Joint UNDP/World Bank Energy Sector Management Assistance Program

Activity Completion Report

No. 062B/86

Country: ETHIOPIA

Activity: AGRICULTURAL RESIDUE BRIQUETTING PILOT PROJECTS FOR SUBSTITUTE DOMESTIC AND INDUSTRIAL FUELS (VOLUME II - ANNEXES)

DECEMBER 1986

ENERGY SECTOR MANAGEMENT ASSISTANCE PROGRAM

The Joint UNDP/World Bank Energy Sector Management Assistance Program (ESMAP), started in April 1983, assists countries in implementing the main investment and policy recommendations of the Energy Sector Assessment Reports produced under another Joint UNDP/World Bank Program. ESMAP provides staff and consultant assistance in formulating and justifying priority pre-investment and investment projects and in providing management, institutional and policy support. The reports produced under this Program provide governments, donors and potential investors with the information needed to speed up project preparation and implementation. ESMAP activities can be classified broadly into three groups:

- Energy Assessment Status Reports: these evaluate achievements in the year following issuance of the original assessment report and point out where urgent action is still needed;

- Project Formulation and Justification: work designed to accelerate the preparation and implementation of investment projects; and

- Institutional and Policy Support: this work also frequently leads to the identification of technical assistance packages.

The Program aims to supplement, advance and strengthen the impact of bilateral and multilateral resources already available for technical assistance in the energy sector.

Funding of the Program

The Program is a major international effort and, while the core finance has been provided by the UNDP and the World Bank, important financial contributions to the Program have also been made by a number of bilateral agencies. Countries which have now made or pledged initial contributions to the programs through the UNDP Energy Account, or through other cost-sharing arrangements with UNDP, are the Netherlands, Sweden, Australia, Switzerland, Finland, United Kingdom, Denmark, Norway, and New Zealand.

Further Information

For further information on the Program or to obtain copies of completed ESMAP reports, which are listed at the end of this document, please contact:

Division for Global and Interregional Projects
United Nations Development Program
One United Nations Plaza
New York, N.Y. 10017

OR

Energy Strategy and Preinvestment Div. II
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ETHIOPIA

AGRICULTURAL RESIDUE BRIQUETTING PILOT PROJECTS
FOR SUBSTITUTE DOMESTIC AND INDUSTRIAL FUELS
(VOLUME II - ANNEXES)

DECEMBER 1986

ANNEXES

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(Consultant: Robert Chronowski; July 1985)

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Annex 1

DETAILED FINANCIAL AND ECONOMIC COSTING FOR POTENTIAL BRIQUETTING PLANTS AND SENSITIVITY ANALYSES OF KEY PARAMETERS

(1985 figures)

Table A1.1: DETAILED ECONOMIC AND FINANCIAL COSTINGS FOR POTENTIAL PILOT BRIQUETTING PLANTS

SUMMARY TABLE AND PARAMETERS

	COST/TON($)				COST/UNIT ENERGY($/GJ)			
	FINANCIAL COST		ECONOMIC COST		FINANCIAL COST		ECONOMIC COST	
	DELIVERED	FACTORY	DELIVERED	FACTORY	DELIVERED	FACTORY	DELIVERED	FACTORY
COFFEE DILLA-HUSK	71.695	37.035	61.985	41.809	3.630	1.875	3.138	2.117
COFFEE DILLA-PULP	92.858	58.198	82.046	61.870	4.806	3.012	4.247	3.202
COFFEE PARCH.-NEW SITE	31.221	31.221	34.498	34.498	1.615	1.615	1.785	1.785
COFFEE PARCH.-MERCATO	37.752	37.752	43.535	43.535	1.953	1.953	2.252	2.252
COTTON STALKS-AWASH	113.941	82.061	113.175	95.445	6.401	4.610	6.358	5.362
WHEAT STRAW-DIXIS	114.674	80.664	105.857	93.577	6.353	4.469	5.865	5.184
CORN STALKS AND STOVER	140.341	108.461	144.655	122.033	7.525	5.816	7.756	6.543

PARAMETERS

DISCOUNT RATE	10.0%
ELECTRICITY RATE ($/KW-H)	0.063
DIESEL RATE ($/LITER)	0.374
PLANT LIFE:	
BUILDING/PROJECT (YRS)	20
BRIQUETTORS (YRS)	15
PLANT EQUIPMENT (YRS)	12
COLLECTION EQUIPMENT (YRS)	8
TRANSFORMER/GENERATOR (YR)	8
SHADOW FACTORS/PRICES:	
FOREIGN EXCHANGE	1.330
UNSKILLED LABOR	0.500
ELECTRICITY ($KW-H)	0.063
DIESEL ($/LITER)	0.397

Table A1.2: RESIDUE: COFFEE HUSK-DILLA

CAPACITY: 5000.000 TONS
ENERGY: 19.750

ALL FIGURES IN '000' U.S. DOLLARS

ITEMS		LIFE (Yrs)	CAP. & OPER. COSTS LOCAL	FOREIGN	TOTAL	ANNUALIZED COST LOCAL	FOREIGN	TOTAL
I. CAPITAL COSTS								
A. CONSTRUCTION [a]								
SITE PREPARATION		20	11.600		11.600	1.363	0.000	1.363
BUILDINGS		20	65.800	19.100	84.900	7.729	2.243	9.972
HOUSING		20		0.000	0.000	0.000	0.000	
SUB-TOTAL			77.400	19.100	96.500	9.091	2.243	11.335
B. EQUIPMENT [b]								
PISTON BRIQ.		15	172.000	172.000	0.000	22.613	22.613	
SCREW BRIQ.		15			0.000	0.000	0.000	0.000
COLLECTION EQUIP.		8		6.000	6.000	0.000	1.125	1.125
STORAGE EQUIP.		12			0.000	0.000	0.000	0.000
CONVEYORS		12	20.000	20.000	0.000	2.935	2.935	
SCREENS		12			0.000	0.000	0.000	0.000
SILOS		12		25.000	25.000	0.000	3.669	3.669
BALE BREAKERS		12		0.000	0.000	0.000	0.000	
ELECTRICAL		12		13.000	13.000	0.000	1.908	1.908
TRANSFORMER/GENER.		8	7.000	7.000	0.000	1.312	1.312	
BAGGING STATIONS		12		2.000	2.000	0.000	0.294	0.294
WORKSHOP EQUIP.		12		12.400	12.400	0.000	1.820	1.820
OTHERS		12		2.500	2.500	0.000	0.367	0.367
MISC.		12			0.000	0.000	0.000	0.000
SUB-TOTAL			0.000	259.900	259.900	0.000	36.043	36.043
C. SPARES AT DELIVERY	10.0%	14	0.000	25.990	25.990	0.000	3.554	3.554
D. TRANSPORT & DELIV.								
FREIGHT	4.0%	14	0.000	11.436	11.436	0.000	1.564	1.564
INSURANCE	1.0%	14	0.000	2.859	2.859	0.000	0.391	0.391
SITE DELIVERY		14	1.800	7.300	9.100	0.246	0.998	1.244
SUB-TOTAL (CIF)			1.800	21.595	23.395	0.246	2.953	3.199
E. ENGG./INSTALL.								
ENGG./PROCUREMENT	5.0%	20	12.995	12.995	0.000	1.526	1.526	
TRAINING	5.0%	20	12.995	12.995	0.000	1.526	1.52[illegible]	
INSTALLATION***		20	7.617	30.468	38.085	0.895	3.579	4.473
SUB-TOTAL			7.617	56.458	64.075	0.895	6.632	7.526
CAPITAL COSTS			86.817	383.043	469.860	10.232	51.425	61.658
CONTINGENCY	10.0%		8.682	38.304	46.986	1.023	5.143	6.166
TOTAL CAP. COSTS			95.499	421.347	516.845	11.255	56.568	67.823

II. OPERATING COSTS

A. LABOR c/							
SKILLED		28.000		28.000	28.000	0.000	28.000
UNSKILLED		7.700		7.700	7.700	0.000	7.700
B. POWER							
ELECTRICITY (1		18.900		18.900	18.900	0.000	18.900
DIESEL (2)		0.000		0.000	0.000	0.000	0.000
C. OPERATION & MAINT.							
FUEL (3)		0.000		0.000	0.000	0.000	0.000
LUBE OIL	10.0%	0.000	0.000	0.000	0.000	0.000	0.000
SPARE PARTS	10.0%	0.000	25.990	25.990	0.000	25.990	25.990
SERVICES	1.0%	2.599		2.599	2.599	0.000	2.599
D. BUILDING MAINT.							
MATERIALS	3.0%	2.895		2.895	2.895	0.000	2.895
E. CONSUMABLES							
BAGS		20.600		20.600	20.600	0.000	20.600
OTHER				0.000	0.000	0.000	
OPERATING COSTS		80.694	25.990	106.684	80.694	25.990	106.684
CONTINGENCY	10.0%	8.069	2.599	10.668	8.069	2.599	10.668
TOTAL OPER. COSTS		88.763	28.589	117.352	88.763	28.589	117.352

	FINANCIAL COST	ECONOMIC COST
CAPITAL CHARGES/YR	67.823	86.491
OPERATING COSTS/YR	117.352	122.552
FACTORY COST/YR	185.176	209.043
TRANSPORTATION COST/YR	173.300	100.880
TOTAL CHARGES/YR	358.476	309.923

		DELIVERED	FACTORY	DELIVERED	FACTORY	
COST/TON ($)		71.695		37.035	61.985	41.809
COST/40KG BAG ($)		2.868		1.481	2.479	1.672
COST/UNIT ENERGY ($/GJ)		3.630		1.875	3.138	2.117
INSTALLATION						
LOCAL	3.0%					
FOREIGN	12.0%					

(1) ELECTRICITY(KW-H/T) 60.000

(2) POWER-DIESEL(L/TON)

(3) FUEL-DIESEL(L/TON)

FOOTNOTES
TABLE A1.2
RESIDUE: COFFEE HUSK-DILLA

a/ Construction cost components for coffee husks:

Plant	68,478
Workshop	1.268
Store	2.536
Bagstore	5.918
Office	2,029
Briquette store	16,232
Total buildings	96,461

b/ Detailed discussion in Chapter 3.

c/ Labor cost components for coffee husks:

1 Plant manager	7,246
2 Shift supervisors	8,696
4 Plant operators	5,797
1 Mechanic/welder	1,449
1 Bench mechanic	1,449
1 Electrician	1,449
1 Storekeeper/clerk	1,884
12 Labourers	5,217
2 Nightguards	870
Seasonal labour 1750 mandays/yr	1,691
	35,747

Table A1.3: RESIDUE: COFFEE PULP-DILLA
CAPACITY: 1000.000 TONS
ENERGY: 19.320 MJ/KG

ALL FIGURES IN '000' U.S. DOLLARS

ITEMS		LIFE(YRS)	CAP. & OPER. COSTS LOCAL	FOREIGN	TOTAL	ANNUALIZED COST LOCAL	FOREIGN	TOTAL
I. CAPITAL COSTS								
A. CONSTRUCTION								
SITE PREPARATION		20	1.700		1.700	0.200	0.000	0.200
BUILDINGS		20	9.900		9.900	1.163	0.000	1.163
HOUSING		20			0.000	0.000	0.000	0.000
SUB-TOTAL			11.600	0.000	11.600	1.363	0.000	1.363
B. EQUIPMENT								
PISTON BRIQ.		15			0.000	0.000	0.000	0.000
SCREW BRIQ.		15			0.000	0.000	0.000	0.000
COLLECTION EQUIP.		8	26.800	17.900	44.700	5.023	3.355	8.379
STORAGE EQUIP.		12			0.000	0.000	0.000	0.000
CONVEYORS		12			0.000	0.000	0.000	0.000
SCREENS		12			0.000	0.000	0.000	0.000
SILOS		12			0.000	0.000	0.000	0.000
BALE BREAKERS		12			0.000	0.000	0.000	0.000
ELECTRICAL		12			0.000	0.000	0.000	0.000
TRANSFORMER/GENER.		8			0.000	0.000	0.000	0.000
BAGGING STATIONS		12			0.000	0.000	0.000	0.000
WORKSHOP EQUIP.		12			0.000	0.000	0.000	0.000
OTHERS		12		21.100	21.100	0.000	3.097	3.097
MISC.		12			0.000	0.000	0.000	0.000
SUB-TOTAL			26.800	39.000	65.800	5.023	6.452	11.475
C.SPARES AT DELIVERY	10.0%	9	2.680	3.900	6.580	0.456	0.664	1.121
D. TRANSPORT & DELIV.								
FREIGHT	4.0%	9	1.179	1.716	2.895	0.201	0.292	0.493
INSURANCE	1.0%	9	0.295	0.429	0.724	0.050	0.073	0.123
SITE DELIVERY		9	0.100	0.400	0.500	0.017	0.068	0.085
SUB-TOTAL (CIF)			1.574	2.545	4.119	0.268	0.433	0.701
E. ENGG./INSTALL.								
ENGG./PROCUREMENT	5.0%	20		3.290	3.290	0.000	0.386	0.386
TRAINING	5.0%	20		3.290	3.290	0.000	0.386	0.386
INSTALLATION		20	0.633	2.532	3.165	0.074	0.297	0.372
SUB-TOTAL			0.633	9.112	9.745	0.074	1.070	1.145
CAPITAL COSTS			43.287	54.557	97.844	7.185	8.620	15.805
CONTINGENCY	10.0%		4.329	5.456	9.784	0.718	0.862	1.580
TOTAL CAP. COSTS			47.616	60.013	107.628	7.903	9.482	17.385

II. OPERATING COSTS							
A. LABOR							
SKILLED		0.500		0.500	0.500	0.000	0.500
UNSKILLED		3.800		3.800	3.800	0.000	3.800
B. POWER							
ELECTRICITY (1)		0.000		0.000	0.000	0.000	0.000
DIESEL (2)		0.000		0.000	0.000	0.000	0.000
C. OPERATION & MAINT.							
FUEL (3)			2.618	2.618	0.000	2.618	2.618
LUBE OIL	10.0%		0.262	0.262	0.262	0.000	0.262
SPARE PARTS	10.0%	2.680	3.900	6.580	2.680	3.900	6.580
SERVICES	1.0%	0.658		0.658	0.658	0.000	0.658
D. BUILDING MAINT.							
MATERIALS	3.0%	0.348		0.348	0.348	0.000	0.348
E. CONSUMABLES							
BAGS		1.000		1.000	1.000	0.000	1.000
OTHER					0.000	0.000	0.000
OPERATING COSTS		8.986	6.78	15.766	8.986	6.78	15.766
CONTINGENCY	10.0%	.899	6.78	1.577	1.187	6.78	1.577
TOTAL OPER. COSTS		9.885	7.458	17.342	9.885	7.458	17.342

	FINANCIAL COST	ECONOMIC COST
CAPITAL CHARGES/YR	17.385	20.514
OPERATING COSTS/YR	17.342	16.845
BRIQUETTING COST/YR	23.470	24.510
FACTORY COST/YR	58.198	61.870
TRANSPORTATION COST/YR	34.660	20.176
TOTAL CHARGES/YR	92.858	82.046

		DELIVERED	FACTORY	DELIVERED	FACTORY
COST/TON ($)		92.858	58.198	82.046	61.870
COST/40KG BAG ($)		3.714	2.328	3.282	2.475
COST/UNIT ENERGY ($/GJ)		4.806	3.012	4.247	3.202
INSTALLATION					
LOCAL	3.0%				
FOREIGN	12.0%				

