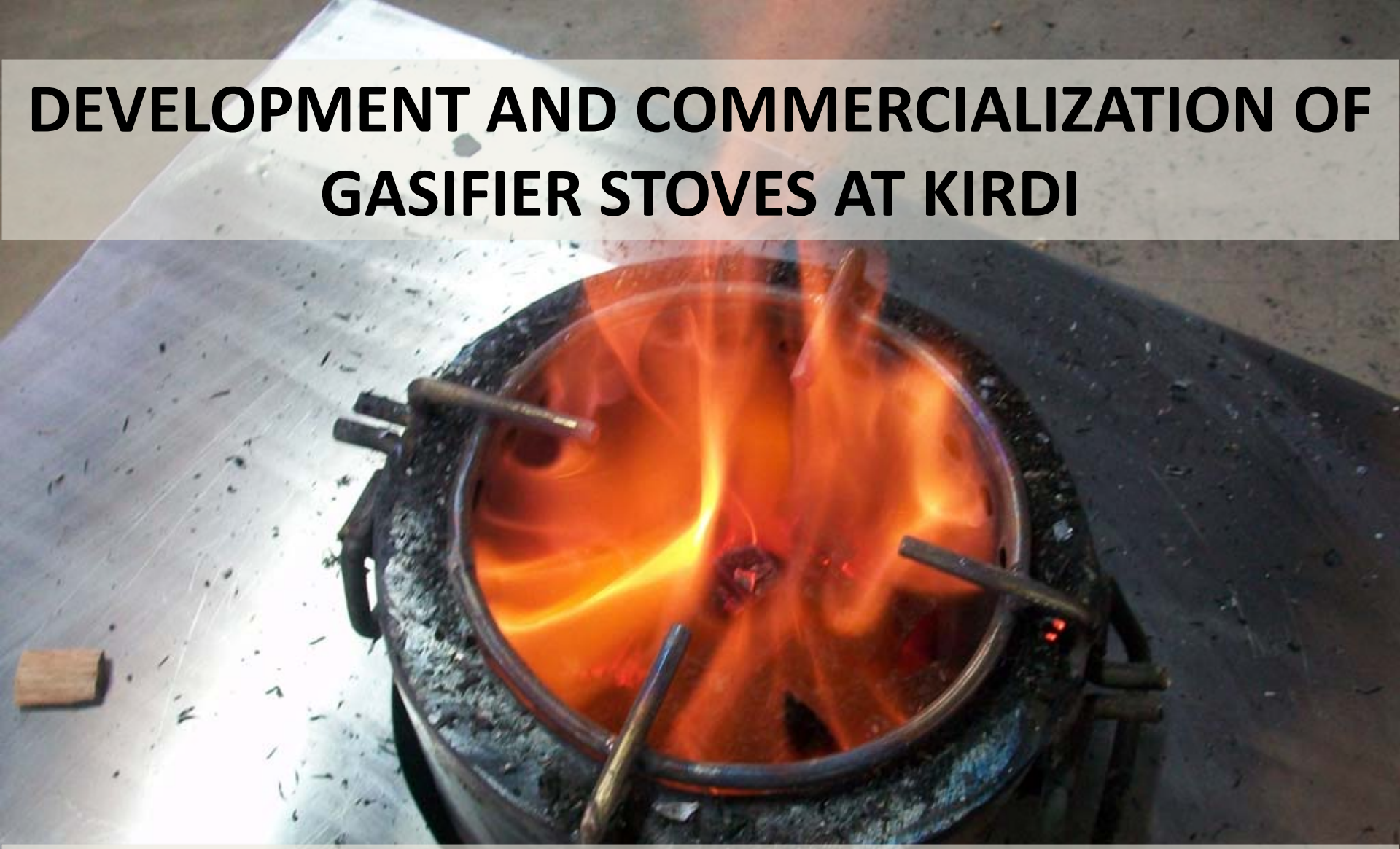
DEVELOPMENT AND COMMERCIALIZATION OF GASIFIER STOVES AT KIRDI



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Panafric Hotel, Nairobi, Kenya. 7th June 2011

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KIRDI

- Est. in 1979 through the Sci. and Tech. Act Cap 250 under the Ministry of Industrialization
- Mandate - to undertake multidisciplinary research and development in industrial and allied technologies and transfer results for the country's industrial development
- A key stakeholder in actualization of the government's Vision 2030
- Rapid acquisition and absorption of requisite technologies by industry, and particularly the MSEs, is key to increasing the manufacturing sectors contribution to Gross Domestic Product from 10% to 20%.

- R&D department
  - Engineering, Energy, Food Technology, Chemical Technology, Environmental Management, Ceramics, Leather, Textiles, ICT and Project studies

- Technology transfer and extension services department
  - 4K MSE 2030 Initiative,
  - Pilot Plants (South C, South B, Kisumu, Mombasa, Kisii, Eldoret, Kapsabet, West Pokot, Garissa),
  - Technology Business Incubation,
  - IP Office, NIIC, EDSC, LSC and LDC

- Technologies disseminated:
  - Leather - technology for utilization of fish by-products (skin, air bladder and oil), mini-tanneries
  - Chemical Technology - processing of different natural products including atemenisinin, Anthrilinic acid (textile dying), bio-pesticides, nutraceuticals, phyto-medicines, adhesives, resins and gums, aloe vera, nuts, soap, detergents, etc.
  - Energy - biogas technology for slaughter houses, LED lighting systems
  - Food technology - vegetable dehydration technology, UV Color sorting technology for coffee beans, honey processing, fruit processing, cereals, roots & tubers, etc
  - Ceramics – Brick making, water filters,
  - Environmental management – waste treatment, cleaner production, waste recycling, gasifier stoves

