Appendix

Appendix A

Table A.1: Commercial Stoves

Sl. No.	Commercial stoves	Draft	Size	Price (₹)
1.	Wood stove family metal smokeless chulha	Forced draft without power bank	Domestic	1450
2.	Nikheel Engineers Smart Wood Burning Cook Stove	Natural draft	Domestic	1499
3.	Super Classic High-End Charcoal Burning Natural draft rocket stove	Natural draft	Domestic	1799
4.	SUPERNOVA Stainless Steel High Wood Stove	Forced draft without power bank	Domestic	2000
5.	Domestic Eco Stove, Sat Saheb Industries	Forced draft	Domestic	2200
6.	Domestic pellet stove, Sat Saheb Industries	Forced draft	Domestic	2200
7.	Fuelnzel ND. No-11 Burner Manual Portable Stove	Natural draft	Domestic	2279
8.	Mild steel biomass pellet stove HPC brand	Forced draft with power bank	Domestic	2300
9.	Domestic cooking pellet stove, Gangotree Eco Technologies Pvt. Ltd.	Forced draft	Domestic	2300
10.	Mild steel biomass pellet stove HPC brand	Forced draft	Domestic	2300
11.	Envirofit Steel SPANDAN Efficient Chulha (Black)	Natural draft	Domestic	2600
12.	AGNEEKA Ecomini Steel Biomass Cook Stove-Brown	Natural draft	Domestic	3000
13.	Jivan Engineers commercial pellet stove	Forced draft	Domestic	4000
14.	Shakthi Wood Stove Burning Stove (Black)	Natural draft	Domestic	4499
15.	Right Ojas Delite Pellet/Biomass stove	Forced draft	Domestic	5853
16.	Enersol Biopower Biomass Cook Stove	Forced draft with power bank	Commercial	30000
17.	BioLite Basecamp Wood Burning Stove System	Natural draft	Domestic	39000
18.	Envirofit Community Biomass Stove for Large Cooking Needs	Forced draft with power bank	Commercial	45000

Appendix B

Table B.1: Completed government initiatives on improved cook stoves

Country	Initiatives	Year	Objective / Outcome
China	Chinese National Improved Stove Programme	1982-1992	• 129 million improved cook stoves were distributed
Bangladesh	Joint initiative by Bangladesh Council of Scientific and Industrial Research (BCSIR), Bangladesh Rural Development Board and Ansar-Village Defense Party	1994-1997, 1998-2001	• Developed new prototypes • 62848 improved cook stoves were installed in first phase and 11573 in second phase • 1000 and 1171 people were trained under first and second phase respectively
	Reduction of Exposure to IAP through Household Energy and Behavioral Improvements (USAID/Winrock)	2005-2007	• More than 580 ICS distributed • 20 entrepreneurs trained • Awareness about IAP
	Grameen Shakti	2009-2012	• Trained more than 600 youths • Targets 2 million ICS
	Sustainable Energy Development Project (GTZ)	2006-2014	• Trained 8000 people • Installed over 1,50,000 ICS
Nepal	National ICS programme (Energy Sector Assistance Programme of DANIDA)	2000-2006, 2007-2011	• 2,13,059 ICS installed in Phase I • Phase II targets 4,34,000 ICS installation, distribute 10,000 household gasifiers and 1,000 institutional gasifiers, 5000 institutional ICS and 50000 metal stoves
	SNV Netherlands Development Organization's improved cookstove programme	2012-2017	• Aims to provide clean cooking solution and develop clean cookstove market
Bhutan	National Stove Project by National Women's Association of Bhutan	1983-1988	• 14000 units if ICS installed • 80 technicians trained
	Improved Community Cooking Stove by UNDP, Bhutan Youth Development Association and Tsirang Women's Group	1999	• 2000 ICS installed • Training
Pakistan	Fuel Saving Technology Programme (Pakistan Council for Appropriate Technology)	1995-1999	• Distributed 70000 mud stoves
	Fuel Efficient Cooking Technology (GTZ)	1988-1992	• Distributed metal stoves and tondoor