(1)ELECTRICITY(KW-H/TON)
(2)POWER-DIESEL(L/TON)
(3)FUEL-DIESEL(L/TON) 7.000

Table A1.4: RESIDUE: COFFEE PARCHMENT-NEW SITE
CAPACITY: 5000.000 TONS
ENERGY: 19.330 MJ/KG

ALL FIGURES IN '000' U.S. DOLLARS

ITEMS		LIFE (YRS)	CAP. & OPER. COSTS LOCAL	FOREIGN	TOTAL	ANNUALIZED COST LOCAL	FOREIGN	TOTAL
I. CAPITAL COSTS								
A. CONSTRUCTION								
SITE PREPARATION		20	5.900		6.900	0.810	0.000	0.810
BUILDINGS		20	39.000	11.400	50.400	4.581	1.339	5.920
HOUSING		20			0.000	0.000	0.000	0.000
SUB-TOTAL			45.900	11.400	57.300	5.391	1.339	6.730
B. EQUIPMENT								
PISTON BRIQ.		15		86.000	86.000	0.000	11.307	11.307
SCREW BRIQ.		15		63.000	63.000	0.000	8.283	8.283
COLLECTION EQUIP.		8			0.000	0.000	0.000	0.000
STORAGE EQUIP.		12			0.000	0.000	0.000	0.000
CONVEYORS		12		8.300	8.300	0.000	1.218	1.218
SCREENS		12			0.000	0.000	0.000	0.000
SILOS		12		25.000	25.000	0.000	3.669	3.669
BALE BREAKERS		12			0.000	0.000	0.000	0.000
ELECTRICAL		12		6.200	6.200	0.000	0.910	0.910
TRANSFORMER/GENER.		8			0.000	0.000	0.000	0.000
BAGGING STATIONS		12		1.200	1.200	0.000	0.176	0.176
WORKSHOP EQUIP.		12		2.400	2.400	0.000	0.352	0.352
OTHERS		12		2.500	2.500	0.000	0.367	0.367
MISC.		12			0.000	0.000	0.000	0.000
		12			0.000	0.000	0.000	0.000
		12			0.000	0.000	0.000	0.000
		12						
SUB-TOTAL			0.000	194.600	194.600	0.000	26.282	26.282
C. SPARES AT DELIVERY	10.0%	14	0.000	19.460	19.460	0.000	2.616	2.616
D. TRANSPORT & DELIV.								
FREIGHT	4.0%	14	0.000	8.562	8.562	0.000	1.151	1.151
INSURANCE	1.0%	14	0.000	2.141	2.141	0.000	0.288	0.288
SITE DELIVERY		14	1.200	4.800	6.000	0.161	0 [illegible]45	0.806
SUB-TOTAL (CIF)			1.200	15.503	16.703	0.161	2.084	2.245
E. ENGG./INSTALL.								
ENGG./PROCUREMENT	5.0%	20		9.730	9.730	0.000	1.143	1.143
TRAINING	5.0%	20		9.730	9.730	0.000	1.143	1.143
INSTALLATION***		20	5.838	23.352	29.190	0.686	2.743	3.429
SUB-TOTAL			5.838	42.812	48.650	0.686	5.029	5.714
CAPITAL COSTS			52.938	283.775	336.713	6.238	37.349	43.587
CONTINGENCY	10.0%		5.294	28.378	33.671	0.624	3.735	4.359
TOTAL CAP. COSTS			58.232	312.153	370.384	6.862	41.084	47.946

II. OPERATING COSTS

A. LABOR						
SKILLED	28.000		28.000	28.000	0.000	28.000
UNSKILLED	7.700		7.700	7.700	0.000	7.700
B. POWER						
ELECTRICITY (1)	18.900		18.900	18.900	0.000	8.900
DIESEL (2)	0.000		0.000	0.000	0.000	0.000
C. OPERATION & MAINT.						
FUEL (3)	0.000		0.000	0.000	0.000	0.000
LUBE OIL 10.0%	0.000	0.000	0.000	0.000	0.000	0.000
SPARE PARTS 10.0%	0.000	19.460	19.460	0.000	19.460	19.460
SERVICES 1.0%	1.946		1.946	1.946	0.000	1.946
D. BUILDING MAINT.						
MATERIALS 3.0%	1.719		1.719	1.719	0.000	1.719
E. CONSUMABLES						
BAGS	20.600		20.600	20.600	0.000	20.600
OTHER				0.000	0.000	0.000
OPERATING COSTS	78.865	19.460	98.325	78.865	19.460	98.325
CONTINGENCY 10.0%	7.887	1.946	9.833	7.887	1.946	9.833
TOTAL OPER. COSTS	86.752	21.406	108.158	86.752	21.406	108.158

	FINANCIAL COST	ECONOMIC COST
CAPITAL CHARGES/YR	47.946	61.504
OPERATING COSTS/YR	108.158	110.986
BRIQUETTING COST/YR		
FACTORY COST/YR	156.104	172.490
TRANSPORTATION COST/YR	24.000	11.250
TOTAL CHARGES/YR	180.104	183.740

		DELIVERED	FACTORY	DELIVERED	FACTORY
COST/TON ($)		36.021	31.221	36.748	34.498
COST/40KG BAG ($)		1.441	1.249	1.470	1.380
COST/UNIT ENERGY ($/GJ)		1.863	1.615	1.901	1.785
***INSTALLATION					
LOCAL	3.0%				
FOREIGN	12.0%				

(1) ELECTRICITY(KW-H/T) 60.000
(2) POWER-DIESEL(L/TON)
(3) FUEL-DIESEL(L/TON)

Table A1.5:

RESIDUE: COFFEE PARCHMENT-MERCATO
CAPACITY: 2500.000 TONS
ENERGY: 19.330 MJ/KG

ALL FIGURES IN '000' U.S. DOLLARS

			CAP. & OPER. COSTS			ANNUALIZED COST		
ITEMS		LIFE (YRS)	LOCAL	FOREIGN	TOTAL	LOCAL	FOREIGN	TOTAL
I. CAPITAL COSTS								
A. CONSTRUCTION								
SITE PREPARATION		20	0.600		0.600	0.070	0.000	0.070
BUILDINGS		20	3.400		3.400	0.399	0.000	0.399
HOUSING		20			0.000	0.000	0.000	0.000
SUB-TOTAL			4.000		4.000	0.470	0.000	0.470
B. EQUIPMENT								
PISTON BRIQ.		15		86.000	86.000	0.000	11.307	11.307
SCREW BRIQ.		15		63.000	63.000	0.000	8.283	8.283
COLLECTION EQUIP.		8			0.000	0.000	0.000	0.000
STORAGE EQUIP.		12			0.000	0.000	0.000	0.000
CONVEYORS		12		8.300	8.300	0.000	1.218	1.218
SCREENS		12			0.000	0.000	0.000	0.000
SILOS		12		25.000	25.000	0.000	3.669	3.669
BALE BREAKERS		12			0.000	0.000	0.000	0.000
ELECTRICAL		12		6.200	6.200	0.000	0.910	0.910
TRANSFORMER/GENER.		8			0.000	0.000	0.000	0.000
BAGGING STATIONS		12		1.200	1.200	0.000	0.176	0.176
WORKSHOP EQUIP.		12		2.400	2.400	0.000	0.352	0.352
OTHERS		12		2.500	2.500	0.000	0.367	0.367
MISC.		12			0.000	0.000	0.000	0.000
SUB-TOTAL			0.000	194.600	194.600	0.000	26.282	26.282
C. SPARES AT DELIVERY	10.0%	14	0.000	19.460	19.460	0.000	2.616	2.616
D. TRANSPORT & DELIV.								
FREIGHT	4.0%	14	0.000	8.562	8.562	0.000	1.151	1.151
INSURANCE	1.0%	14	0.000	2.141	2.141	0.000	0.288	0.288
SITE DELIVERY		14	1.200	4.800	6.000	0.161	0.645	0.806
SUB-TOTAL (CIF)			1.200	15.503	16.703	0.161	2.084	2.245
E. ENGG./INSTALL.								
ENGG./PROCUREMENT	5.0%	20		9.730	9.730	0.000	1.143	1.143
TRAINING	5.0%	20		9.730	9.730	0.000	1.143	1.143
INSTALLATION***		20	5.838	23.352	29.190	0.686	2.743	3.429
SUB-TOTAL			5.838	42.812	48.650	0.686	5.029	5.714
CAPITAL COSTS			11.038	272.375	283.413	1.317	36.010	37.327
CONTINGENCY	10.0%		1.104	27.238	28.341	0.132	3.601	3.733
TOTAL CAP. COSTS			12.142	299.613	311.754	1.449	39.611	41.059

II. OPERATING COSTS

A. LABOR							
SKILLED		14.000		14.000	14.000	0.000	14.000
UNSKILLED		3.900		3.900	3.900	0.000	3.900
B. POWER							
ELECTRICITY (1)		9.450		9.450	9.450	0.000	9.450
DIESEL (2)		0.000		0.000	0.000	0.000	0.000
C. OPERATION & MAINT.							
FUEL (3)		0.000	0.000	0.000	0.000	0.000	0.000
LUBE OIL	10.0%	0.000	0.000	0.000	0.000	0.000	0.000
SPARE PARTS	10.0%	0.000	9.730	9.730	0.000	9.730	9.730
SERVICES	1.0%	0.973		0.973	0.973	0.000	0.973
D. BUILDING MAINT.							
MATERIALS	3.0%	0.120		0.120	0.120	0.000	0.120
E. CONSUMABLES							
BAGS		10.300		10.300	10.300	0.000	10.300
OTHER					0.000	0.000	0.000
OPERATING COSTS		38.693	9.730	48.623	38.693	9.730	48.623
CONTINGENCY	10.0%	3.869	0.973	4.862	3.859	0.973	4.842
TOTAL OPER. COSTS		42.562	10.703	53.265	42.562	10.703	53.265

	FINANCIAL COST	ECONOMIC COST
CAPITAL CHARGES/YR	41.059	54.131
OPERATING COSTS/YR	53.265	54.680
FACTORY COST/YR	94.325	108.811
TRANSPORTATION COST/YR	12.000	5.625
TOTAL CHARGES/YR	106.325	114.436

	DELIVERED	FACTORY	DELIVERED	FACTORY
COST/TON ($)	42.530	37.730	45.774	43.524
COST/40KG BAG ($)	1.701	1.509	1.831	1.741
COST/UNIT ENERGY ($/GJ)	2.200	1.952	2.368	2.252

***INSTALLATION	
LOCAL	3.0%
FOREIGN	12.0%

(1) ELECTRICITY(KW-H/T) 60.000
(2) POWER-DIESEL(L/TON)
(3) FUEL-DIESEL(L/TON)

Table A1.6: RESIDUE: COTTON STALKS-AWASH

CAPACITY: 5000.000 TONS
ENERGY: 17.800 MJ/KG

ALL FIGURES IN '000' U.S. DOLLARS

ITEMS			CAP. & OPER. COSTS			ANNUALIZED COST		
		LIFE (YRS)	LOCAL	FOREIGN	TOTAL	LOCAL	FOREIGN	TOTAL
I. CAPITAL COSTS								
A. CONSTRUCTION[a/]								
SITE PREPARATION		20	10.000		10.000	1.175	0.000	1.175
BUILDINGS		20	49.600	12.400	62.000	5.826	1.456	7.282
HOUSING		20	112.500	28.100	140.600	13.214	3.301	16.515
SUB-TOTAL			172.100	40.500	212.600	20.215	4.757	24.972
B. EQUIPMENT[b/]								
PISTON BRIQ.		15		172.000	172.000	0.000	22.613	22.613
SCREW BRIQ.		15			0.000	0.000	0.000	0.000
COLLECTION EQUIP.		8		204.800	204.800	0.000	38.389	38.389
STORAGE EQUIP.		12		17.000	17.000	0.000	2.495	2.495
CONVEYORS		12		23.200	23.200	0.000	3.405	3.405
SCREENS		12		3.000	3.000	0.000	0.440	0.440
SILOS		12		20.000	20.000	0.000	2.935	2.935
BALE BREAKERS		12		21.000	21.000	0.000	3.082	3.082
ELECTRICAL		12		12.200	12.200	0.000	1.791	1.791
TRANSFORMER/GENER.		8		106.300	106.300	0.000	19.925	19.925
BAGGING STATIONS		12		2.400	2.400	0.000	0.352	0.352
WORKSHOP EQUIP.		12		24.200	24.200	0.000	3.552	3.552
OTHERS		12		4.500	4.500	0.000	0.660	0.660
MISC.		12			0.000	0.000	0.000	0.000
		12			0.000	0.000	0.000	0.000
		12			0.000	0.000	0.000	0.000
SUB-TOTAL			0.000	610.600	610.600	0.000	99.640	99.640
C.SPARES AT DELIVERY	10.0%	11	0.000	61.060	61.060	0.000	9.496	9.496
D. TRANSPORT & DELIV.								
FREIGHT	4.0%	11	0.000	26.866	26.866	0.000	4.178	4.178
INSURANCE	1.0%	11	0.000	6.717	6.717	0.000	1.045	1.045
SITE DELIVERY		11	1.000	4.100	5.100	0.156	0.638	0.793
SUB-TOTAL (CIF)			1.000	37.683	38.683	0.156	5.860	6.016
E. ENGG./INSTALL.								
ENGG./PROCUREMENT	5.0%	20		30.530	30.530	0.000	3.586	3.586
TRAINING	5.0%	20		30.530	30.530	0.000	3.586	3.586
INSTALLATION***		20	12.174	48.696	60.870	1.430	5.720	7.150
SUB-TOTAL			12.174	109.756	121.930	1.430	12.892	14.322
CAPITAL COSTS			185.274	859.599	1044.873	21.800	132.645	154.446
CONTINGENCY	10.0%		18.527	85.960	104.487	2.180	13.265	15.445
TOTAL CAP. COSTS			203.801	945.559	1149.360	23.980	145.910	169.890

II. OPERATING COSTS

A. LABOR c/						
SKILLED	40.400		40.400	40.400	0.000	40.400
UNSKILLED	13.900		13.900	13.900	0.000	13.900
B. POWER						
ELECTRICITY (1)	0.000		0.000	0.000	0.000	0.000
DIESEL (2)		54.604	54.604	0.000	54.604	54.604
C. OPERATION & MAINT.						
FUEL (3) d/		8.228	8.228	0.000	8.228	
8.228						
LUBE OIL 10.0%		6.283	6.283	6.283	0.000	6.283
SPARE PARTS 10.0%	0.000	61.060	61.060	0.000	61.060	61.060
SERVICES 1.0%	6.106		6.106	6.106	0.000	6.106
D. BUILDING MAINT.						
MATERIALS 3.0%	6.378		6.378	6.378	0.000	6.378
E. CONSUMABLES						
BAGS	20.600		20.600	20.600	0.000	20.600
OTHER	1.000		1.000	1.000	0.000	1.000
OPERATING COSTS	88.384	130.175	218.559	88.384	130.175	218.559
CONTINGENCY 10.0%	8.838	13.018	21.856	8.838	13.018	21.856
TOTAL OPER. COSTS	97.222	143.193	240.415	97.222	143.193	240.415

	FINANCIAL COST	ECONOMIC COST
CAPITAL CHARGES/YR	169.890	218.040
OPERATING COSTS/YR	240.415	259.185
FACTORY COST/YR	410.305	477.226
TRANSPORTATION COST/YR	159.400	88.650
TOTAL CHARGES/YR	569.705	565.876

	DELIVERED	FACTORY	DELIVERED	FACTORY
COST/TON ($)	113.941	82.061	113.175	95.445
COST/40KG BAG ($)	4.558	3.282	4.527	3.818
COST/UNIT ENERGY ($/GJ)	6.401	4.610	6.358	5.362

