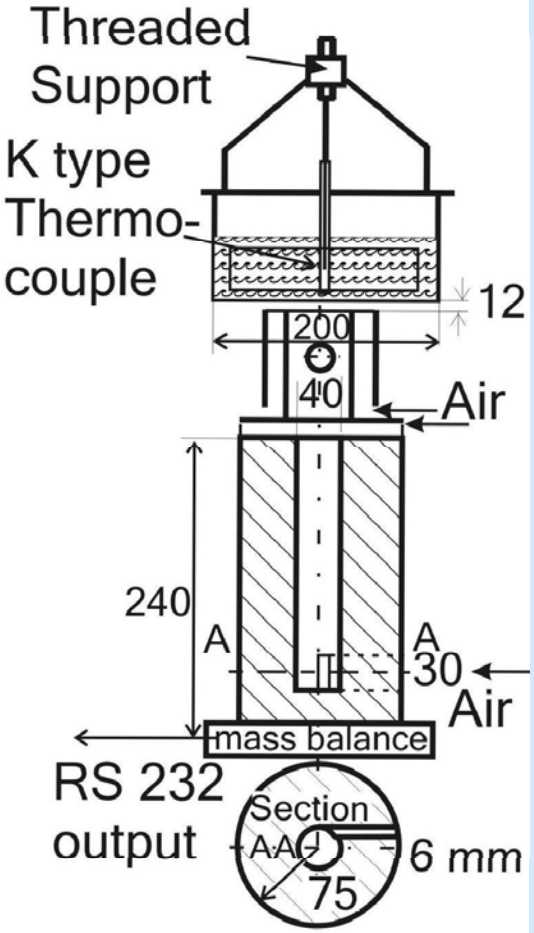


- Based on sawdust Stove Design
- Works on Gasification mode for part of burn time
- Flame quality is excellent
- Performance has been tested for sawdust and leafy droppings