Country	Initiatives	Year	Objective / Outcome
	Building and Construction Improvement Programme	1999-2009	• Distributed 10,500 ICS
	ICS programme by Escorts Foundation	1995-1999	• Trained to construct ICS
	Conservation of Wildlife in Selected Areas of Northern Area (World Wide Fund for Nature-Pakistan)	1999-2004	• Distributed ICS
Sri Lanka	ICS programme in Sri Lanka	1985-1990	• Distributed 3,00,000 ICS • Trained 200 potters and 2,000 stove installers
Indonesia	Indonesian Clean Stove Initiative	2012	• To disseminate 25 million households
African Countries	Global Alliance for Clean Cookstoves (GACC) (Ghana, Kenya, Nigeria, Uganda)		• Targets more than 20 million clean cook stoves to be distributed • Market development
	Africa Biogas Partnership Programme (ABPP), (Burkina Faso, Ethiopia, Kenya, Tanzania, Uganda)	2009-17	• More than 40,000 biogas plants installed in Africa by 2014 and targets 1,00,000 more till 2017
	Biomass Energy Initiative for Africa (BEIA), (Benin, Democratic Republic of the Congo, Ethiopia, The Gambia, Kenya, Rwanda, South Africa, Tanzania, Uganda)	2010-15	• Nine pilot projects on providing modern cooking facilities, improving charcoal industry, improving bioelectricity and strengthening leadership
	Global Village Energy Partnership (GVEP)-Developing Energy Enterprises Program (DEEP) (Kenya, Tanzania, Uganda)	2008-12	• More than 400 cook stove enterprises were created • More than 200,000 improved cook stoves were distributed annually
	United Nations Environment Programme (UNEP)-Africa Rural Energy Enterprise Development (AREED) (Ghan, Mali, Senegal, Tanzania, Zambia)	2000-12	• About 24 sustainable rural enterprises were established by 2009 • More than 50,000 LPG and improved cook stoves distributed
	Gesellschaft für Internationale Zusammenarbeit (GIZ) Programme for Basic Energy and Conservation (ProBEC) (Botswana, Democratic Republic of the Congo, Lesotho, Malawi, Mozambique, Tanzania, South Africa, Swaziland, Zambia)	1998-2010	• About 250,000 improved cook stoves were distributed
	Zimbabwe's Tso Tso Stove Program	1980	• Development and mass

Country	Initiatives	Year	Objective / Outcome
			production of TsoTso stove
	Namibian Stove Project		• Modifications and distribution of TsoTso stove
Launceston, Australia	Launceston Wood Heater Replacement Program	2001-2004	• PM_{10} reduced by 38% • Wood heating appliances reduced from 66% to 30%
British Colombia, Canada	Wood stove change-out programs	2004-2006	• Improved technology stoves introduction increased from 25% to 41% • Open fireplaces were reduced from 15% to 3% • $PM_{2.5}$ reduced by 22%
Libby, USA	Wood stove changeout programme	2005-2009	• Replacement of 1147 wood stoves • 27.6% reduction in winter ambient $PM_{2.5}$ of Libby

Appendix C

Table C.1: Boundary conditions for ducts

Boundary conditions	Features		
T	Constant wall temperature both at the periphery and axially		
H1	• High conductive materials, Constant wall heat flux, Uniform peripheral wall temperature		
H2	• Low conductive materials, Uniform wall thickness, Fixed axial wall heat flux		
Versions	**Features**	**Versions**	**Features**
4	• Constant four wall temperature (T, H1) • Constant four heated sides (H2)	2S	• Constant two wall temperature (T, H1) and two long adiabatic side • Constant two heated sides (H2) and two long adiabatic side
3L	• Constant three wall temperature (T, H1) and one short adiabatic side • Constant three heated sides (H2) and one short adiabatic side	2C	• Both one short and long constant wall temperature (T, H1) or heated sides (H2)
3S	• Constant three wall temperature (T, H1) and one long adiabatic side • Constant three heated sides (H2) and one long adiabatic side	1L	• One constant temperature of wall (T, H1) or heated (H2) long side
2L	• Constant two wall temperature (T, H1) and two short adiabatic side • Constant two heated sides (H2) and two short adiabatic side	1S	• One constant temperature of wall (T, H1) or heated (H2) short side