***INSTALLATION

LOCAL	3.0%
FOREIGN	12.0%

(1) ELECTRICITY(KW-H/TON)	70.00
(2) POWER-DIESEL(L/TON)	29.200
(3) FUEL-DIESEL(L/TON)d/	4.400

FOOTNOTES
TABLE A1.6
RESIDUE: COTTON STALKS-AWASH

a/ Construction cost components for cotton residues:

Site preparation	10,000
	=======
Buildings	
Plant	32,609
Power house	3,804
Workshop	2,536
Parts store	3,804
Bagstore	4,227
Briquette store	9,275
Office	2,029
Parking shed	3,092
Equipment foundations	604
	61,978
	======
Housing requirements	
Plant manager	8,696
18 Skilled labourers	69,565
32 Perm. Labourers	61,836
Seasonal (drivers)	580
	140,677
	========

b/ Detailed discussion in Chapter 4.

c/ Labor cost components for cotton residues

Collection and Storage Personnel

7 Tractor Drivers	1,692
1 Headman	145
3 Labourers	217
	2,054

Briquetting Plant Personnel

1 Plant Manager	7,246
2 Shift supervisors ;	8,696
4 Plant operators	5,797
2 Powerplant operators	2,319
4 Tractor drivrs	4,831

1 Mchanic/welder	1,449
1 Electrician	1,449
1 Machine operator	1,449
1 Tractor mechanic	1,594
1 Storekeeper/clerk	1,884
1 Clerk	1,884
27 Permanent Labourers	11,739
3 Labourers (10 months)	1,087
2 Nightguards	870
	52,294

d/ Fuel Requirements for Collection of Cotton Residues

	Hours		L/HR
Baling	2,400		6
Hauling	1,527		5
Fuel (L)		22,035	
Capacity (TON)		5,000	
Fuel-Diesel (L/T)		4,407	

Table A1.7.: RESIDUE: WHEAT STRAW-DIXIS
CAPACITY: 5000.000 TONS
ENERGY: 18.050 MJ/KG
ALL FIGURES IN '000' U.S. DOLLARS

		CAP. & OPER. COSTS			ANNUALIZED COST			
ITEMS		LIFE(YRS)	LOCAL	FOREIGN	TOTAL	LOCAL	FOREIGN	TOTAL
I. CAPITAL COSTS								
A. CONSTRUCTION a/								
SITE PREPARATION		20	10.000		10.000	1.175	0.000	1.175
BUILDINGS		20	62.200	15.400	77.600	7.306	1.809	9.115
HOUSING		20	115.000	28.400	143.400	13.508	3.336	16.844
SUB-TOTAL			187.200	43.800	231.000	21.988	5.145	27.133
B. EQUIPMENT b/								
PISTON BRIQ.		15		215.000	215.000	0.000	28.267	28.267
SCREW BRIQ.		15			0.000	0.000	0.000	0.000
COLLECTION EQUIP.		8		98.500	98.500	0.000	18.463	18.463
STORAGE EQUIP.		12		9.000	9.000	0.000	1.321	1.321
CONVEYORS		12		23.500	23.500	0.000	3.449	3.449
SCREENS		12		3.000	3.000	0.000	0.440	0.440
SILOS		12		20.000	20.000	0.000	2.935	2.935
BALE BREAKERS		12		40.000	40.000	0.000	5.871	5.871
ELECTRICAL		12		12.200	12.200	0.000	1.791	1.791
TRANSFORMER/GENER.		8		106.300	106.300	0.000	19.925	19.925
BAGGING STATIONS		12		2.400	2.400	0.000	0.352	0.352
WORKSHOP EQUIP.		12		24.200	24.200	0.000	3.552	3.552
OTHERS		12		5.000	5.000	0.000	0.734	0.734
MISC.		12			0.000	0.000	0.000	0.000
SUB-TOTAL			0.000	559.100	559.100	0.000	87.100	87.100
C. SPARES AT DELIVERY	10.0%	12	0.000	55.910	55.910	0.000	8.323	8.323
D. TRANSPORT & DELIV.								
FREIGHT	4.0%	12	0.000	24.600	24.600	0.000	3.662	3.662
INSURANCE	1.0%	12	0.000	6.150	6.150	0.000	0.916	0.916
SITE DELIVERY		12	1.700	6.900	8.600	0.253	1.027	1.280
SUB-TOTAL (CIF)			1.700	37.651	39.351	0.253	5.605	5.858
E. ENGG./INSTALL.								
ENGG./PROCUREMENT	5.0%	20		27.955	27.955	0.000	3.284	3.284
TRAINING	5.0%	20		27.955	27.955	0.000	3.284	3.284
INSTALLATION***		20	13.818	55.272	69.090	1.623	6.492	8.115
SUB-TOTAL			13.818	111.182	125.000	1.623	13.059	14.682
CAPITAL COSTS			202.718	807.643	1010.361	23.865	119.231	143.096
CONTINGENCY	10.0%		20.272	80.764	101.036	2.386	11.923	14.310

TOTAL CAP. COSTS		222.990	888.407	1111.397	26.251	131.154	157.405
II. OPERATING COSTS							
A. LABOR [c/]							
SKILLED		33.400		33.400	33.400	0.000	33.400
UNSKILLED		7.200		7.200	7.200	0.000	7.200
B. POWER							
ELECTRICITY(1)		0.000		0.000	0.000	0.000	0.000
DIESEL(2)			66.198	66.198	0.000	66.198	66.198
C. OPERATION & MAINT.							
FUEL(3)			6.919	6.919	0.000	6.919	6.919
LUBE OIL	10.0%		7.312	7.312	0.000	7.312	7.312
SPARE PARTS	10.0%	0.000	55.910	55.910	0.000	55.910	55.910
SERVICES	1.0%	5.591		5.591	5.591	0.000	5.591
D. BUILDING MAINT.							
MATERIALS	3.0%	6.930		6.930	6.930	0.000	6.930
E. CONSUMABLES							
BAGS		20.600		20.600	20.600	0.000	20.600
OTHER		13.500			13.500	0.000	13.500
OPERATING COSTS		87.221	136.339	210.060	87.221	136.339	223.560
CONTINGENCY	10.0%	8.722	13.634	22.356	8.722	13.634	22.356
TOTAL OPER. COSTS		95.943	149.973	245.916	95.943	149.973	245.916

	FINANCIAL COST	ECONOMIC COST
CAPITAL CHARGES/YR	157.405	200.686
OPERATING COST/YR	245.916	267.197
BRIQUETTING COST/YR		
FACTORY COST/YR	403.321	467.883
TRANSPORTATION COST/YR	170.048	61.400
TOTAL CHARGES/YR	573.369	529.283

	DELIVERED	FACTORY	DELIVERED	FACTORY
COST/TON($)	114.674	80.664	105.857	93.577
COST/40KG BAG($)	4.587	3.227	4.234	3.743
COST/UNIT ENERGY($/GJ)	6.353	4.469	5.865	5.184

***INSTALLATION	
LOCAL	3.0%
FOREIGN	12.0%

(1)ELECTRICITY(KW-H/TON)	
(2)POWER-DIESEL(L/TON)	35.400
(3)FUEL-DIESEL(L/TON)	3.700

FOOTNOTES
Table A1.7
RESIDUE: WHEAT STRAW-DIXIS

a/ Construction cost components for wheat straw:

Site preparation	10,000
	========
Buildings	
Plant	32,609
Reception	10,870
Workshop	2,536
Powerhouse	3,804
Briquette store	9,275
Office	2,029
Bagstore	4,227
Parts store	3,804
Parking shed	7,729
Foundation equipment	725
Total buildings	77,608
	========

Housing requirements

Plant manager	8,696
16 Skilled labourers	61,836
32 Unskilled labourers	61,836
Seasonal labour	11,014
Total housing requirements	143,382

b/ Detailed discussion in Chapter 5.

c/ Labor cost components for wheat straw:

Residue collection and storage personnel

3 Baler oprators	1,090
2 Tractor drivers	725
40 Labourers	3,785
1 headman	435
	6,035
	=========

Briquetting plant personnel

1 Plant manager	7,246
2 Shift supervisors	8,696
4 Plant operators	5,797

2 Drivers	2,174
1 Welder (mechanic)	1,449
1 Machine operator	1,449
1 Electrician	1,449
1 Tractor mechanic	1,594
1 Storekeeper/clerk	1,884
6 Labourers	1,957
2 Nightguards	870
	34,565

d/ Fuel requirements for collection of wheat straw residues:

	Hours	L/HR
Baling	1,800	6
Hauling	1,500	5

Fuel (L)	18,300
Capacity (TON)	5,000
Fuel-Diesel (L/T)	3,660

Table A1.8: RESIDUE: CORN STALKS AND STOVER

CAPACITY: 5000.000 TONS
ENERGY: 18.650 MJ/KG

ALL FIGURES IN '000' U.S. DOLLARS

			CAP. & OPER. COSTS			ANNUALIZED COST		
ITEMS		LIFE (YRS)	LOCAL	FOREIGN	TOTAL	LOCAL	FOREIGN	TOTAL
I. CAPITAL COSTS								
A. CONSTRUCTION [a]								
SITE PREPARATION		20	10.000		10.000	1.175	0.000	1.175
BUILDINGS		20	65.800	16.400	82.200	7.729	1.926	9.655
HOUSING		20	177.700	44.400	222.100	20.873	5.215	26.088
SUB-TOTAL			253.500	60.800	314.300	29.776	7.142	36.918
B. EQUIPMENT [b]								
PISTON BRIQ.		15		206.400	206.400	0.000	27.136	27.136
SCREW BRIQ.		15			0.000	0.000	0.000	0.000
COLLECTION EQUIP.		8		238.100	238.100	0.000	44.630	44.630
STORAGE EQUIP.		12		37.200	37.200	0.000	5.460	5.460
CONVEYORS		12		23.500	23.500	0.000	3.449	3.449
SCREENS		12		3.000	3.000	0.000	0.440	0.440
SILOS		12		20.000	20.000	0.000	2.935	2.935
BALE BREAKERS		12		40.000	40.000	0.000	5.871	5.871
ELECTRICAL		12		12.200	12.200	0.000	1.791	1.791
TRANSFORMER/GENER.		8		127.500	127.500	0.000	23.899	23.899
BAGGING STATIONS		12		2.400	2.400	0.000	0.352	0.352
WORKSHOP EQUIP.		12		24.200	24.200	0.000	3.552	3.552
OTHERS		12		5.000	5.000	0.000	0.734	0.734
MISC.		12			0.000	0.000	0.000	0.000
SUB-TOTAL			0.000	739.500	739.500	0.000	120.249	120.249
C.SPARES AT DELIVERY	10.0%	11	0.000	73.950	73.950	0.000	11.469	11.469
D. TRANSPORT & DELIV.								
FREIGHT	4.0%	11	0.000	32.538	32.538	0.000	5.046	5.046
INSURANCE	1.0%	11	0.000	8.135	8.135	0.000	1.262	1.262
SITE DELIVERY		11	2.700	10.800	13.500	0.419	1.675	2.094
SUB-TOTAL (CIF)			2.700	51.473	54.173	0.419	7.983	8.402
E. ENGG./INSTALL.								
ENGG./PROCUREMENT	5.0%	20		36.975	36.975	0.000	4.343	4.343
TRAINING	5.0%	20		36.975	36.975	0.000	4.343	4.343
INSTALLATION***		20	15.042	60.168	75.210	1.767	7.067	8.834
SUB-TOTAL			15.042	134.118	149.160	1.767	15.753	17.520
CAPITAL COSTS			271.242	1059.841	1331.083	31.962	162.595	194.557
CONTINGENCY	10.0%		27.124	105.984	133.108	3.196	16.260	19.456
TOTAL CAP. COSTS			298.366	1165.825	1464.191	35.158	178.855	214.013

II. OPERATING COSTS

A. LABOR c/							
SKILLED		40.800		40.800	40.800	0.000	40.800
UNSKILLED		42.800		42.800	42.800	0.000	42.800
B. POWER							
ELECTRICITY(1)		0.000		0.000	0.000	0.000	0.000
DIESEL(2)			70.125	70.125	70.125	0.000	70.125
C. OPERATION & MAINT.							
FUEL (3)d/			11.669	11.669	0.000	11.669	11.669
LUBE OIL	10.0%		8.179	8.179	8.179	0.000	8.179
SPARE PARTS	10.0%	0.000	73.950	73.950	0.000	73.950	73.950
SERVICES	1.0%	7.395		7.395	7.395	0.000	7.395
D. BUILDING MAINT.							
MATERIALS	3.0%	9.429		9.429	9.429	0.000	9.429
E. CONSUMABLES							
BAGS		20.600		20.600	20.600	0.000	20.600
OTHER		13.500			13.500	0.000	13.500
OPERATING COSTS		134.526	163.923	298.447	134.526	163.923	298.447
CONTINGENCY	10.0%	13.452	16.392	29.845	13.452	16.392	29.845
TOTAL OPER. COSTS		147.976	180.315	328.292	147.976	180.315	328.292

	FINANCIAL COST	ECONOMIC COST
CAPITAL CHARGES/YR	214.013	273.035
OPERATING COSTS/YR	328.292	337.129
FACTORY COST/YR	542.304	610.163
TRANSPORTATION COST/YR	159.400	113.110
TOTAL CHARGES/YR	701.704	723.273

		DELIVERED	FACTORY	DELIVERED	FACTORY
COST/TON ($)		140.341	108.461	144.655	122.033
COST/40KG BAG ($)		5.614	4.338	5.786	4.881
COST/UNIT ENERGY ($/GJ)		7.525	5.816	7.756	6.543
***INSTALLATION					
LOCAL	3.0%				
FOREIGN	12.0%				

(1) ELECTRICITY(KW-H/TON)
(2) POWER-DIESEL(L/TON) 37.500
(3) FUEL-DIESEL(L/TON) 6.240

FOOTNOTES
Table A1.8
RESIDUE: CORN STALKS AND STOVER

a/ Construction cost componants for corn residues:

Site Preparation	10,000
	=======
Buildings	
Plant	32,609
Reception	14,493
Power-house	3,804
Gasifier	3,551
Cobstore	1,268
Workshop	2,174
Parts store	3,804
Briquette Store	9,275
Office	2,029
Bagstore	4,227
Parking shed	3,865
Equipment foundation	1,087
	82,186
	=======

Housing requirements

Plant manager	8,696
18 Skilled labourers	69,565
38 Permanent labourers	73,430
Seasonal labour	70,435
	222,126
	=======

b/ Detailed discussion in Chapter 6.

c/ Labor Cost components for corn residues:

Residue collection and Storage Personnel

240 Labourers	26,087
9 Tractor drivers	3,261
6 Baling labourers	652
2 Headmen	870
	30,870
	=======

Briquetting Plant Personnel

1 Plant manager	7,246

2 Shift supervisors	8,696
4 Plant operators	5,797
2 Power plant operators	2,319
2 Gasifier operators	2,319
2 Tractor drivers	2,174
1 Mechanic/welder	1,449
1 Machine operator	1,449
1 Electrician	1,449
1 Tractor mechanic	1,594
1 Store-keeper/clerk	1,884
1 Clerk	1,884
32 Labourers	11,643
2 Nightguards	870
	52,730

d/ Fuel Requirements for Collection of Corn Residues:

	Hours		L/HR
Chopping	3,350		6
Transport	1,912		5
Cobb Trans	310		5
Fuel (L)		31,210	
Capacity (TON)		5,000	
Fuel-Diesel (L/T)		6,242	

Table A1.9: SENSITIVITY ANALYSIS

(1) PRODUCTION CAPACITY(TONS/YR) VS. DELIVERED COST($/TON)