Activities

1. **Development of gasifier stoves**
   - Improved cook stoves are an attempt to address the negative environmental and social effects of the three stone fire.
     - Kenya Ceramic Jiko (Charcoal), Kuni Mbili, Maendeleo/Upesi and Rocket Mud Stoves.
     - Rocket stoves like Jiko poa (Eco-jiko, Eco-stove, Environfit) - being disseminated by JP Morgan Chase for carbon credits Gunther, M. (2008), GIZ-PSDA, Paradigm, etc
     - Thai bucket (charcoal), Improved Chulha (india), Lorena adobe stove (Central America), Justa stove, Onil stove , Berkeley-Darfur stove, etc.
   - Latest in Kenya: Envirofit, StoveTec, Philips Natural Drafte, Save80 and Vesto Berkeley Air Monitoring Group (2010)


JIKOPOA

- Possible advantages of gasifier stoves over conventional stoves:
  - Less emissions (particulates and CO)
  - Higher thermal efficiency (25-50%) Panwar and Rathore (2008), Mukunda et al. (2010),(25-35) Bhattacharya and Leon (2005)
  - Less supervision – load once in batches
  - Utilize wider variety of fuels - agri. Wastes e.g rice husks, coffee husks, maize cobs, coconut and macadumia shells, etc
  - Make charcoal as you cook (over 70% of the tree will not be wasted via traditional charcoal burning)
    - A household that relies exclusively upon charcoal will consume between 240kg and 600kg of charcoal annually; the input of biomass required in the production of this charcoal is 1.5 to 3.5 tons. Chardust Ltd. and Spectrum Technical Services (2004)

Gasification

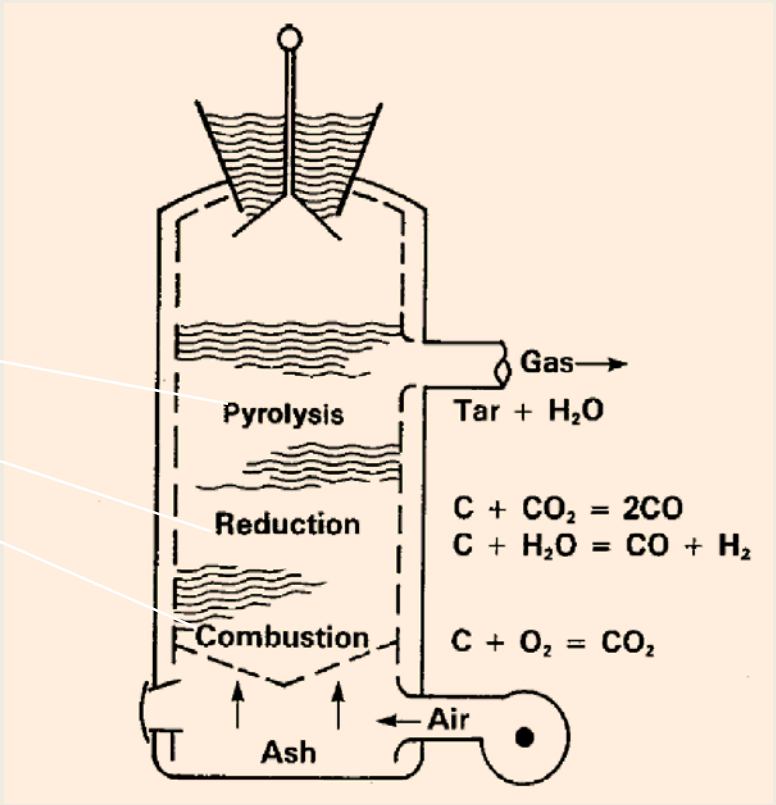


Fig. - updraft gasifier

- Various gasifier stoves prorotypes
  - Fixed bed gasifier stoves developed: Anderson's "Champion-2008", Reed's Woodgas Campstove, Daxu, BP, Reddy's Magh-CM1, Belonio's Rice Husks gasifier stove, MJ Rice Husks Gas Stove, IISc-CGPL Lapsi Candy, Anderson's Sanghi, Anderson's Juntos B3, NERD Sri Lanka, ARTI's Agni, Peko Pee, Oorja and Phillips. Anderson, P.S. (2008 & 2009), Miles, T. (2008 & 2009)., Mukunda, H.S. et al (2010),
  - Others: DA-IRRI, CPU Single-Burner Batch-Type, CPU TLUD, CPU Cross-Flow Type, San San, CPC Turbo Wood Gas Stove, Special Purpose Straw Gas Cooker, CRESSARD Gasifier Stove (downdraft type), Pellet, Holey Briquette, and the AIT Wood Gasifier Stove Belonio, A. T. (2005)
- KIRDI has adapted some of these stoves and developed prototypes for testing