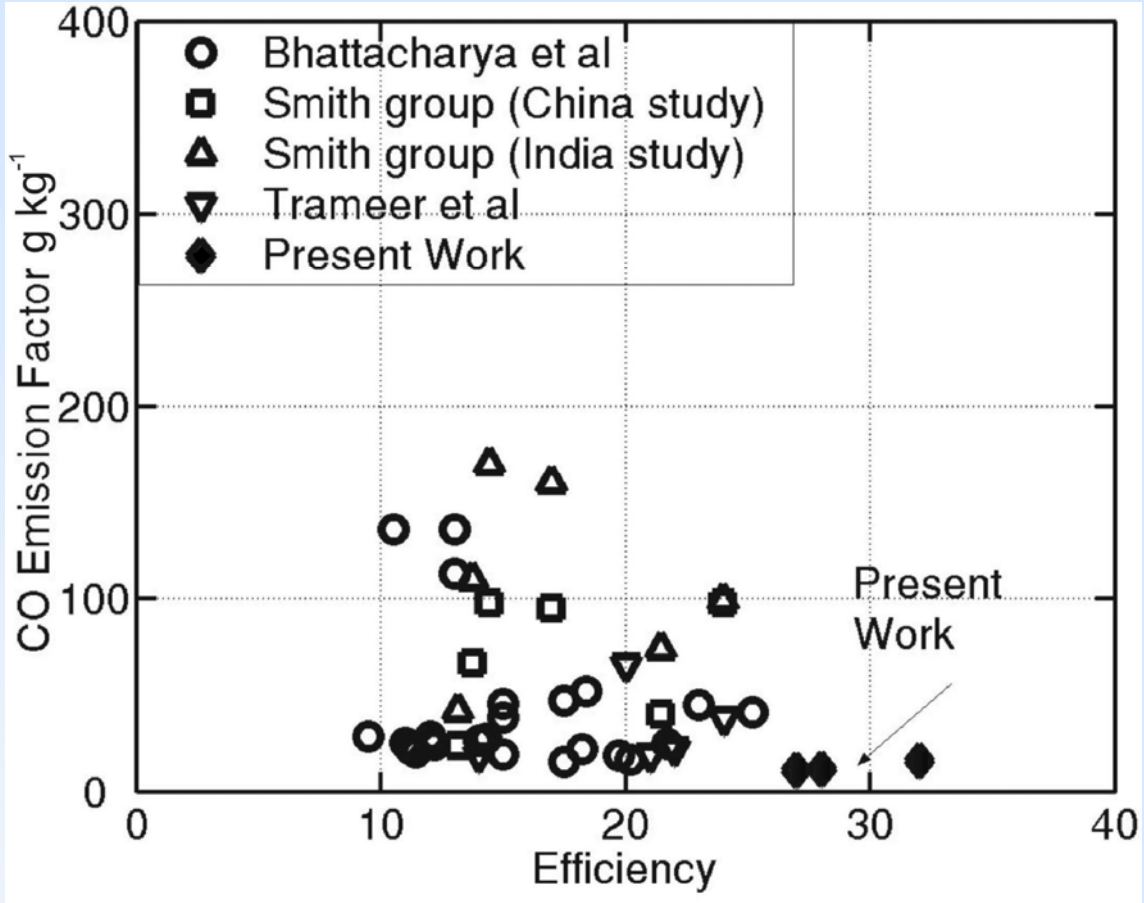
# Devices - Pulverised Fuel Stove

Spacing Between Stove and Vessel = 12 mm

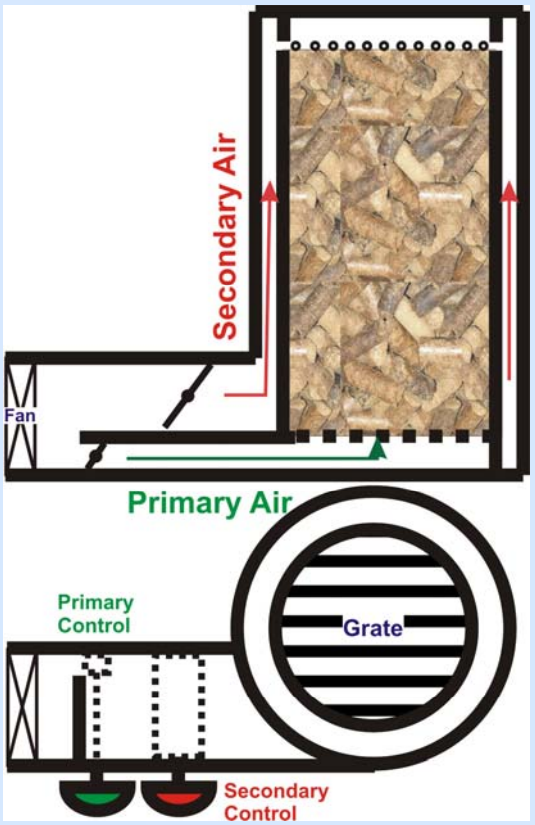


# Devices - Pulverised Fuel Stove



# Devices - Gasifier Stove




Staged air addition with separate controls for primary and secondary air

# Devices - Gasifier Stove

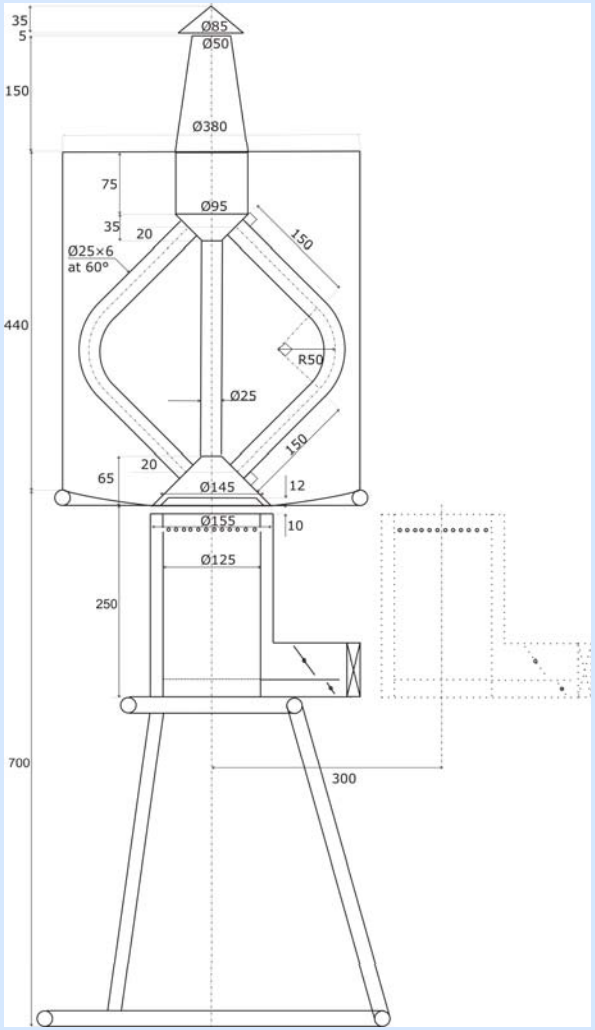
- The stove can accept fuel in the form of pellets or wood chips
- The stove works at a power level of 2-3 kW convenient for cooking
- The stove has water heating efficiency greater than 50% and operation is smoke free.
- Field trials are being conducted in association with British Petroleum