Appendix D

Table D.1: Flue gas properties

Temperature	Density	Enthalpy	Specific Heat	Thermal Conductivity	Dynamic Viscosity
K	kg/m^3	kJ/kg	J/ (kg K)	W/(m K)	$(N\ s)/m^2$
				$\times 10^2$	$\times 10^5$
293.5	1.21	4.56	1026.18	2.54	1.77
298.5	1.19	9.69	1027.02	2.58	1.79
303.5	1.17	14.83	1028.28	2.61	1.82
308.5	1.15	19.97	1029.53	2.65	1.84
313.5	1.13	25.12	1030.79	2.70	1.86
323.5	1.10	35.44	1032.88	2.77	1.91
333.5	1.07	45.78	1035.40	2.84	1.95
343.5	1.03	56.15	1037.49	2.91	2.00
353.5	1.01	66.53	1040.00	2.98	2.04
363.5	0.98	76.94	1042.09	3.05	2.09
373.5	0.95	87.38	1044.61	3.10	2.13
393.5	0.90	108.32	1049.21	3.24	2.21
423.5	0.84	139.90	1056.33	3.43	2.34
453.5	0.78	171.71	1063.87	3.62	2.46
473.5	0.75	193.03	1068.47	3.76	2.53
523.5	0.68	246.76	1080.61	4.05	2.72
573.5	0.62	301.11	1093.17	4.34	2.89
623.5	0.57	356.07	1105.32	4.62	3.06
673.5	0.53	411.66	1117.88	4.90	3.22
723.5	0.49	467.86	1130.44	5.18	3.38
773.5	0.46	524.68	1142.58	5.44	3.53
823.5	0.43	582.12	1154.72	5.69	3.67
873.5	0.41	640.16	1166.86	5.94	3.81
923.5	0.38	698.80	1178.58	6.18	3.95
973.5	0.37	758.03	1190.31	6.42	4.08
1023.5	0.35	817.83	1201.61	6.66	4.21
1073.5	0.33	878.19	1212.92	6.89	4.33
1123.5	0.32	939.10	1223.38	7.11	4.46
1173.5	0.30	1000.53	1233.85	7.34	4.57
1223.5	0.29	1062.46	1243.48	7.55	4.69
1273.5	0.28	1124.87	1252.69	7.77	4.80

Appendix E

Table E.1: List of components

Part No.	Component	Part No.	Component	Part No.	Component
1	Stove	14	Air distribution control knob	27	Flue gas collection holes
2	Inner combustion chamber	15	In-line forced draft fan	28	Parallel flow flue gas heat extractor
3	Feed door	16	Rectangular pre-heated air outlet	29	Induced draft fans
4	Feed door stopper	17	Legs of stove	30	Annular ring
5	Grate	18	Legs of upper chamber	31	Stove handle
6	Primary air holes	19	Upper chamber handles	32	Combustion air inlet holes
7	Hinged ash tray	20	Air pre-heater	33	Hole to adjust primary pot
8	Outer cover	21	Flue gas heat extractor	34	Central hole of spiral flow flue gas extractor
9	Annular space divider	22	Parallel flow air pre-heater	35	Flue gas collector chamber
10	Secondary air holes	23	Air connector tunnels	36	Flue gas connector channel
11	Pot holder	24	Radial flow air pre-heater	37	Hole for flue gas collector chamber
12	Rectangular tunnel	25	Spiral flow flue gas heat extractor	38	Upper chamber
13	Combustion air distributor plate	26	High thermal conductivity plate	39	Bottom plate
				40	Annular space

Appendix F

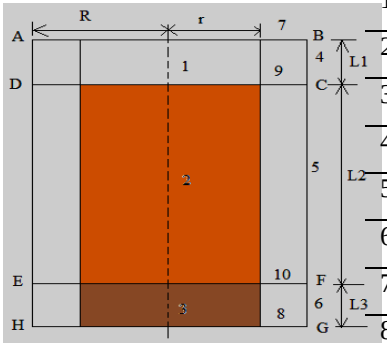
Table F.1: Input parameters

Input Parameters	Value	Input Parameters	Value	Input Parameters	Value
Stove properties	• Burn rate: 0.88kg/hour • Firepower: 4.5 kW • Weight: 2.9 kg • Specific heat: 490 J/kg K	**Pot**	• Height: 0.14m • Diameter: 0.26m • Thickness: 1.2× 10^{-3} m • Capacity: 6.10 kg	**Flue gas**	• Composition: CO_2: 3.91× 10^{-4}% • H_2O: 2.91× 10^{-4}% • O_2: 0.12% • N_2 : 0.40%
Combustion chamber	• Shape: Circular • Diameter: 8.3×10^{-2} m	**Spiral flow heat extractor**	• Height: 0.07 m • Diameter: 0.18 m • Plate thickness: 2×10^{-3} m • Pitch: 0.02 m	**Temperature**	• Ambient temperature: 298.15 K • Pot inner temperature: 377.15 K
Parallel flow heat extractor	• Height: 0.07 m • No. of fins: 11 • Pitch: 0.02 m • Fin thickness: 2×10^{-3} m	**Parallel flow heat extractor**	• Height: 0.07 m • No. of fins: 04 • Fin thickness: 2×10^{-3} m		
Fuel parameters	• Fuel name: *Shorea Robusta,* • Common name: Sal wood • Dimensions: 5.5×1.5×1.5× 10^{-6} m^3	• Thermal conductivity: 0.17 W/mK • Moisture content: 10% • Calorific value: 18.31 MJ/kg • Density: 1000 kg/m^3		• Composition: • Carbon: 46.88% • Hydrogen: 5.82% • Nitrogen: 0.58% • Oxygen: 46.72%	