Gasi-201


Gasi-101


Gasi-301

Gasi-111 – With gas piping

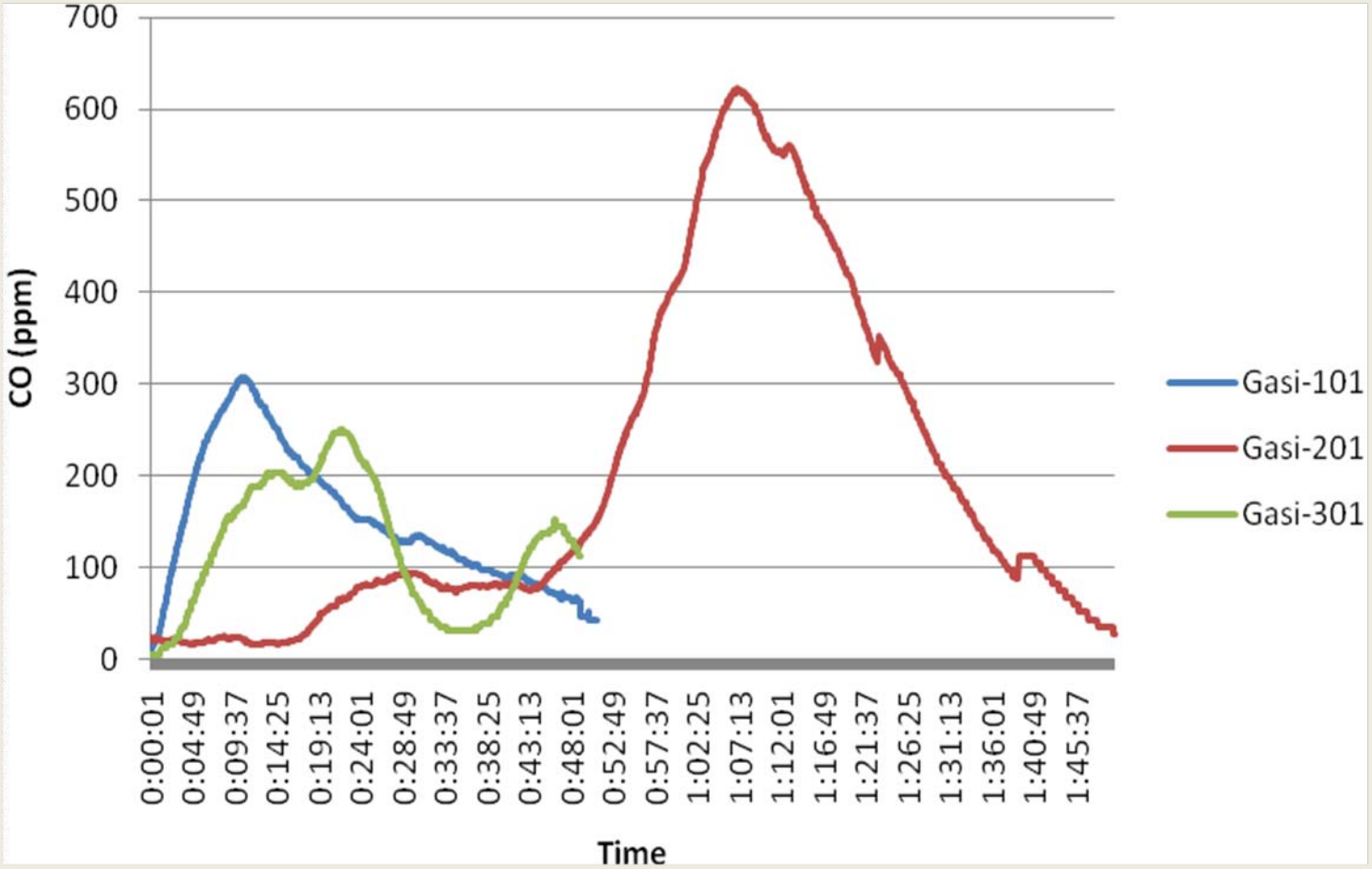
Testing methods applied – protocols, equipment

- Water Boiling Test (lab)
  - *VITA protocols* (1970s and 80s)
  - *Chinese standard WBT*
  - *Indian standard WBT*
  - *WBT Version 3.0 (2007) and Version 4.1.2* Bailis, R., Ogle, D., MacCarty, N. and Still, D. (2007).
- Controlled cooking test (lab)
- Kitchen performance test (field)
- Flue gas analysis – using flue gas analyzers to dtm combustion efficiency
- Indoor air quality ($PM_{2.5}$and CO) using personal CO and particulate monitors
- Criteria-Based Stove Evaluation Johnson, M., Edwards, R., Ghilardi, A., Berrueta, V. and Masera, O. (2010)

- Fuels and energy systems testing centre
  - KIRDI setting up a centre to be equipped with the energy efficiency and environmental monitoring testing equipments
  - including: flue gas analyzers, real time particulate monitors, and data loggers for temperatures, personal CO & particulates monitors, air flow meters, etc.
  - A model kitchen with a chimney will be installed for stove testing. The centre will also offer testing facilities for biofuels.