# Devices - Gasifier Stove

| Fuel | Bulk Density $kg/m^3$ | Charge g | Time min |
|---|---|---|---|
| Wood Chips | 200-225 | 225-250 | 30-35 |
| Briquettes | 325-350 | 350-400 | 45-50 |
| Coffee Pellets | 525-550 | 550-600 | 65-70 |

- LPG worth 11 US cents is replaced by 2 US cents worth biomass for one hour of cooking

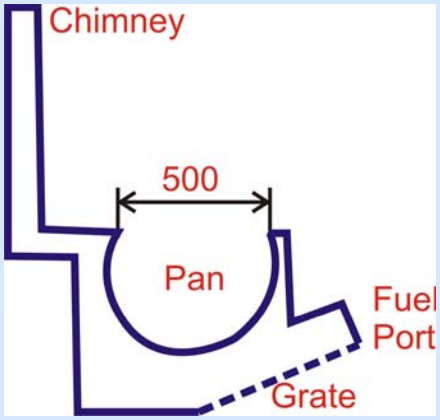
# Devices -Bath Water Heating



# Devices- Bath Water Heating

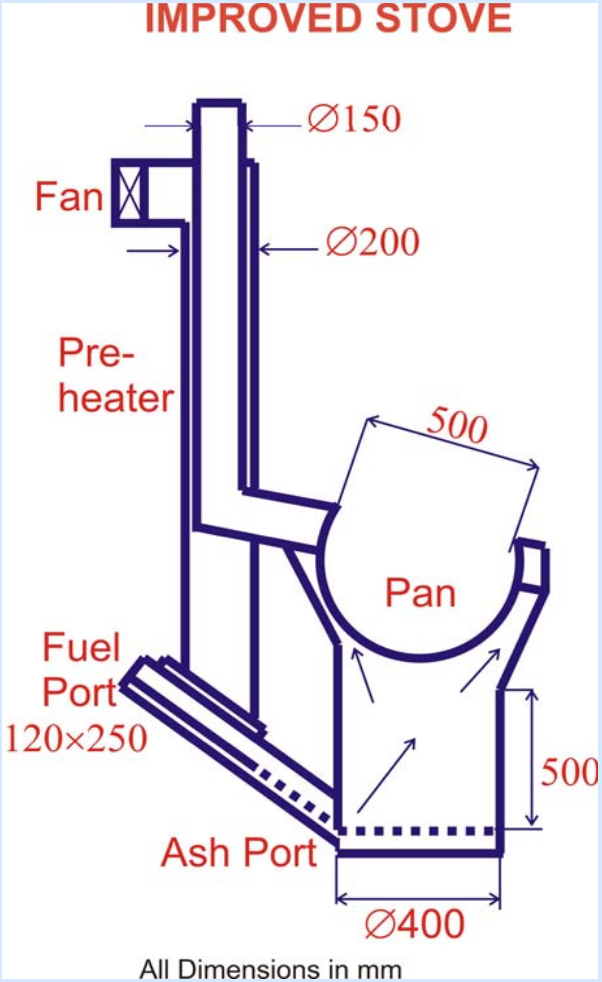
- Uses Gasifier Stove for Combustion of 2-3 kW power level
- Over all water heating efficiency greater than 80% due to larger Heat Transfer area
- Designed for convenience in usage
- 45 litres of 50 °C Water in 30 min using 0.6 kg biomass
- Cost including gasifier stove which can be used for cooking also: 100 $

# Devices - Puffed Rice Stove




- Puffed Rice– a popular snack.
- Prepared by roasting conditioned rice grains in hot sand bed.
- Traditional devices highly inefficient, use tyre to achieve high temperatures.