CAPACITY	1000	2000	3000	4000	5000	6000	7000	8000
COFFEE DILLA-HUSK	153.660	102.432	85.356	76.818	71.695	68.280	65.841	64.011
COFFEE DILLA-PULP	120.564	92.410	83.026	78.333	75.518	73.641	72.300	71.295
COFFEE PARCH.-NEW SITE	91.502	56.826	45.268	39.488	36.021	33.709	32.058	30.819
COFFEE PARCH.-MERCATO	73.587	47.706	39.079	34.766	32.177	30.452	29.220	28.295
COTTON STALKS-AWASH	303.586	185.058	145.549	125.794	113.941	106.039	100.395	96.162
WHEAT STRAW-DIXIS	289.799	180.346	143.861	125.619	114.674	107.377	102.165	98.256
CORN STALKS AND STOVER	376.627	228.948	179.722	155.109	140.341	130.496	123.463	118.189

(2) DISCOUNT RATE(%) VS. DELIVERED COST($/TON)

DISCOUNT RATE	6.00%	8.00%	10.00%	12.00%	14.00%	16.00%	18.00%	20.00%
COFFEE DILLA-HUSK	68.713	70.163	71.695	73.301	74.973	76.701	78.479	80.300
COFFEE DILLA-PULP	89.897	91.345	92.858	94.431	96.060	97.737	99.459	101.222
COFFEE PARCH.-NEW SITE	33.880	34.920	36.021	37.175	38.376	39.619	40.897	42.207
COFFEE PARCH.-MERCATO	38.958	40.695	42.530	44.453	46.454	48.525	50.657	52.841
COTTON STALKS-AWASH	107.461	110.621	113.941	117.407	121.002	124.712	128.524	132.425
WHEAT STRAW-DIXIS	108.348	111.429	114.674	118.066	121.589	125.228	128.967	132.794
CORN STALKS AND STOVER	132.058	136.095	140.341	144.774	149.374	154.122	159.000	163.992

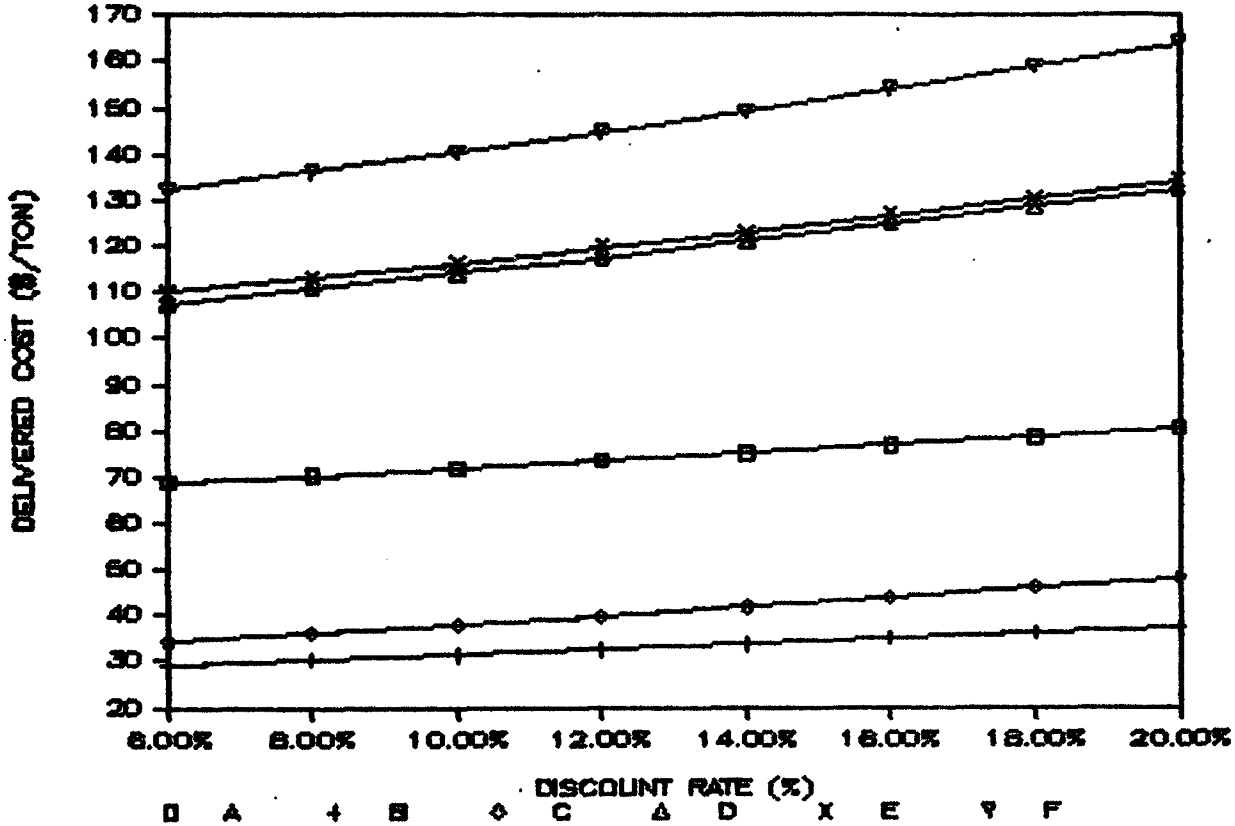
(3) SERVICE LIFE-BRIQUETTORS(YEARS) VS. DELIVERED COST($/TON)

SERVICE LIFE	6	8	10	12	14	16	18	20
COFFEE DILLA-HUSK	75.989	74.194	73.113	72.397	71.893	71.524	71.245	71.030
COFFEE DILLA-PULP	92.858	92.858	92.858	92.858	92.858	92.858	92.858	92.858
COFFEE PARCH.-NEW SITE	39.740	38.174	37.237	36.620	36.189	35.876	35.640	35.460
COFFEE PARCH.-MERCATO	49.968	46.836	44.962	43.729	42.867	42.240	41.769	41.408
COTTON STALKS-AWASH	118.265	116.501	115.420	114.686	114.155	113.753	113.439	113.188
WHEAT STRAW-DIXIS	120.052	117.841	116.493	115.585	114.934	114.447	114.071	113.775
CORN STALKS AND STOVER	145.562	143.438	142.133	141.245	140.601	140.113	139.730	139.424

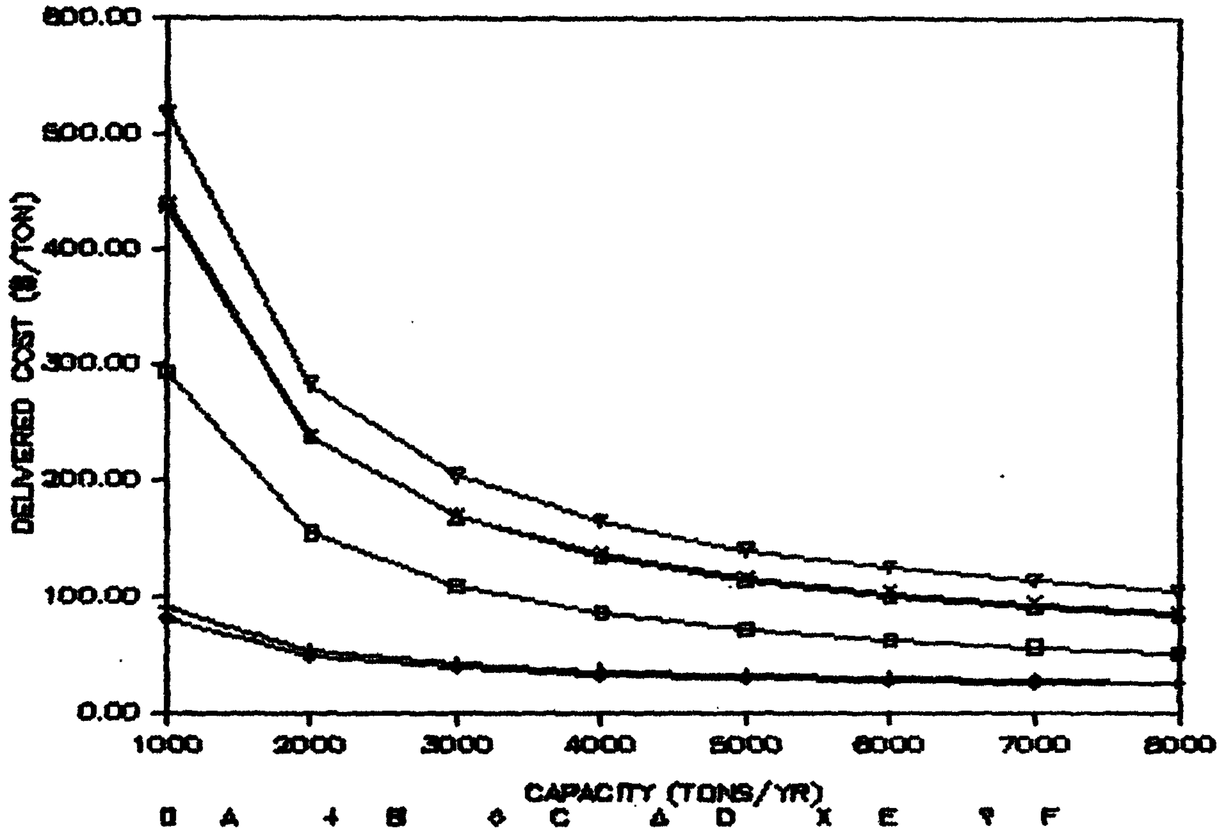
(4) POWER REQUIREMENTS(KW-H/TON) VS. DELIVERED COST($/TON)

POWER	-60.00%	-40.00%	-20.00%	0.00%	20.00%	40.00%	60.00%	80.00%
COFFEE DILLA-HUSK	69.200	70.032	70.864	71.695	72.527	73.358	74.190	75.022
COFFEE DILLA-PULP	92.858	92.858	92.858	92.858	92.858	92.858	92.858	92.858
COFFEE PARCH.-NEW SITE	33.526	34.358	35.189	36.021	36.852	37.684	38.516	39.347
COFFEE PARCH.-MERCATO	40.035	40.867	41.698	42.530	43.361	44.193	45.025	45.856
COTTON STALKS-AWASH	106.013	108.655	111.298	113.941	116.584	119.227	121.870	124.512
WHEAT STRAW-DIXIS	105.062	108.266	111.470	114.674	117.878	121.082	124.286	127.490
CORN STALKS AND STOVER	130.159	133.553	136.947	140.341	143.735	147.129	150.523	153.917

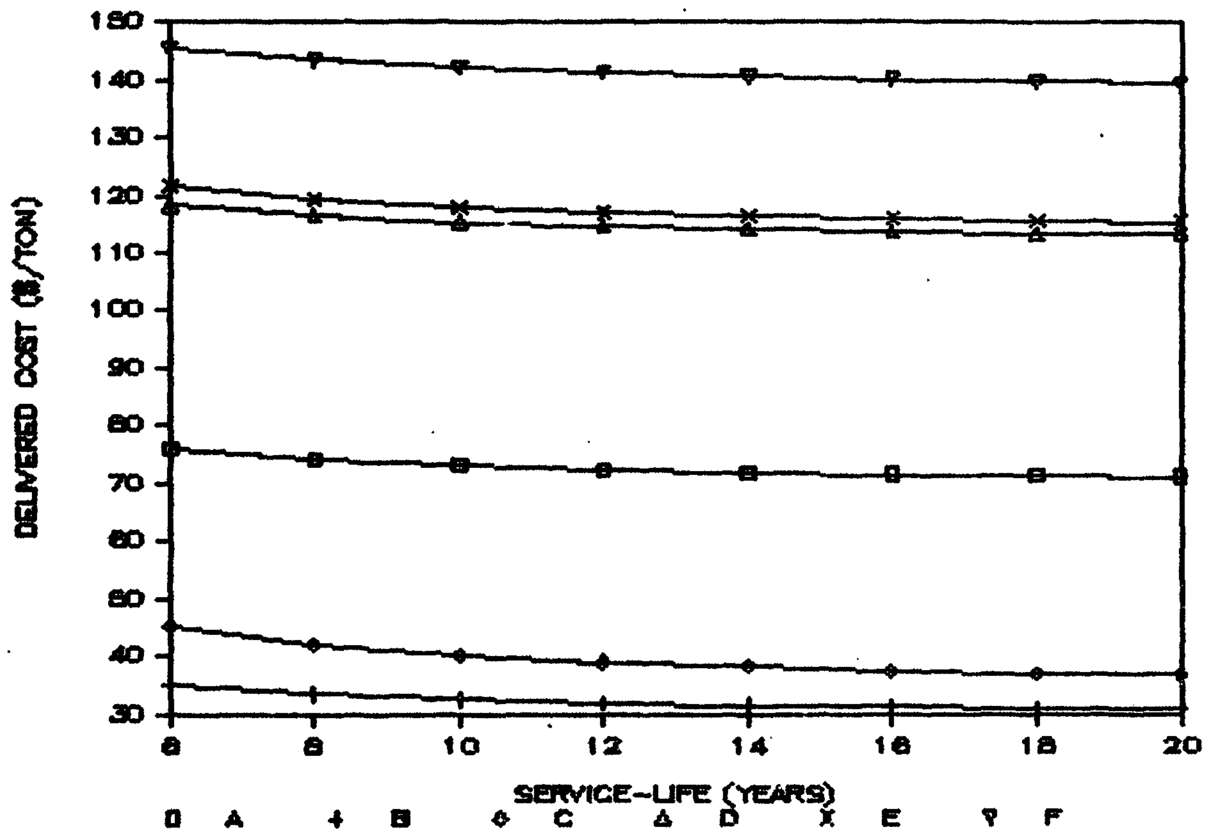
DISCOUNT RATE ANALYSIS



PRODUCTION CAPACITY ANALYSIS



SERVICE-LIFE (BRIQUETTORS) ANALYSIS



Annex 2

CHEMICAL AND PHYSICAL ANALYSIS OF ETHIOPIAN AGRICULTURAL RESIDUES BRIQUETTING

(TNO REPORT)

division of technology for society

netherlands organization for
applied scientific research

SUITABILITY TESTS OF BRIQUETTES FROM ETHIOPEAN AGRICULTURAL RESIDUES

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SUMMARY

Within the framework of a feasibility study of briquetting plants for Ethiopia, the World Bank commissioned the Netherlands Organization for Applied Scientific Research, TNO, Division of Technology for Society, Apeldoorn, the Netherlands to test briquettes of five agricultural residues from Ethiopia in order to assess their suitability for domestic and other purposes.

The five residues concerned are: corn stover, cotton stalks, wheat straw, white coffee parchment and black coffee husks. In fact, two different species of black coffe husks could be distinguished, the so-called agglomerated and non-agglomerated specie. It was attempted to compress all residues by a conical screw extruder. Good briquettes resulted from the corn stover, cotton stalks and white coffee parchment, but the compression of the wheat straw and black coffee husks was unsuccessful. Therefore those materials were compressed by a hydraulic piston press. Because the preprocessing of the materials had taken place in accordance with the specifications imposed by the conical screw extruder the characteristics of the material fed into the hydraulic piston press were not optimal. The quality of the resulting briquettes may not be termed representative for the quality that can be obtained by such a compression process. Moreover, black coffee husks briquettes were produced only from the agglomerated species. The results obtained with the latter briquettes may not be valid for the non-agglomerated species of black coffee husks.

The briquettes were submitted to an extensive testprogramme comprising the determination of their composition, the fusion behaviour of the ashes and several physical properties including the friability of the briquettes, the resistance to storage in a humid atmosphere and the bulk densities of raw materials and briquettes. Finally, combustion tests were carried out in a domestic metal cooking stove. Comparisons were made with combustion results of Eucalyptus.