Results

Variable	Gas stove type		
	Gasi-101	Gasi-201	Gasi-301
Lighting time (min)	6	19	7
Fuel type	Rice husks	Wood blocks	Briquettes
Fuel amount (g)	1259	1375	780
Fire starting materials (g)	9	52	46
Highest flame temperature (deg. c)	700	800	750
Residue (g)	444	23	168
Water evaporated up to extinguishing of fire (g)	642	1535	469
Total water evaporated up to end of operation (g)	642	1989	619
Time to boil (min)	30	19	19
Boiling duration (min)	15	39	16
Duration of fire (= time to boil + boiling duration) (min)	46	58	35
Warming duration after fire (min)	0	43	9
Total operating time (= duration of fire + warming duration) (min)	46	101	44
Performance			
Thermal efficiency (%)	22	26	30
Specific fuel consumption	2.0	0.7	1.3
Fire power	5190	4358	4088
Turn down ratio	1	1	1
Carbon monoxide monitoring			
Average (ppm)	158	203	112
Max. (ppm)	313	656	243
Start level (ppm)	9	24	9
End level (ppm)	65	103	157
Period above 100 ppm (min)	28	41	23



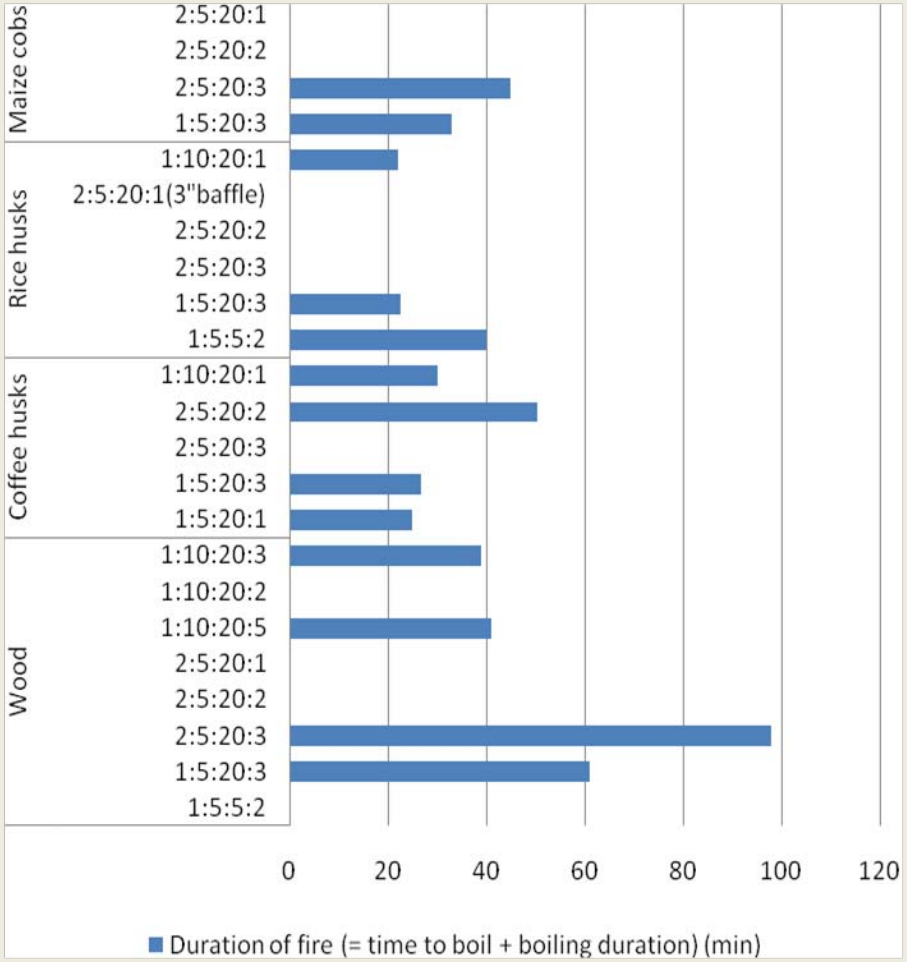
Variation of ambient CO (ppm) in a poorly ventilated room with time

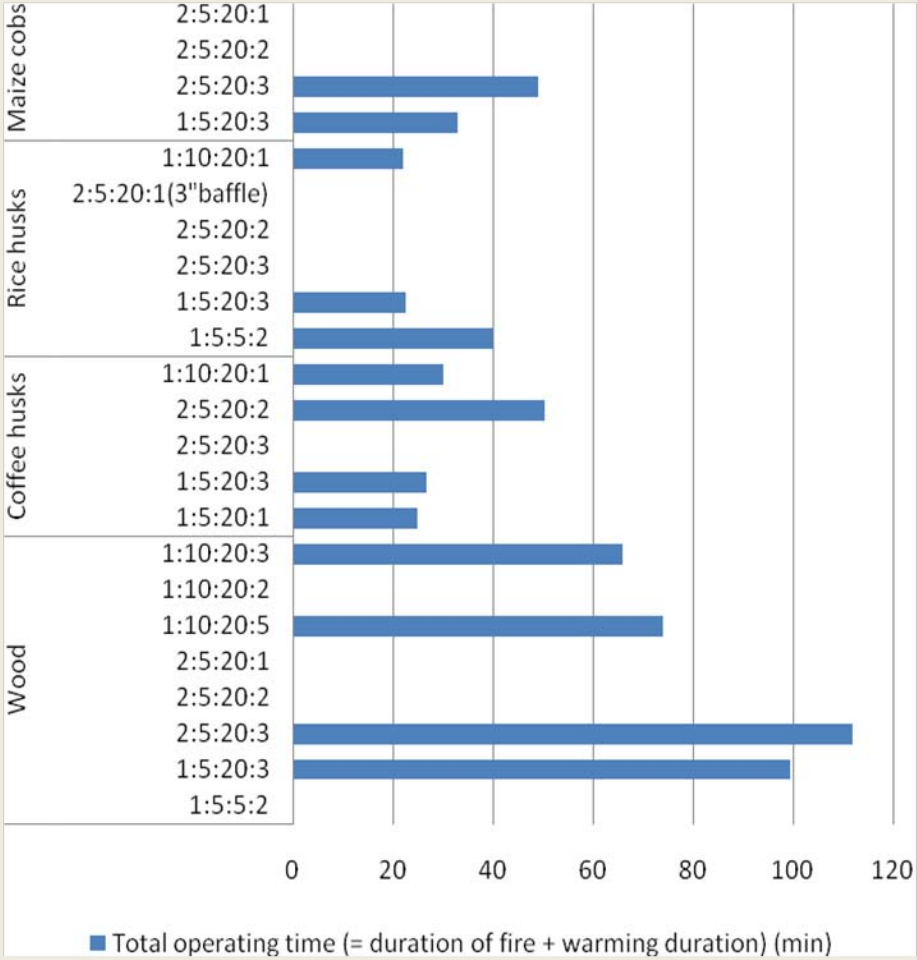
- Recommendations (on Gasi-101 , 201 & 301):
  - redesigning of the burners to reduce emission of CO and increase thermal efficiency;
  - use of ceramic refractory insulation instead of metal to increase the life of the stove;
  - use fuel canisters to facilitate control of fuel amount to be used;
  - improving the turn down ratio of the stoves through using suitable primary air controls; and
  - situating the reactor of Gasi-101 outside the kitchen, then piping the producer gas to a burner located within the kitchen.