# Devices – Puffed Rice Stove



# Devices - Puffed Rice Stove

- Puffing time 10 – 15 Seconds
- Volume appreciation about 4 times
- Sand bed at  573 K – critical for the process.
- The recuperated stove uses flue gas to heat incoming air.
- 100 W fan used for air supply

# Devices - Puffed Rice Stove

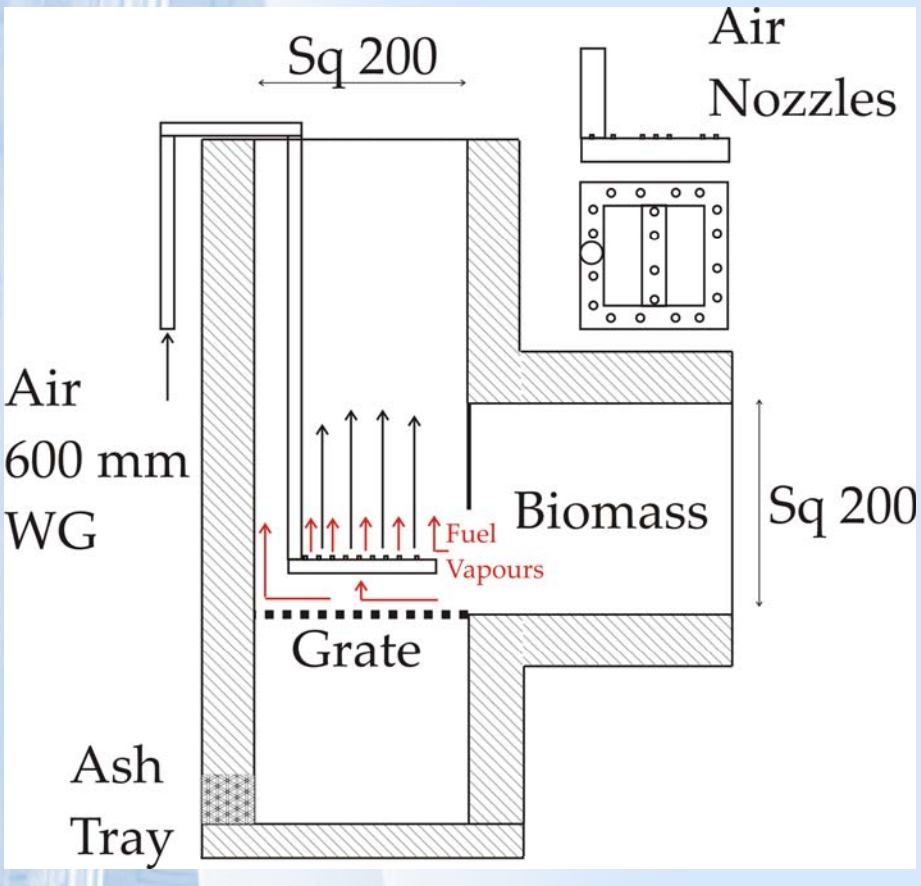
- Combustion complete with clean exhaust
- Significant improvement in environmental conditions
- Can also be used for other applications

# Devices - Puffed Rice Stove

| Parameter | Conventional | Improved |
|---|---|---|
| Fuel (in 3 hr) | 40 kg Biomass + 20 kg tyre | 50 kg Biomass |
| Fuel Cost | $3 | $2.5 |
| Emissions | Smoke, Soot, PIC | 17g CO/kg fuel |
| Power | 120 kW | 74 kW |
| Production | 13-14 bags Puffed Rice | 16 bags |
| Savings | - | $8 - $10 |
| Investment | - | $1000 |
| Payback | - | 100 Days |