Appendix G

Table G.1: View factors

1. View factor between flame, fuel bed and combustion chamber inner surface.

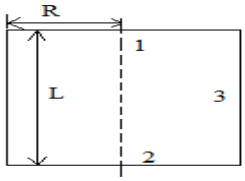


Labels	Indicators
1	Side surface of the gap between pot bottom and flame top
2	Side surface of the flame
3	Side surface of the fuel bed
4	Side surface of CC in the region ABCD
5	Side surface of CC in the region CDEF
6	Side surface of CC in the region EFGH
7	Annular ring between r & R at the top of CC
8	Annular ring between r & R at the bottom of CC
9	Annular ring between r & R located between the flame top and gap
10	Annular ring between r & R located between the fuel bed and flame b

View factor	Value	View factor	Value	View factor	Value	View factor	Value	View factor	Value
F11	0	F52	0.74	F89	0.50	F10-9	0.51	F5+6-5+6	0.18
F14	0.61	F55	0.16	F8-10	0.51	F10-10	0	F5+6-9	0.03
F17	0.19	F59	0.05	F91	0.30	F1+2-1+2	0	F5+6-8	0.03
F19	0.19	F5-10	0.05	F92	0.35	F1+2-4+5	0.94	F5-1+2+3	0.85
F22	0	F63	0.74	F94	0.07	F1+2-7	0.03	F7-4+5	0.14
F25	0.93	F66	0.16	F95	0.14	F1+2-10	0.03	F7-1+2	0.35
F29	0.04	F68	0.05	F97	0.63	F2+3-9	0.02	F7-1+2	0.35
F2-10	0.04	F6-10	0.05	F98	0.50	F2+3-8	0.02	F8-2+3	0.35
F33	0	F71	0.30	F99	0	F2+3-2+3	0	F8-5+6	0.14
F36	0.93	F74	0.07	F9-10	0.51	F2+3-5+6	0.96	F8-2+3	0.35
F3-10	0.04	F77	0	F10-2	0.35	F2-4+5+6	0.99	F9-2+3	0.35
F38	0.04	F79	0.63	F10-3	0.35	F4+5-1+2	0.75	F9-5+6	0.14
F41	0.49	F7-10	0.51	F10-5	0.14	F4+5-7	0.04	F10-1+2	0.35
F44	0.06	F83	0.35	F10-6	0.14	F4+5-10	0.04		
F47	0.23	F86	0.14	F10-7	0.51	F4+5-4+5	0.17		
F49	0.23	F88	0	F10-8	0.51	F5+6-2+3	0.77		

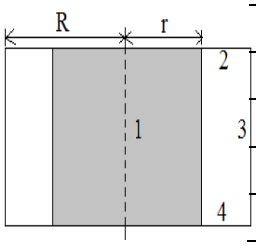
2. View factor between pot bottom and flame top		**3. View factor between flame bottom to fuel bed top**		**4. View factor between fuel bed top and pot bottom**	
View factor	**Value**	**View factor**	**Value**	**View factor**	**Value**
F_{fp}	0.99	F_{fb}	2.82×10^{-3}	F	0.53

5. View factor between fuel bed, combustion chamber inner wall and pot bottom



Labels	Indicators	View factor	Value	View factor	Value
1	Pot bottom	F11	0	F23	0.89
2	Combustion cha	F12	0.21	F31	0.15
	inner wall	F13	0.79	F32	0.19
3	Fuel bed top	F21	0.34	F33	0.66
		F22	0		

6. View factor between flame and inner surface of upper chamber central hole



Labels	Indicators	View factor	Value	View factor	Value	View factor	Value
1	Pot side wall	F11	0	F22	0	F33	0.11
2	Top boundary	F12	0.14	F23	0.11	F34	0.18
3	Annular ring	F13	0.71	F24	0.59	F41	0.31
4	Bottom bounda	F14	0.14	F31	0.53	F42	0.59
		F21	0.31	F32	0.18	F43	0.11
						F44	0