- Improvements were made to optimize the functionality and thermal efficiency of gasifier stoves resulting to a new deign - Gasi-501 (patent applied)
- Features:
  - Fuels canisters to enable functionality
  - Wood can be used without cutting to small pieces
  - Operates at natural draft using wood, maize cobs, briquettes, etc. Stove can be used with a variety of fuels (including agricultural wastes) through forced draft
  - Control of firepower using nozzles
  - Burner redesigned to incorporate tertiary air in addition to secondary air reduced CO emissions, smoke and specific fuel consumption
  - New geo-polymer based reactor lining facilitates better insulation, durability, heat storage and cheaper material for construction

Gasi-501

Fuel type	Configuration	Lighting time (min)	Fuel amount (g)	Fire starting materials (g)	Change in water temperature (deg. c)	Residue (g)	Water evaporated up to extinguishing of fire (g)	Total water evaporated up to end of operation (g)	Time to boil (min)	Boiling duration (min)	Duration of fire (= time to boil + boiling duration) (min)	Warming duration after fire (min)	Total operating time (= duration of fire + warming duration) (min)
Wood	1:5:5:2	5	4658		70.3				15				
	1:5:20:3	6	4658	178	74.7	1263	4588	4588	18	43	61	39	100
	2:5:20:3	6	8396	105	74.5	2925	7003	7003	22	76	98	14	112
	2:5:20:2												
	2:5:20:1												
	1:10:20:5	15	3986	130	75.2	741	2393	3093	11	30	41	33	74
	1:10:20:2												
	1:10:20:3	20	4083	207	74.2	981	2672	3002	6	33	39	27	66
Coffee husks	1:5:20:1	10	2341	173	69.3	1573	720	720	12	13	25		25
	1:5:20:3	7	2459		74.1	670	1025	1025	15	12	27	0	27
	2:5:20:3												
	2:5:20:2	5	4306		70.7	963	1888	1888	28	23	51	0	51
	1:10:20:1	7	2480		73.4	3047	1049	1049	12	18	30		30
Rice husks	1:5:5:2	4	2120	155	72.7	1718	824	824	13	27	40		40
	1:5:20:3	8	1734		74.2	450	604	604	15	8	23	0	23
	2:5:20:3	5	2970										
	2:5:20:2												
	2:5:20:1(3"baffle)												
	1:10:20:1	6	1833		73.8	1707	475	475	15	7	22		22
Maize cobs	1:5:20:3	8	2332		73.4	863	1062	1062	23	10	33	0	33
	2:5:20:3	5	4315	163	73.7	673	2612	2612	18	27	45	4	49
	2:5:20:2												
	2:5:20:1												


Maize cobs
2:5:20:1
2:5:20:2
2:5:20:3
1:5:20:3
Rice husks
1:10:20:1
2:5:20:1(3"baffle)
2:5:20:2
2:5:20:3
1:5:20:3
1:5:5:2
Coffee husks
1:10:20:1
2:5:20:2
2:5:20:3
1:5:20:3
1:5:20:1
Wood
1:10:20:3
1:10:20:2
1:10:20:5
2:5:20:1
2:5:20:2
2:5:20:3
1:5:20:3
1:5:5:2
0
20
40
60
80
100
120
Duration of fire (= time to boil + boiling duration) (min)