On the basis of the testdata it can be concluded that the three "screw-made" briquettes from cotton stalks, corn stover and white coffee parchment are most likely to be suitable to serve as fuel for domestic use. The

results with regard to their resistance to storage in a humid atmosphere and their resistance to mechanical shocks from transport - even after their exposure to a humid atmosphere - were good and the results may be expected to be even better under more favourable atmospheric conditions. The combustion tests rendered results that were comparable to, or even slightly better than those from tests conducted with Eucalyptus.

The wheat straw briquettes rendered good results with regard to their combustion. However, the resistance of this particular briquette to mechanical shocks - even in dry condition - must be termed poor. Therefore their suitability for domestic use must be doubted, and further examination of the compression potentials of this material is recommended.

The particular agglomerated black coffee husks briquettes that were produced during this project, are of a very poor quality in every respect, although the lignin content of the material is not in any way lower than the content of the other materials. The briquettes may be crumbled by hand, and they did not survive any of the mechanical tests they were submitted to, nor did they outlive their exposure to a humid atmosphere. The combustion tests also rendered poor results because of the bad ignition qualities of the briquettes and the fact that they disintegrated during the combustion process.

Whether the briquettes may be suitable for other than domestic purposes will largely depend on the process under consideration.

1. INTRODUCTION

Within the framework of a feasibility study of briquetting plants for Ethiopia, the World Bank commissioned the Netherlands Organization for Applied Scientific Research, TNO, Division of Technology for Society, Apeldoorn, the Netherlands to test briquettes of five agricultural residues from Ethiopia in order to assess their suitability for domestic and other purposes.

The five residues concerned are corn stover, cotton stalks, wheat straw, white coffee parchment and black coffee husks. In fact, two slightly different species of black coffee husks could be distinguished, the so-called agglomerated and non-agglomerated husks. The raw materials were transported by air from Ethiopia and had to be compressed in Europe.

This report describes the compression of the materials (section 2) and presents the results of the testprogramme to which the briquettes were submitted.

The test programme comprised the determination of the composition of the materials (section 3) and the ashes (section 4); the determination of the calorific value (section 3) and combustion tests performed in a domestic one-hole metal stove without chimney (section 8); the determination of the fusion behaviour of the ashes (section 4); and finally, the determination of several physical properties, namely the basic- and bulk densities of the raw materials and the briquettes (section 5), the resistance to storage in a humid atmosphere (section 6) and the friability of the briquettes (section 7). Conclusions are drawn in section 9 of the report.

Various institutes and firms have contributed to the execution of the testprogramme and will be mentioned in the relevant sections.

2. COMPRESSION

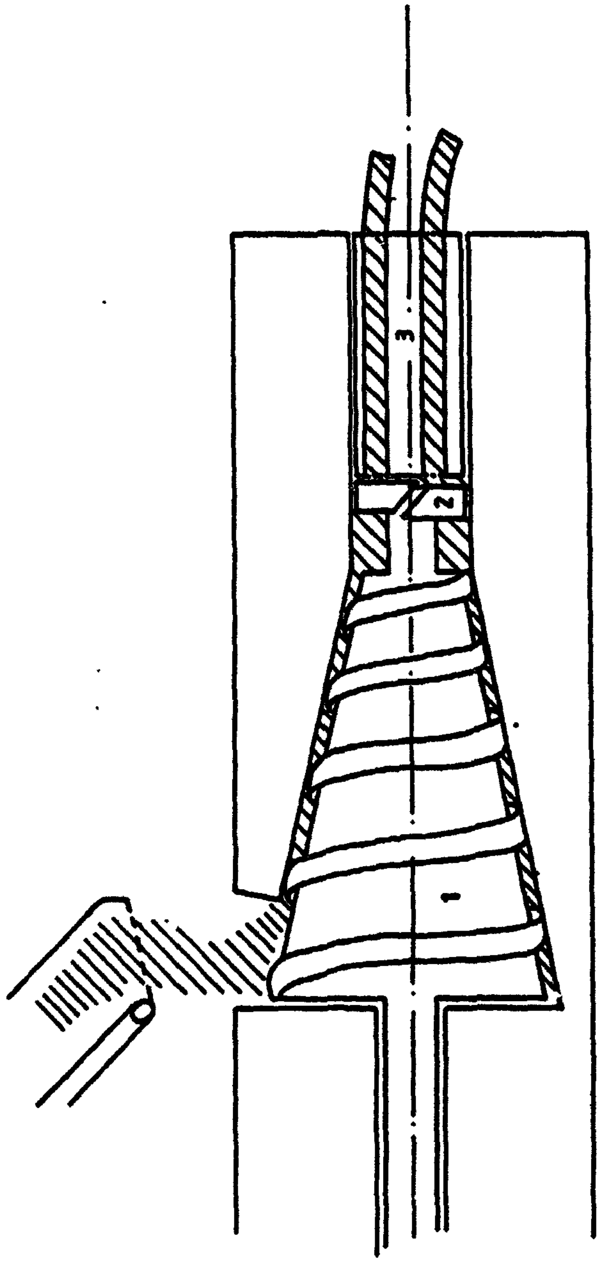
Before a material can be fed into a press certain specifications concerning moisture content and particle size have to be met. The residues were ground and dried by the "Centre de Recherches Agronomiques" (C.R.A.), Gembloux, Belgium. The material was dried to below 5% moisture content. The grinding to a particle size between 1 and 10 mm was performed by a hammer mill.

The cotton stalks, corn stover and white coffee parchment were compressed by a conical screw press of Biomass Development Europe s.a. (B.D.E.), Brussels, Belgium. The briquettes produced have a diameter of 30 mm and vary in length between 5 and 15 cm.

Attempts to compress the wheat straw and the black coffee husks with this equipment were unsuccessful, because the pressure build-up was insufficient. The sketch of fig. 1 shows the working principle of the extruder: First the material is compressed by the conical screw. The screw-head cuts the material and forces it into the die. Owing to the friction the material is heated to above 200 °C, which causes the lignin to fuse and act as a binder. The working pressure largely depends on the friction that is generated in the die. This depends on the die lay-out (number and diameter of the holes) and the die length, in combination with the material properties.

The bad compression results with the black coffee husks and the wheat straw cannot be explained by a lower lignin content than the content of the other materials (see section 3); nor by the temperature build-up, which was sufficient to cause the lignin to fuse. Apparently the friction that was generated in the die was insufficient, to build up high enough a pressure.

It is the experience of B.D.E. that any wood species may be compressed into good quality briquettes with dies consisting of 7 or 8 holes with a 30-mm diameter and lengths varying between 170 and 180 mm. During the compression trials of the black coffee husks and the wheat straw, dies consisting of 7 holes and a 173-mm length and 8 holes and a 180-mm length were used. The proceeding of the compression trials has given rise to the impression that a longer die might have led to better results. However, owing to B.D.E.'s experience quoted above, no longer die was available.



1. conical screw
2. screw head
3. replaccble die

Conical screw extruder	MT — TNO 13801 Fig. 1

The conical screw press operated at a power of about 45 kW. A rough estimate of the briquette output from the press comes to 500 kg/h for the three materials. The moisture content of the material entering the press should be below 5% and the particle size 1 - 10 mm.

The remainder of the black coffee husks and the wheat straw was compressed by a hydraulic piston press of Kusters b.v., Venlo, the Netherlands. While C.R.A. appeared to have kept part of the wheat straw this quantity was still available for compression at Kusters. The quantity of wheat straw that was not used during the compression attempts at B.D.E. was added to this. As for the black coffee husks it appeared that only the agglomerated species was kept unused at B.D.E. This was sent to Kusters. The input condition of both materials was 1-10 mm particle size and about 5% moisture content. The demands concerning the particle size and moisture content of the material to be fed into the hydraulic piston press are less severe than those concerning the conical screw press, namely below 20 mm and 18% respectively. Therefore the particle size of 1-10 mm and the moisture content of 5% were not ideal characteristics and may have influenced the resulting briquette quality.

The briquettes produced have a diameter of 50 mm and vary in length between 1 and 8 cm. The agglomerated black coffee husks briquettes are of a poor quality because their composition is very loose. The quality of the wheat straw briquettes is slightly better, although still very moderate. Compared to known compression results of wood wastes with the same press the quality of the briquettes produced cannot be termed representative for this production method.

The briquettes were produced by one of Kusters' smaller presses operating at a power of 15 kW. The briquette output amounted to roughly 150 kg/h for both materials. The press operated at a pressure of about 1200 bar.

Table 1 summarizes the overall results of preprocessing and compression.

Table 1: Quantities of raw materials and briquettes

Raw material	Quantity received by CRA (kg)	Quantity left after grinding and drying (kg)	Quantity sent to B.D.E. (kg)	Quantity of briquettes produced at B.D.E. (kg)	Quantity sent to Kusters (kg)	Quantity of briquettes produced at Kusters (kg)
Corn stover	192	139 (72%)	119	96.9	-	-
Cotton stalks	118	75.5 (64%)	51.5	30.9	-	-
Wheat straw	153	145 (95%)	106	-	110	72.0
White coffee parchment	180	168 (93%)	168	51.3	-	-
Black coffee husks	230	171 (74%)	171	-	-	-
Agglomerated black coffee husks	150	100 (67%)	100	-	100	57.4

The reduction in mass after grinding and drying is caused by loss of moisture and formation of dust. Table 2 shows the moisture content of the raw materials on receipt at C.R.A.

Table 2: Initial moisture content of the raw materials as received by C.R.A.

raw material	moisture content (% on a dry-matter basis)
Corn stover	9.7
Cotton stalks	14.4
Wheat straw	9.6
White coffee parchment	4.4
Black coffee husks	12.2
Agglomerated black coffee husks	12.3

It is obvious that the reduction in mass c not solely be accounted for by the drying process to below 5% moisture content.
The major part of the loss is caused by the formation of dust during grinding. Part of this could not be recovered by the cyclone that was used. However, because C.R.A. does not use industrial equipment, the mass reduction due to drying and grinding, presented in table 1, cannot be considered to be representative of the losses that will occur in practice.

It should be noticed that where this report speaks of black coffee husks briquettes in fact agglomerated black coffee husks briquettes are meant. Because the origine of the agglomerated and non-agglomerated species of black coffee husks is unknown - while no indications whatsoever accompanied the residues at their arrival in Belgium - it is not clear to what extent the conclusions about the agglomerated husks may be valid for the non-agglomerated husks too.

3. COMPOSITION AND CALORIFIC VALUE OF THE BRIQUETTES

The gross and net calorific value of the briquettes were determined in accordance with the International Standard ISO 1928-1976.

The lignin content was determined by C.R.A. Gembloux and constitutes an average of 3 measurements. The analysis determining the sulphuric lignin uses the Ritter method adapted to an automatical Fibertec (Tecator) apparatus. The standard error S*) is given in brackets.

The species of Eucalyptus wood used for the combustion tests that were conducted for the sake of comparison is named Eucalyptus Globulus Labil. This species was long ago imported into Ethiopia and contributed in this way to the development of Addis Abeba into the country's Major city [1].

Table 3 shows the composition and the calorific value of the briquettes and the Eucalyptus. Except for the moisture content all data are given on a dry-matter basis. It should be noticed that the moisture content of the briquettes used in the combustion tests was lower than the moisture content shown in table 3. This is caused by the fact that the samples that were analyzed had for some time been exposed to the ambient atmosphere in pulverized condition.

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*) $S = \frac{\sigma}{\sqrt{n}}$ in which σ = standard deviation

n = number of measurements

Table 3: Composition and calorific value of the briquettes and Eucalyptus

	Cotton stalks	Corn stover	White coffee parchment	Black coffee husks (aggl.)	Wheat straw	Eucalyptus Globulus
moisture content (%)	5.88	5.70	5.36	9.10	7.60	6.84
ash content (%)	3.16	3.45	0.33	8.90	4.50	0.29
volatile content (%)	75.8	77.5	83.4	65.4	78.1	82.2
C-content (%)	47.1	47.1	50.1	47.8	47.5	47.46
H-content (%)	5.99	6.05	6.19	5.10	6.00	6.08
O-content (%)	43.9	43.5	42.7	36.0	42.6	45.82
N-content (%)	0.35	0.40	0.24	3.00	0.42	not determined
sulphuric lignin content (%)	21.5 (S = 0.4)	17.16 (S = 0.06)	25.1 (S = 0.3)	37.2* (S = 0.3)	17.6 (S = 0.2)	not determined
gross calorific value (MJ/kg)	19.05	19.90	20.55	18.65	18.35	21.00
net calorific value (MJ/kg)	17.80	18.65	19.33	17.60	17.10	19.75

* The sulphuric lignin content of the non-agglomerated black coffee husks is 20.6% (S = 0.6)

- all data are given on a dry-matter basis, except for the moisture content.

4. PROPERTIES OF THE ASHES

The fusion behaviour of the ashes of all five briquettes has been examined by the Technical Laboratory Laura, Eygelshoven, The Netherlands.
Because ashes are heterogeneous mixtures of minerals of various compositions they do not melt at a standard temperature but soften gradually. Therefore their fusion behaviour is characterized in terms of three characteristic temperatures, viz. the deformation temperature, the hemisphere temperature and the flow temperature [2].

The method applied to determine these temperatures comprises the observation of the melting of an ash cube mounted on a Platinum support in an oxidizing atmosphere (air), in accordance with the International Standard ISO 540-1981. At deformation temperature the first rounding of the vertices takes place, at hemisphere temperature the cube has assumed the shape of a hemisphere (i.e. its height equals half its width), and at flowtemperature the cube's height has been reduced to 1/6 of its width.

Table 4 presents the fusion points of the five ash samples. Because the cotton ashes started to soften already below 815 °C this sample was only heated to 500 °C, which may have caused the sample to contain some organic matter. The corn ashes contained some plastic particles from a broken packing.

Table 4: Characteristic points of the melting course of five ash samples

	Deformation temperature (°C)	Hemisphere temperature (°C)	Flow temperature (°C)
Corn stover	1100	1230	1370
Cotton stalks	720	> 1560	> 1560
Wheat straw	1110	1370	1410
White coffee parchment	1310	> 1560	> 1560
Black coffee husks (aggl.)	940	1200	1500

The chemical composition of the ashes of the corn-, cotton- and white coffee briquettes was also determined, by means of a semi-quantitative emission spectrometric screen of the ashes. The relative accuracy of the data amounts to 20%.

Table 5 presents the results in percentages by mass.

The fusion behaviour of an ash cannot easily be correlated with its composition. However, some rough tendencies are known. The fusion points are generally lowered by an increase in the content of fluxing oxides (CaO, MgO, FeO, Fe_2O_3 etc.). In the case of a constant content of fluxing oxides the fusion points may be expected to increase with the ratio Al_2O_3/SiO_2 [2].