800 Stoves in a cluster in Davanagere & 4000 Stoves in Karnataka

# Devices - Ejector Stove



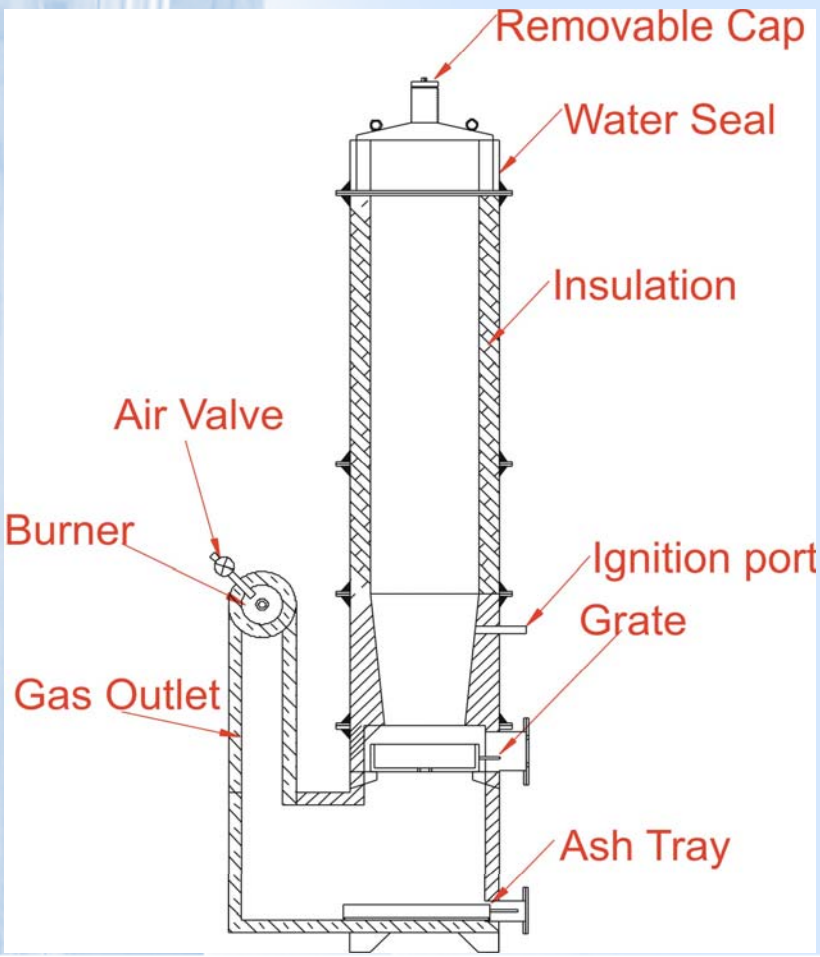

# Devices - Ejector Stove

- Based on ejector action of high pressure air which draws fuel vapours across char bed.
- Community cooking applications
- Efficiency:  34%
- Power Level: 25 kW , can also be designed for any power level
- Low emissions
- Cost: 600 $

# Devices: Ejector Stove Applications

- LPG required for mid day meals scheme in one month (25 days) for 2000 children): 300 kg
- Cost of LPG @ 0.5 $/kg = 150 $
- 10 Stoves of 6 kg/hr (30 kW) required
- Biomass used in one month : 1500 kg
- Biomass Cost per month = 30 $
- Electricity (6 cents/unit) / month = 12 $
- Maintenance, if any = 20 $
- Saving per month: 88 $
- Saving per year: 1056 $
- Pay Back of investment: ~ 5 years

# Devices - Cardamom Dryer




# Devices - Cardamom Dryer

- Drying is a 22 hour cycle with controlled heating rate (45 to 85 °C).
- Biomass combustor replaces Diesel fired indirect heating system
- The hot gas is sucked through the system by a blower.
- The change in power level for controlled operation is through speed change in suction blower.
- 2 litres/hr diesel replaced by 8 – 10 kg/hr biomass, implies 85% reduction in fuel cost
- Device cost for 2 litres/hr substitution
  ~ 2750 $
- Can also be used for other applications

# Review

- Biomass, woody or non-woody, will have comparable energy content on dry ash free basis.
- Proper Air to fuel ratio and staged air addition leads to complete combustion with reduced emissions.
- Case studies where high efficiency and reduced emissions are discussed for devices with different power levels

Thank You