Maize cobs
2:5:20:1
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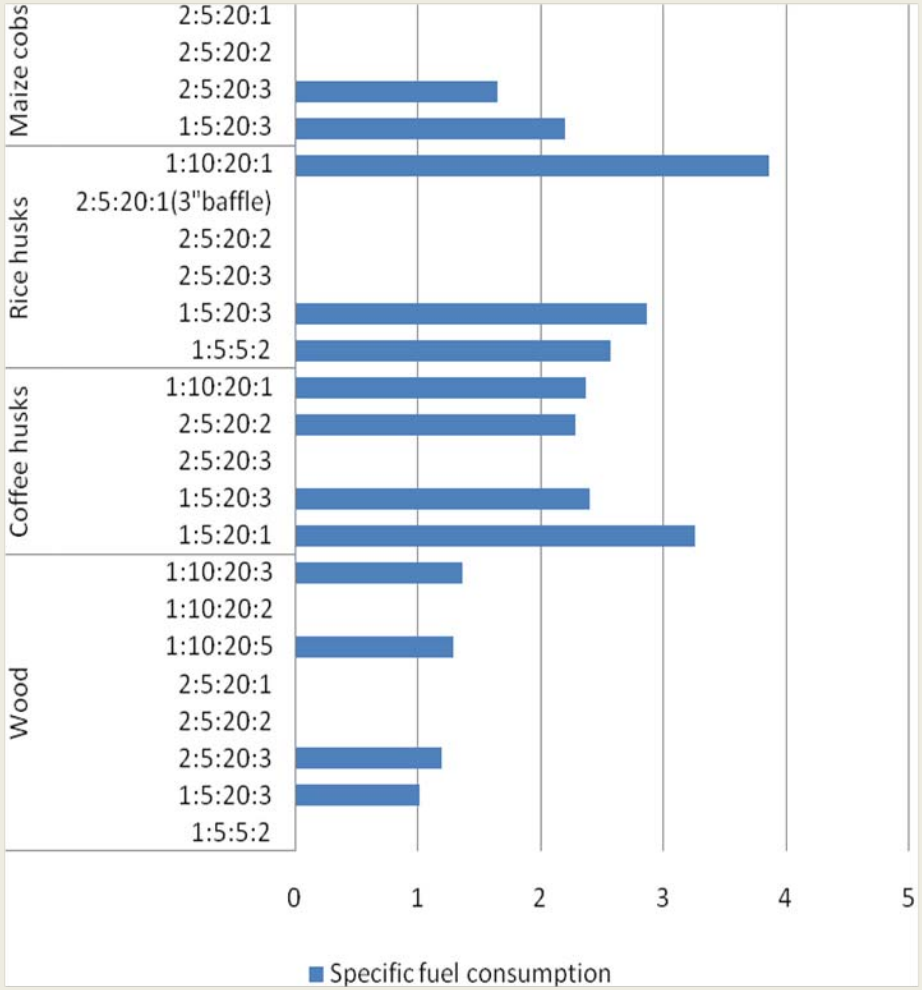
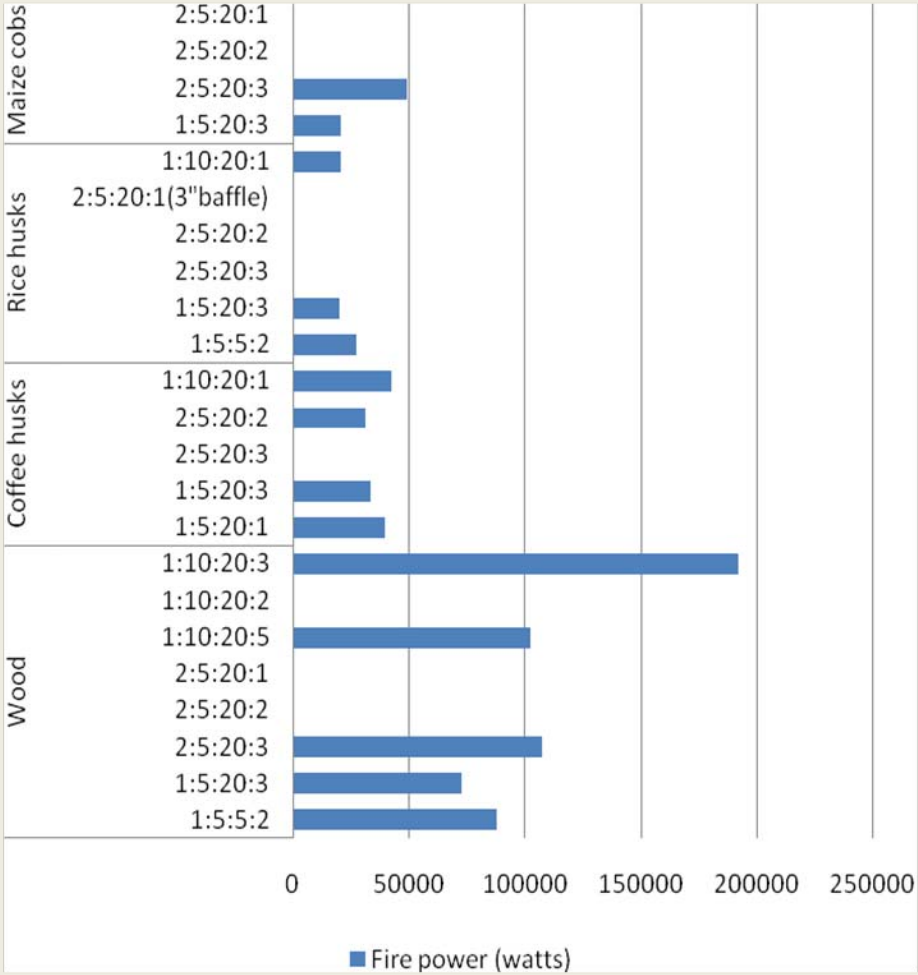
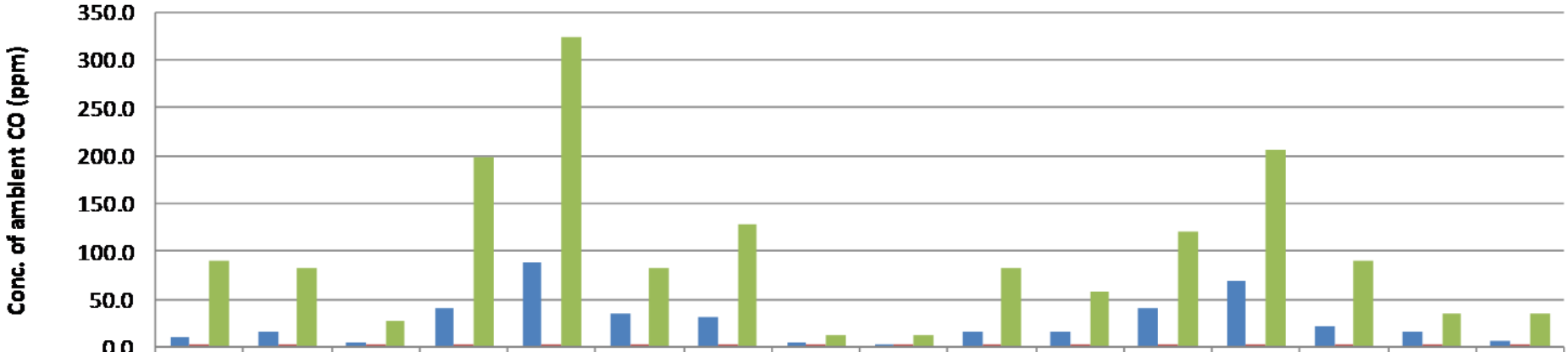
2:5:20:2
2:5:20:3
1:5:20:3
1:5:20:1
Wood
1:10:20:3
1:10:20:2
1:10:20:5
2:5:20:1
2:5:20:2
2:5:20:3
1:5:20:3
1:5:5:2
0
20
40
60
80
100
120
Total operating time (= duration of fire + warming duration) (min)