Table 5: Chemical composition of the ashes of the cotton-, corn- and white coffee briquettes

Element	Cotton stalks (wt. %)	Corn stover (wt. %)	White coffee parchment (wt. %)
K	M > 10	M > 10	M > 5
Ca	M > 10	M > 5	M > 10
Mg	nM (1-5)	M > 5	M > 5
Si	0.7	M > 10	nM (1-5)
Fe	0.3	nM (1-5)	nM (1-5)
Al	0.3	ca. 1	nM (1-5)
Na	0.5	0.06	0.6
Mn	≦ 0.06	0.3	0.6
Zn	b.m.c. < 0.1	b.m.c. < 0.1	0.3
Ti	0.03	0.2	0.2
Cu	≦ 0.01	≦ 0.02	≦ 0.1
Ni	0.01	0.03	0.06
Ba	b.m.c. < 0.06	b.m.c. < 0.06	0.2
B	0.04	≦ 0.01	0.08
Cr	b.m.c. < 0.005	0.01	0.015
Pb	b.m.c. < 0.01	b.m.c. < 0.01	0.01
Sr	b.m.c. < 0.1	b.m.c. < 0.1	≦ 0.1
Sn	≦ 0.005	≦ 0.005	≦ 0.005
V	< 0.01	≦ 0.01	< 0.01
Zr	b.m.c. < 0.01	b.m.c. < 0.01	≦ 0.01
Sb	b.m.c. < 0.03	b.m.c. < 0.03	b.m.c. < 0.03
Nb	b.m.c. < 0.03	b.m.c. < 0.03	b.m.c. < 0.03
Co	b.m.c. < 0.01	b.m.c. < 0.01	b.m.c. < 0.01
W	b.m.c. < 0.1	b.m.c. < 0.1	b.m.c. < 0.1
Cd	b.m.c. < 0.01	b.m.c. < 0.01	b.m.c. < 0.01
Bi	b.m.c. < 0.005	b.m.c. < 0.005	b.m.c. < 0.005
Mo	b.m.c. < 0.005	b.m.c. < 0.005	b.m.c. < 0.005
Ag	b.m.c. < 0.002	b.m.c. < 0.002	b.m.c. < 0.002
Be	b.m.c. < 0.001	b.m.c. < 0.001	b.m.c. < 0.001

M = main component

nM = secondary component

b.m.c. = below measurable concentration

5. DENSITIES

The basic (or specific) density and the bulk density of the raw materials were determined by C.R.A. Gembloux. The basic densities were determined by using a Breuil mercury volumenometer and constitute an average of 5 measurements. The standard error as well as the moisture content at the moment of testing are presented.
The bulk densities were measured after drying and grinding of the raw materials had taken place, so the moisture content at the moment of testing was below 5%. The test-volume used was 0.003 m^3. Table 6 shows the results.

Table 6: Basic and bulk density of the raw materials

	moisture content (%)*	basic density (kg/m³)	standard error	bulk density (kg/m³)
Corn stover	9.6	221	9	99
Cotton stalks	10.4	450	10	143
Wheat straw	8.0	380	50	97
White coffee parchment	9.2	920	30	100
Black coffee husks	12.6	1090	80	142

* on a dry-matter basis

The basic density of the briquettes was determined as follows: After the briquette had been weighed its volume was determined by immersing it in paraffin and by measuring the paraffin's volume displacement. Paraffin was chosen because it is barely absorbed by the briquettes. Five fragments of briquettes from each material have been tested in this way. The spread in the results is quite extensive, especially in the case of the white coffee parchment briquettes, the cotton stalks briquettes and the agglomerated black coffee husks briquettes. Table 7 discloses the results. The standard error - which may be considered to constitute a measure for the accuracy of the mean value of the measurements - is given, and so are the moisture content on a wet-matter basis of the briquettes at the moment of testing. The briquettes were exposed to the ambient for several weeks at the time.

Table 7: Basic density of the briquettes and Eucalyptus

	Basic density (kg/m^3)	Standard error	Moisture content (%)*
Corn stover	990	20	3.1
Cotton stalks	1090	50	4.1
Wheat straw	1050	15	3.3
White coffee parchment	1240	70	3.1
Black coffee husks (aggl.)	1170	40	9.9
Eucalyptus	950	40	9.9

* on a wet-matter basis

The bulk density of the briquettes was measured after they had been conditioned for 6 days in a climatic room at 23 °C and 50% relative humidity. The values given in table 8 are averages of three measurements with various test volumes. Owing to the rather small quantity of briquettes available the shape and size of the boxes that were used had some influence on the measured values. Therefore the test-volumes applied and the standard error are given, the latter serving as a measure for the accuracy of the mean values. The briquettes in the box were allowed to settle by vibrating the box for some time. Table 8 also presents the moisture content of the briquettes at the moment of testing.

For the corn-, cotton- and white coffee briquettes one measurement was done, after conditioning at 20 °C and 90% relative humidy, with a test volume of 0.024 m^3. No such values could be obtained in the case of the agglomerated black coffee- and wheat straw briquettes, see section 6.

The higher bulk density of the agglomerated black coffee husks briquettes should be attributed to the fact that a large part of the briquettes had crumbled.

Table 8: Bulk density of the briquettes

	Conditioning at 23 °C, 50% relative humidity				Conditioning at 20 °C and 90% r.h.	
	bulk density (kg/m^3)	standard error	test volume (10^{-3} m^3)	moisture content (%)*	bulk density (kg/m^3)	moisture content (%)*
Corn stover	510	30	3.9;12.3; 9.9	3.8	460	9.4
Cotton stalks	530	10	3.9;10.1; 9.7	3.9	440	10.8
Wheat straw	500	10	14.0;14.9;12.1	5.0	-	-
White coffee parchment	600	10	3.9;11.7;11.1	3.4	600	8.6
Black coffee husks (aggl.)	680	20	20.0;12.1;14.4	7.8	-	-

* % on a wet-matter basis.

6. STORAGE IN A HUMID ATMOSPHERE

Table 9 shows the increase in the moisture content of the corn-, cotton- and white coffee briquettes during storage in a climatic room at 20 °C and 90% relative humidity. After 16 days the corn stover briquettes started to swell, the cotton stalks and white coffee parchment briquettes did not then show any signs of alteration yet. The corn- and cotton briquettes had reached a stable condition at the time, whereas the white coffee parchment briquettes may not have been stable yet. The transport simulation tests were carried out with these three materials in this particular condition.

Table 9: The moisture content as a function of time

	moisture content (% on a wet basis)			
	t = 0 days	t = 4 days	t = 9 days	t = 16 days
corn stover	1.9	4.3	9.6	9.4
cotton stalks	2.5	4.5	10.5	10.8
white coffee parchment	1.9	4.9	6.8	8.6

The agglomerated black coffee husks briquettes were put into the climatic room at 20 °C and 90% relative humidity with an initial moisture content of 9.9% (on a wet-matter basis). The briquettes appeared to have completely disintegrated after having remained in the climatic room for 7 days.

Because of the limited quantity of material available, the wheat straw briquettes have not been submitted to conditioning at 20 °C and 90% relative humidity in order to save enough material to do a transport simulation test. Although the quality of the wheat straw briquettes is slightly better than the quality of the agglomerated black coffee husks briquettes, it was still expected that they would not survive the conditioning.

The condition of 20 °C and 90% relative humidity may be considered to constitute a "worst case" of the conditions occurring in Ethiopia.

This is illustrated by table 10, in which the average humidity per month is given, measured daily at 07.00 hours in Addis Abeba and Gimma. This is the time of day when the relative humidity is generally at it's maximum. The choice of the 20 °C, 90% r.h. level was related to the levels of conditioning applied prior to the transport simulation tests (see section 7).

Table 10: Relative humidity in Addis Abeba and Gimma

month	relative humidity (%)		month	relative humidity (%)	
	Addis Abeba	Gimma [1)]		Addis Abeba	Gimma
Jan.	61	53	July	64	77
Feb.	58	61	Aug.	65	79
Mar.	63	63	Sept.	76	78
Apr.	86	66	Oct.	86	67
May	79	74	Nov.	56	53
Jun.	59	78	Dec.	62	52

1) The data of Gimma are averages over 2 years; of Addis Abeba over 12 years.
source: KNMI, de Bilt, the Netherlands.

The following conclusion may be drawn:
The corn stover-, cotton stalks- and white coffee parchment briquettes withstood storage at 20 °C and 90% relative humidity for 16 days, showing only minor signs of deterioration or none at all. In this context the corn stover briquettes appear to be slightly more sensitive to moisture than the cotton stalks and white coffee parchment briquettes.
The agglomerated black coffee husks briquettes have a poor resistance to moisture, and this same conclusion is expected to hold for the wheat straw briquettes while these are only of slightly better quality than the agglomerated black coffee husks briquettes.
The salient difference between the results with the conical screw press briquettes - the former three - and piston press briquettes - the latter two - should not be generalized. It is beyond discussion that the agglomerated black coffee husks briquettes and wheat straw briquettes are not the best quality briquettes that may be produced by a piston press. The bad results may thus have little significance to the production method.

7. TRANSPORT SIMULATION TESTS

The transport simulation tests were carried out by the Institute TNO of Packaging Research, Delft, the Netherlands. Prior to exposing briquettes to mechanical treatments that simulate real-life transport and handling, the briquettes have to be conditioned. Based on the International Standard ISO 2233, part 2, "Conditioning for testing of complete, filled transport packages", two levels of conditioning were selected from the list of standard levels, namely 20 °C, 90% relative humidity (r.h.) and 23 °C, 50% r.h. These levels are commonly applied for conditioning prior to simulation of transport under tropical and subtropical conditions. Unfortunately the quantity of briquettes produced was too small to do tests at both levels of conditioning. Because it was expected that a "worst-case" experiment would give the most useful information it was decided to condition the briquettes at 20 °C and 90% r.h. before exposing them to the mechanical treatments.

The quantities of briquettes that were delivered to the Institute TNO of Packaging materials were the following:

- corn stover	80 kg
- cotton stalks	15 kg
- wheat straw	50 kg
- white coffee parchment	32 kg
- agglomerated black coffee husks	40 kg

The briquettes were tested in thin gunny bags of 50 x 100 cm and 305 gr. of gunny/m^2 quality.
The bags were filled with 40 kg of briquettes. Some spruce briquettes, produced by a conical screw press, and with a diameter of 30 mm, were added to the quantities of cotton stalks briquettes and white coffee parchment briquettes in order to attain the 40-kg filling mark of the bag. The bags were sealed by means of a joggle.

The three screw-made materials, i.e. the corn-, cotton- and white coffee briquettes were conditioned for 16 days at 20 °C and 90% relative humidity. It was attempted to submit the agglomerated black coffee husks briquettes also to the above-mentioned treatment, but after 7 days the briquettes had completely disintegrated. Meanwhile, 20 kg of agglomerated black coffee husks briquettes had been set apart and were submitted to a reduced set of mechanical tests after having been conditioned at 23 °C and 50% relative humidity with an additional filling of unconditioned spruce briquettes up to 40 kg. Finally, the wheat straw briquettes were also submitted to a reduced set of mechanical tests in order to gain a better insight into the friability of the piston-made briquettes. The wheat straw briquettes were tested without prior conditioning. The moisture content of the briquettes at the moment of testing is set out in table 11.

The mechanical treatments to which the briquettes were submitted comprised the following tests:

1. rotating-drum test:
   - drum diameter : 4.20 m
   - number of rotations : 4 (i.e. 24 falls)
2. free-fall test:
   - falling height : 1.20 m
   - number of falls : 5

     1st: perpendicular, on the bottom of the bag.
     2nd: flat, on a lateral face of the bag.
     3nd: perpendicular, on the filling side of the bag.
     4th: at an angle of 45 degrees on the filling side of the bag.
     5th: perpendicular, on the bottom of the bag, but on a log of 10 x 10 cm.
3. vibration test:
   - position of the bag on the vibration table: vertical
   - direction of the vibrations : vertical
   - duration of the vibrations : 30 min.
   - intensity of the vibrations : about 5 Hz and 1 G, i.e. so that the bag gets only just lifted off the table.
   - load of the bag : corresponding with a truck load of 2.2-m height, by means of an intermediate layer of spruce briquettes filled up with bags of sand or steel sheet (120 kg in all).

The mechanical tests no. 1 and 2 represent a standard programme for simulating various ways of transporting general cargo all over the world, handling by hand included. The mechanical test no. 3 adds the effects of a truck load and the prevailing bad conditions of roads in developing countries to the above.

As has been mentioned before the agglomerated black coffee husks briquettes and wheat straw briquettes were only submitted to a reduced set of tests. The agglomerated black coffee husks briquettes had been pulverized for 95% after test no. 1. Consequently, there was no need for the other tests to be carried out anymore. The wheat straw briquettes were only exposed to tests no. 1 and 2, essentially for the same reason. The effects of the mechanical treatments on the briquettes are presented in table 11.

Table 11: Results of the transport simulation tests

	moisture content (%) 1)	exposed to tests nrs.	pulver (%) 2)	fragments up to 3 cm length (%) 2)	fragments above 3 cm length (%) 2)
corn stover	9.4	1,2,3	13	35	52
cotton stalks	10.8	1,2,3	20	30	50
white coffee parchment	8.6	1,2,3	20	39	41
black coffee husks (aggl.)	7.8 5)	1	95	5 3)	-
wheat straw	3.3 6)	1,2	50	50 4)	-

1) % on a wet-matter basis.

2) % by mass relative to the initial mass of briquettes.

3) all fragments that could be distinguished from pulver.

4) all fragments above 1-cm length.

5) after conditioning at 23 °C, 50% r.h.

6) without prior conditioning.

From table 11 it is clear that the resistance to mechanical shocks due to handling and transport of the three screw-made briquettes from corn stover, cotton stalks and white coffee parchment is remarkably better than the resistance of the two piston-made briquettes from wheat straw and agglomerated black coffee husks. Though former experiences with screw-made and piston-made briquettes of the same material indicate this same tendency from the present data no general conclusions may be drawn about the difference between screw-made and piston-made briquettes. Firstly because no briquettes of the same material produced by either method were available. Secondly because the quality of the wheat straw and agglomerated black coffe husks briquettes was not optimal - as was mentioned before.

With respect to the particular briquettes tested the following conclusions may be drawn:

- After their storage in a humid atmosphere (90% r.h), followed by handling and transport, between 40 and 80% of the corn-, cotton- and white coffee briquettes may still be usable as fuel for domestic purposes. It can be expected that the output will be even better under more favourable atmospheric conditions.
- From the materials that were tested, the corn stover briquettes appear to have the best resistance to mechanical shocks.
- These particular agglomerated black coffee husks briquettes, which were already of poor quality even before they were exposed to any mechanical test, must be considered absolutely unsuitable to serve as fuel for domestic purposes, because any mechanical load reduces the briquettes to pulver.
- After handling by hand and transport under conditions as found in the western hemisphere in a relatively dry atmosphere have taken place, less than 50% of these particular wheat straw briquettes may be considered usable as fuel for domestic purposes.