Fuel type	Configuration	Burning rate (g/sec)	Specific fuel consumption	Fire power (watts)
Wood	1:5:5:2			87757
	1:5:20:3	76	1.0	73131
	2:5:20:3	86	1.2	107850
	2:5:20:2			
	2:5:20:1			
	1:10:20:5	97	1.3	102404
	1:10:20:2			
	1:10:20:3	105	1.4	192309
Coffee husks	1:5:20:1	94	3.3	40031
	1:5:20:3	92	2.4	33639
	2:5:20:3			
	2:5:20:2	85	2.3	31553
	1:10:20:1	83	2.4	42408
Rice husks	1:5:5:2	53	2.6	27476
	1:5:20:3	76	2.9	19915
	2:5:20:3			
	2:5:20:2			
	2:5:20:1(3"baffle)			
	1:10:20:1	83	3.9	20589
Maize cobs	1:5:20:3	71	2.2	20805
	2:5:20:3	96	1.7	49191
	2:5:20:2			
	2:5:20:1			


Maize cobs
2:5:20:1
2:5:20:2
2:5:20:3
1:5:20:3
Rice husks
1:10:20:1
2:5:20:1(3"baffle)
2:5:20:2
2:5:20:3
1:5:20:3
1:5:5:2
Coffee husks
1:10:20:1
2:5:20:2
2:5:20:3
1:5:20:3
1:5:20:1
Wood
1:10:20:3
1:10:20:2
1:10:20:5
2:5:20:1
2:5:20:2
2:5:20:3
1:5:20:3
1:5:5:2
0
1
2
3
4
5
Specific fuel consumption


Maize cobs
2:5:20:1
2:5:20:2
2:5:20:3
1:5:20:3
Rice husks
1:10:20:1
2:5:20:1(3"baffle)
2:5:20:2
2:5:20:3
1:5:20:3
1:5:5:2
Coffee husks
1:10:20:1
2:5:20:2
2:5:20:3
1:5:20:3
1:5:20:1
Wood
1:10:20:3
1:10:20:2
1:10:20:5
2:5:20:1
2:5:20:2
2:5:20:3
1:5:20:3
1:5:5:2
0
50000
100000
150000
200000
250000
Fire power (watts)



	1:10:20:1	1:5:20:3	2:5:20:2	1:5:20:3	1:5:20:3	1:5:20:3	1:5:20:3	2:5:20:3	2:5:20:3	1:5:20:1	1:5:20:3	1:10:20:1	1:5:20:3	1:5:20:3	1:5:20:3	1:5:5:2
	Coffee husks					Wood			Maize cobs			Rice husks				
Average (ppm)	10.9	17.1	5.8	40.3	88.6	35.1	32.3	4.2	4.1	17.1	16.9	40.6	69.9	23.0	15.6	6.1
Min. (ppm)	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
Max. (ppm)	90	82	27	199	324	82	129	12	12	82	59	121	207	90	35	35

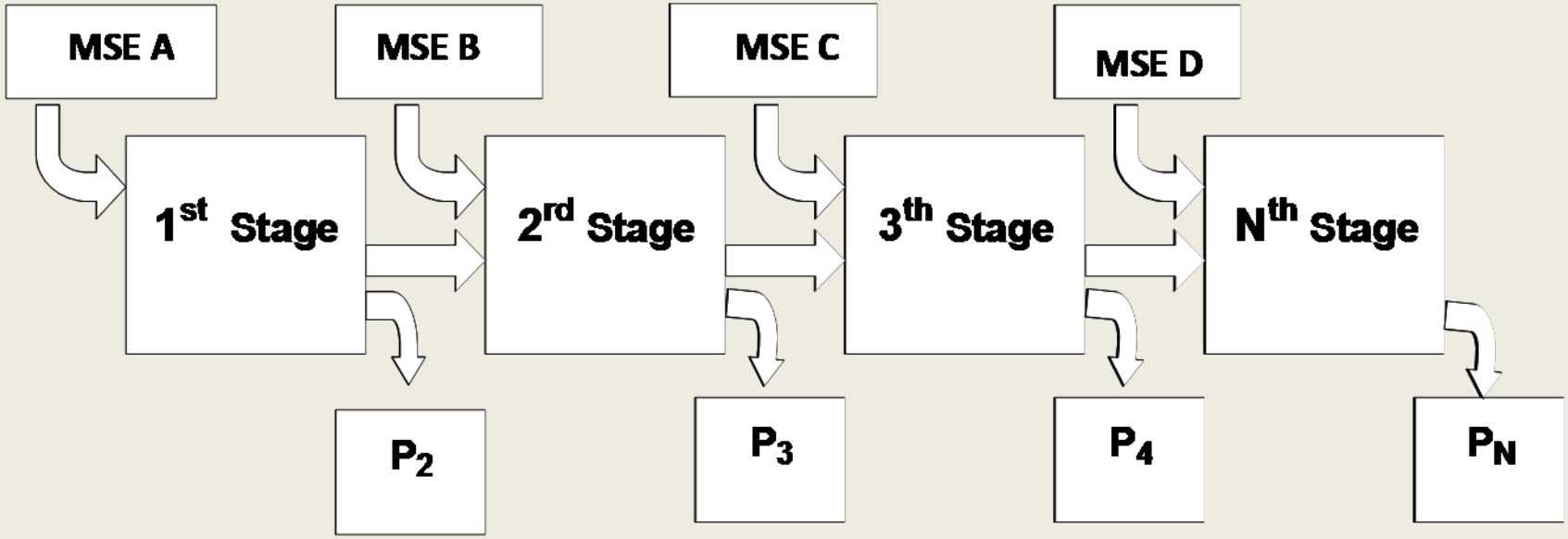
Variation of ambient CO in a well ventilated room with stove configuration

- Further lab tests being carried out to determine significance of variances
- The improved gasifier stove (with firepower of btw 4 -5kw) will then be compared to the other designs (rocket, 3 stone, Jiko-poa, kuni-mbili, etc) and ANOVA carried out to determine significance of improvements
- The project can then continue to the next objective of field testing (CCT and KPT)

2. Technology transfer

- MSEs have a huge potential of job and wealth creation and contributing to GDP growth
- MSEs register the bulk of patent applications at KIPI
- Strategies by KIRDI to assist MSEs:
  - Training
  - Consultancy
  - The 4K MSE 2030 Initiative – innovation system to upgrade MSEs products to be competitive internationally
  - Technology Business Incubation
  - Laboratory services for quality control (e.g stove and fuels testing)
  - Pilot plants with common manufacturing facilities for MSEs

- Pilot plants with common manufacturing facilities
  - MSEs take their raw materials and/or semi-processed products to the CMF which provides intermediate and advanced processing
  - In the case of a gasifer stove pilot plant, equipment availed include: Tig welding, plasma cutting, spot welding, sheet folding & rolling, etc
  - products meet set standards in terms of quantity and consistency
  - enhancing the productivity and competitiveness of MSEs
  - Enterprises are expected to graduate with time to acquire the necessary processing facilities for each stage.



- MSEs A, B, C, & D have various needs in terms of value added processing along the chain. P_2, P_3, P_4 to P_N represent products from each processing stage. The products may be taken directly to the market or for further processing within the CMF or elsewhere.
- A pilot plant is being established in South C for training and pilot production of gasifier stoves and related technologies. Critical equipments and jigs, fixtures, dies will be installed.

Partners involved

- Kenya Bureau of Standards (4K programme)
- Kenya Industrial Estates (4K programme)
- Kenya Industrial Property Institute (4K programme)
- Universities – UoN, Moi, JKUAT, Kenyatta, etc (lab testing and collaborative research)
- International Development Partners – GIZ, UNIDO, UNEP, World Bank, DANIDA, JICA. (technology transfer)
- NGOs (technology transfer, consultancy)
- CBOs (stove testing and dissemination)
- MSEs (technology transfer)

Conclusion

- At least 5 prototype gasifier stoves available for technology transfer (Gasi-101, Gasi-111, Gasi-201, Gasi-301, Gasi-401 and Gasi-501 (patent applied)
- 2 small scale industrial gasifier systems under development
- 1 Pilot plant being developed for manufacture of gasifier stoves for field testing (various equipments including jigs, fixtures, dies, etc
- 1 Fuels and Energy Systems Testing Centre being set up
- Refractory lining technology developed (patent applied)
- Products exhibited at shows – interest developed

Challenges

- Suitable testing procedures for gasifier stoves needed
  - *WBT v 3 & 4.1.2* - where the weight of fuel after boiling and before simmering is to be taken, gasification process will be interfered
  - Note also the final product is charcoal and not ash, hence its calorfic value should be accounted for
- Cost of materials for fabrication going up – Price of stainless steel sheets has doubled in the last one year. Need for alternatives
- Weak quality control measures - standardization and branding of stoves needed to improve quality and fetch better prices
- MSEs still grappling with inadequate tools and equipments to be competitive – More funds to equip MSEs to take up technology

Thank you

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