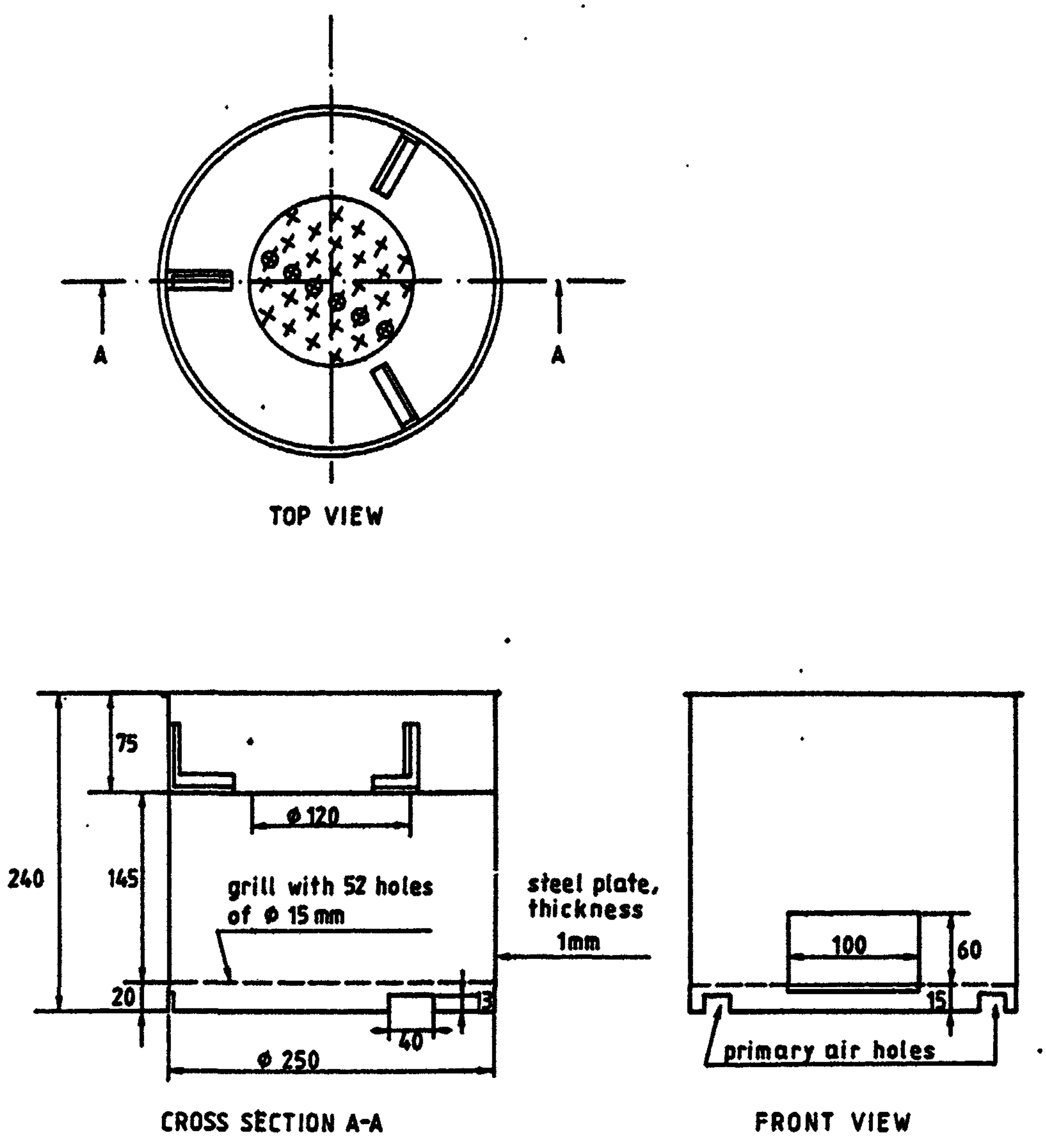
8. COMBUSTION TESTS

8.1 Test procedure and equipment

The combustion tests were performed in a domestic cooking stove, designed and manufactured by the Woodburning Stove Group, Eindhoven, the Netherlands. It concerns a cylindrical one-hole metal stove with grate and without chimney, see fig. 2. A diafragm forces the flue gases to flow initially to the middle of the pot bottom and then through a one-cm wide gap along the pot bottom and -sides. A flat bottomed aluminium pot with a 22.8-cm inner diameter was used. When filled to about 3/4 of its height, the pot contained about 3 kg of water. During the tests the pot was covered by a lid.

The test procedure applied to investigate the combustion of the briquettes constitutes the water boiling test. A known quantity of water is brought to boiling point and is kept boiling for at least 30 minutes. The energy absorbed by the water may be calculated from the quantity of water that has evaporated and the temperature rise of the initial quantity of water. The energy that was supplied by the fire may be calculated from the measured quantity of fuel burnt during the test and its calorific value (corrected for the moisture content of the fuel).
The ratio of absorbed and supplied energy makes out the cooking efficiency. The accuracy of the efficiencies is found to be in the order of 10%, due to the spread that usually occurs in cases of these particular types of experiments.

With each material a high power water boiling test and a low power water boiling test was carried out. Because a solid fuel combustion process is essentially a non-stationary process with a fluctuating power output level, the fuel loading procedure which was different for the high power- and the low power tests requires some explanation.



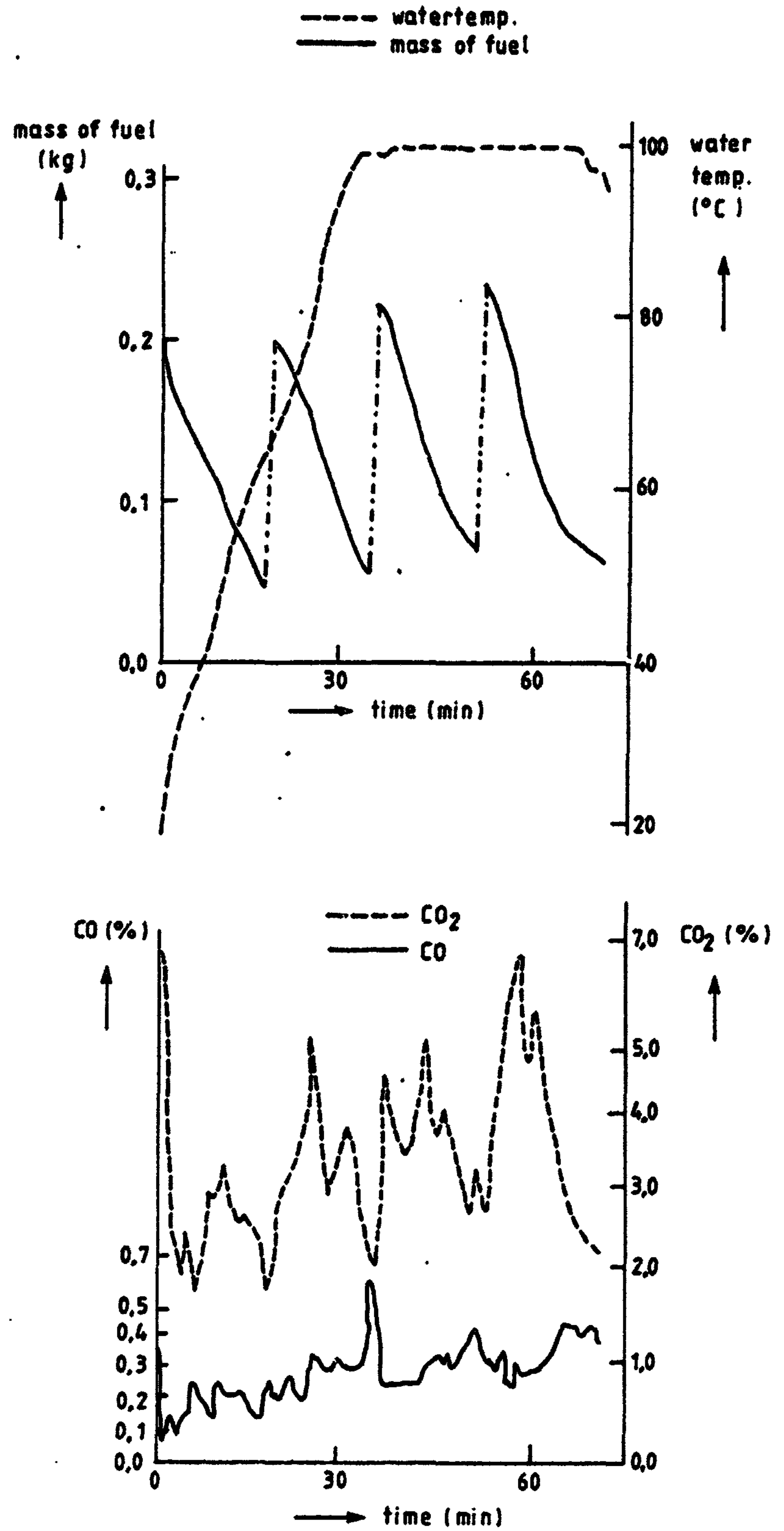
scale 1:5 (dimensions in mm)

Dimensions of the stove	MT-TNO 13801 Fig. 2

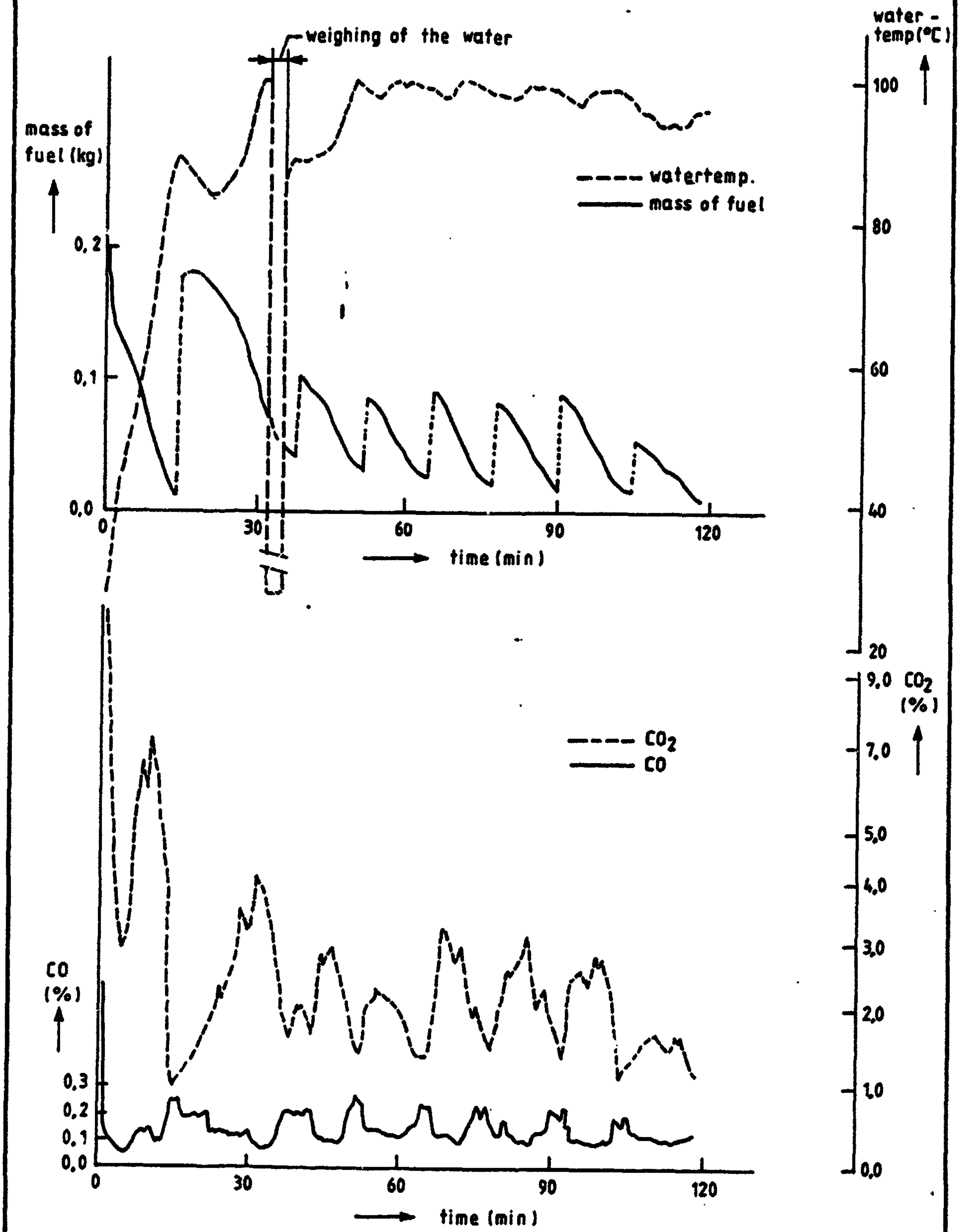
The high power tests were performed according to the batchwise fuel loading procedure generally applied by the Woodburning Stove Group [3]. This means that equal charges of fuel are loaded at equal intervals of time. The power output is then considered to be the ratio of the energy content of one charge of fuel and the time between the addition of two charges (see section 8.2). Fig. 3 illustrates this batchwise procedure; it shows the reduction in the fuel mass as a function of time for a high power test with wheat straw. Notice that the course taken by the gas concentrations also clearly reflects the batchwise fuel loading procedure.
The high power tests were carried out in such a way that there was hardly any build-up of the fuel bed.

The low power tests were carried out according to a procedure resembling the procedure described by the provisional International Standards for the testing of cooking stoves [4]. The experiment is initiated in the same way as the high power tests. At the moment when the water reaches boiling point it is weighed and put back on the stove. It is then kept boiling for about one hour, using as little fuel as possible. The fuel is freely added at moments judged opportune by the experimenter. However, it appeared that fragments of briquettes had to be added regularly (almost batchwise) in order to prevent the water-temperature from dropping below 97 °C. This is very well illustrated by fig. 4, which presents the reduction in mass as a function of time for a low power experiment with white coffee parchment. The average power output during the simmering period is calculated from the overall efficiency, the total quantity of fuel burnt during the test, the calculated energy that was necessary to bring the water to boiling point and the measured boiling time (see section 8.2).

The main difference between the procedure described above and the procedure described by the provisional standards is that the low power phase is started directly after the moment when the water reaches boiling point and the water - instead of the fuel - is weighed at the end of the high power phase. Apart from the fact that this procedure is far more convenient to the experimenter, the problem of distinquishing between initial fuel and charcoal is also avoided in this way.



Reduction of the mass of fuel and the CO and CO_2 concentrations as a function of time for a high power experiment with wheat straw	MT—TNO 13801 Fig. 3



Reduction of the mass of fuel and the CO and CO_2 concentrations as a function of time for a low power experiment with white coffee parchment	MT–TNO 13801 Fig. 4

During all experiments a gas analysis was made by means of the gas sampling system shown in fig. 5. A gas sample is sucked at various points along the gap between pot side and stove wall. Before entering the analysers the flue gas sample passes a condensation pot, a particle filter and two cooling elements. The levels of carbon monoxide and carbon dioxide are therefore measured on a dry flue gas basis. The levels presented in the report are average concentrations over the duration of the test. The combustion quality may conveniently be expressed by the ratib of the CO- and CO_2-concentration, because this value is independent of the measure of dilution of the flue gas samples. In order to make a fair comparison between the various fuels the quantity of carbon monoxide produced per useful quantity of heat was also calculated (see section 8.2).

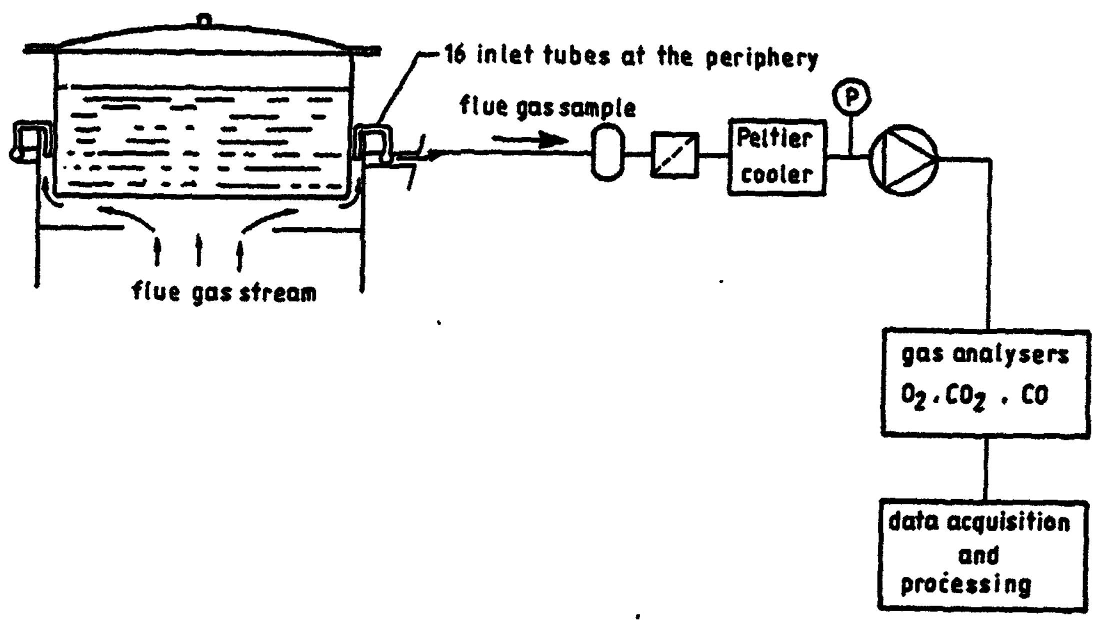
The ease of ignition, smoke production, odour and cohesion of the briquettes during the combustion process were not determined quantitatively, but a sensory judgement was passed on the basis of comparison with results from similar tests with Eucalyptus Globulus. The Eucalyptus was burnt in fragments of 2.4 x 2.8 x 10 cm.

8.2 Some definitions

The cooking efficiency is defined as the ratio of the energy absorbed by the water (or food) and the energy supplied by the fuel:

$$\eta = \frac{m_w\, C(T_b - T_i) + m_e\, L}{m_f\, H} \cdot 100\% \qquad (8.2.1)$$

η	= cooking efficiency	[%]
m_w	= initial mass of water	[kg]
m_e	= mass of evaporated water	[kg]
m_f	= total mass of consumed fuel	[kg]
C	= specific heat of water	[kJ/kgK]
T_b	= boiling temperature of water	[°C]
T_i	= initial water temperature	[°C]
L	= evaporation heat of water at 100 °C and 10^5 Pa	[kJ/kg]
H	= net calorific value of the fuel	[kJ/kg]



Experimental set-up of the gas analysis system	MT—TNO 13801 Fig. 5

The following numerical values are used:

$C = 4.19$ kJ/kgK

$L = 2256.9$ kJ/kg

The average power output of the fire over a certain period is the amount of heat released by the fire per unit of time.

$$P = \frac{m_f \cdot H}{t} \qquad (8.2.2)$$

P	= power output	[kW]
m_f	= total mass of fuel consumed during period t	[kg]
H	= net calorific value of the fuel.	[kJ/kg]
t	= period of time	[s]

In case a batchwise fuel loading procedure is applied the power output may be defined as:

$$P = \frac{\Delta m_f \cdot H}{\Delta t} \qquad (8.2.3)$$

Δm_f	= mass of a charge of fuel	[kg]
Δt	= interval between the addition of successive charges of fuel	[s]

The calculation procedure applied to determine the average power output during the simmering period of the low power tests reads as follows:

$$P_s = \frac{(m_{f_t} \cdot H - E_b/\eta_t)}{(t_t - t_b)} \qquad (8.2.4)$$

P_s	= power output during the simmering period	[kW]
m_{f_t}	= total mass of fuel burnt during the test	[kg]
η_t	= efficiency over the whole test	[%/100]
t_t	= duration of the whole test	[s]
t_b	= time required to bring the water to boiling point	[s]
E_b	= energy required to bring the water to boiling point in the case of 100% efficiency	[kJ]

E_b is calculated from:

$$E_b = m_w \cdot C\,(T_b - T_i) + m_e\,(100\ ^\circ C)\,L \qquad (8.2.5)$$

m_w = initial mass of water

m_e (100 °C) = mass of water evaporated at the moment when the water starts to boil.

In this calculation it is assumed that the overall efficiency η_t is valid for the period before the water starts to boil as well as the simme-ing period.

<u>The carbon monoxide production per useful quantity of heat</u> for a certain fuel/stove combination may be derived from:

$$p_{CO_h} = \frac{p_{CO_m}}{H \cdot \eta} \qquad (8.2.6)$$

p_{CO_h} = CO production per useful quantity of heat [kg/useful MJ]

in which:

$$p_{CO_m} = \frac{C}{12} \cdot \frac{CO}{CO_2 + CO} \cdot 28 \qquad (8.2.7)$$

p_{CO_m} = CO production per kg of fuel [kg/kg of fuel]

C = mass fraction of carbon [%/100]

CO, CO_2 = average gas concentrations [%]

In this calculation it is assumed that the quantity of hydrocarbons, formed during combustion, is negligible. Cases in point bear out the theory.

8.3 Results and discussion

The net calorific values of the briquettes, corrected for the prevailing moisture contents during the combustion tests, are given in table 12.

Table 12: Corrected calorific value of the briquettes and Eucalyptus

	calorific value (MJ/kg)
Corn stover	18.30
Cotton stalks	17.36
Wheat straw	16.46
White coffee parchment	18.93
Black coffee husks (aggl.)	15.63
Eucalyptus G.	18.25

The results of the high power tests are set out in table 13. The agglomerated black coffee husks generate a significantly lower efficiency than is obtained from the other fuels. Ignition proved very difficult and it was also hard to keep the fire going. The flames disappeared very quickly compared to the other fuels. The briquettes also disintegrated during the combustion process, so that small fragments of unburnt fuel fell through the grate, in this way causing a loss of fuel on the one hand and blocking the air flow through the grate on the other hand. Notice that the agglomerated black coffee husks had the highest ashcontent and the lowest volatile content.

The other fuels do not differ a great deal. The white coffee parchment briquettes and Eucalyptus give slightly higher efficiencies and power output levels than the corn- and cotton briquettes, which in their turn contained slightly more ash than the other two. The wheat straw has a lower power output than the other fuels, except for the agglomerated black coffee husks briquettes. This phenomenon cannot be accounted for by a significantly higher ash content of the wheat straw; however, it should be noticed that the wheat straw briquettes had a diameter of 50 mm set against a 30-mm diameter of the corn-, cotton- and white parchment briquettes.

Apart from the agglomerated black coffee husks briquettes none of the fuels disintegrated during combustion. They neither smoked excessively nor significantly less than wood. No extraordinary odour was noticed. Because of their volatile content the briquettes burn like wood rather than charcoal. The volatiles initiate the first combustion phase which involves yellowish flames.

Table 13: Results of the high power water boiling tests

symbols:

- n - number of charges
- m_f - total mass of fuel (kg)
- m_i - initial water quantity (kg)
- T_i - initial water temperature (°C)
- m_e - mass of evaporated water (kg)
- t_t - duration of the test (min)
- t_b - boiling time (min)
- P - power output level (kW)
- η - cooking efficiency (%)

	n	m_f (kg)	m_i (kg)	T_i (°C)	m_e (kg)	t_t (min)	t_b (min)	P (kW)	η (%)
Corn stover	4	0.8081	2.946	27.1	1.559	67	8	3.7	29.9
Cotton stalks	4	0.8013	2.946	25.6	1.344	56	11	4.1	28.4
Wheat straw	4	0.6861	2.947	17.2	1.043	66	31	2.8	29.9
White coffee parchment	4	0.8055	2.946	25.6	1.733	52	8	4.9	31.7
Black coffee husks (aggl.)	4	0.6640	2.946	18.4	0.369	67	(T_e = 88 °C)	2.6	16.3
Eucalyptus	2	0.4750	2.800	20.0	0.860	32	10	4.5	33.2

Table 14 presents the results of the low power water boiling tests. The best results were obtained with corn stover, wheat straw and white coffee parchment. In the case of the cotton stalks briquettes a very low power output was obtained. However, compared to the high power test the efficiency was quite low. From the gas analysis results it appears that a great deal of carbon monoxide is produced per useful quantity of heat, see table 15. This constitutes a poor combustion quality indicating that the power output has been too low. In the case of a somewhat higher power output the cotton briquettes may be expected to behave similarly to the corn-, wheat- and white coffee briquettes. The white coffee parchment briquettes perform best; their ratio of high and low power output level is 3.5, which is considerable for the rather small stove used. The agglomerated black coffee husks briquettes and the Eucalyptus are difficult to burn at a low power level, however for quite different reasons. Ignition of the agglomerated black coffee husks briquettes is poor, as has already been noticed. Eucalyptus however burns fiercely so that a lower burning rate could not be obtained.

The gas analysis results are set out in table 15.
It is obvious that the combustion quality of the agglomerated black coffee husks briquettes is poor, especially during the high power test. The carbon monoxide production per useful quantity of heat is for all other fuels higher at a low power level than at a high power level. The white coffee parchment has the best combustion quality in terms of carbon monoxide production, an even better quality than Eucalyptus supplies. The corn stover and cotton stalks briquettes, and the Eucalyptus do not differ significantly at a high power level, but only the corn stover briquettes maintain a low CO-production at a low power level too.

The moisture content of the Eucalyptus used was 6.8%, which may be lower that the moisture content of the Eucalyptus prevailing in Ethiopia. If Eucalyptus of a higher moisture content would have been used the conclusions described in this section had not been significantly different. Experiments conducted in the framework of the Woodburning Stove Group programme [3], have shown that the efficiency does not change more than within the range of the spread, using wood with moisture contents up to 30%. The carbon monoxide production also

Table 14: Results of the low power water boiling tests

symbols

- m_{f_t} - total mass of fuel (kg)
- m_i - initial water quantity (kg)
- T_i - initial water temperature (°C)
- m_e (100 °C) - quantity of water evaporated when the water reaches boiling point (kg)
- m_e - quantity of water evaporated during the test (kg)
- t_t - total duration of the test (min)
- t_b - boiling time (min)
- P_s - power output during the simmering period (kW)
- η - total efficiency (%)

	m_{f_t} (kg)	m_i (kg)	T_i (°C)	m_e (100 °C) (kg)	m_e (kg)	t_t (min)	t_b (min)	P_s (kW)	η_t (%)
Corn stover	0.6845	2.946	25.7	0.166	1.028	98	20	1.6	25.8
Cotton stalks	0.9428	2.946	16.9	0.371	1.133	171	68	1.3	21.9
Wheat straw	0.7335	2.946	14.2	0.139	0.966	104	22	1.4	26.8
White coffee parchment	0.6898	2.946	20.0	0.240	1.125	117	29	1.4	27.0
Black coffee husks	1.0215	2.946	26.0	0.172	1.290	93	45	1.9*	23.9
Eucalyptus	0.9213	2.946	17.3	0.170	1.285	121	42	2.3	23.3

* the water temperature dropped below 97 °C several times

Table 15: Gas analysis data of the water boiling tests corresponding with the data presented in table 13 and 14

symbols CO_2 - average CO_2-concentration during the test (%)
CO - average CO -concentration during the test (%)

	High power tests				Low power tests			
	CO_2 (%)	CO (%)	CO/CO_2	*gr. CO/ useful MJ	CO_2 (%)	CO (%)	CO/CO_2	*gr. CO/ useful MJ
Corn stover	5.9	0.4	0.07	13	3.0	0.2	0.06	14
Cotton stalks	4.6	0.3	0.06	12	1.8	0.2	0.13	32
Wheat straw	3.2	0.3	0.08	17	2.6	0.3	0.10	22
White coffee parchment	5.6	0.2	0.03	6	2.3	0.1	0.06	12
Black coffee husks	2.4	0.3	0.13	51	3.1	0.3	0.10	28
Eucalyptus	3.5	0.2	0.06	10	2.4	0.2	0.09	21

* for the calculation the corresponding efficiencies from table 13 and 14 were used.

does not differ significantly when wood with moisture contents up to 20% is burned, in the case of 30% m.c. it may be expected that sligthly more CO will be produced. As for the power output again minor changes were observed, except for the 30% m.c. case. The low power level of 2.3 kW obtained with the Eucalyptus of 6.8% m.c. can be expected to become somewhat lower if Eucalyptus of 30% m.c. would be used.

In summarizing the foregoing discussion the following conclusions concerning the combustion of the briquettes may be drawn:

- The white coffee parchment briquettes perform best: they allow for a high power ratio, a good efficiency, both at high power level and low power level and generate a considerably lower carbon monoxide production per useful quantity of heat then Eucalyptus.
- These particular agglomerated black coffee husks briquettes give poor results: ignition is poor, which causes quite an amount of smoke, the power may barely be varied, cooking efficiency is low and carbon monoxide production is high. Moreover, the briquettes disintegrate during the combustion process.
- The results reached with the corn stover briquettes, the cotton stalks briquettes and the wheat straw briquettes are comparable to those with Eucalyptus. At a high power level they perform slightly worse, and at a low power level slightly better. In the case of wheat straw it is more difficult to attain a high power level.
- The corn-, cotton-, wheat- and white coffee briquettes may serve as fuel for domestic use: the combustion results are comparable to, or sometimes even better than those reached with Eucalyptus, ignition is good, they do not smoke significantly more, or less than Eucalyptus and they keep their shape during the combustion process. Because of their volatile content the briquettes burn like wood rather than charcoal.

9. CONCLUSIONS AND RECOMMENDATIONS

The conclusions about distinct properties of the briquettes presented in the foregoing sections of this report may be put together in a few general conclusions. These should be viewed in the light of the specific constraints under which this research programme was carried out. It was attempted to compress all residues by a conical screw extruder. Good briquettes resulted from the corn stover, cotton stalks and white coffee parchment, but the compression of the wheat straw and non-agglomerated black coffee husks was unsuccessful. Therefore those materials were compressed by a hydraulic piston press. Because the preprocessing of the materials had taken place in accordance with the specifications imposed by the conical screw extruder the characteristics of the material fed into the hydraulic piston press were not optimal. Moreover, black coffee husks were produced only from the agglomerated species. The results obtained with the latter briquettes may not be valid for the non-agglomerated species of black coffee husks.

The conclusions are the following:

1. During the compression with the comical screw extruder the non-agglomerated black coffee husks and the wheat straw appeared to behave differently from the corn stover, cotton stalks and white coffee parchment. Too low a friction was generated in the case of the former two materials, whereas good quality briquettes, were produced from the latter three materials, at the same working conditions of the equipment. This cannot be explained from large differences in the lignin content of the materials.
2. The quality of the briquettes from the wheat straw and the agglomerated black coffee husks, which were produced by a hydraulic piston press, cannot be termed representative for the quality that is obtainable with this production method (on the basis of comparison with known compression results of e.g. wood wastes). Therefore the results with these briquettes do not apply to "piston-made" briquettes in general and the salient difference in the results with respect to shock- and moisture resistance of the "screw-made" and "piston-made" briquettes may not be generalized.

3. The briquettes from corn stover, cotton stalks and white coffee parchment - i.e. the briquettes that were produced by the conical screw extruder - are most likely to be suitable to serve as fuel for domestic use. Their resistance to storage in a humid atmosphere, followed by mechanical treatments simulating handling and transport is quite good - up to 80% output. It may be expected that the output will be even better under more favourable atmospheric conditions. Their combustion performance is comparable to, or even better than the performance of Eucalyptus.

4. The suitability of the particular wheat straw briquettes tested, to serve as fuel for domestic use must be doubted. Although their combustion performance is quite good, their resistance to mechanical treatments, even in dry condition, is only very moderate (maximum output 50%).

5. The particular agglomerated black coffee husks briquettes that were produced during this project, are not suitable for use in domestic cooking because they are of a very poor quality in every respect. Their combustion performance is poor, low cooking efficiencies are obtained, their ignition qualities are poor and the briquettes disintegrate during combustion. The effects of storage in a humid atmosphere and of any mechanical treatment, even in dry condition, are disastrous.

6. The usefulness of the briquettes for other than domestic purposes will strongly depend on the process under consideration. Therefore no general conclusions may be drawn on this point.

In view of conclusion 2 it is recommended that the shock- and moisture resistance of similar materials produced by a conical screw extruder on the one hand and by a piston press on the other hand be examined more closely in order to provide a sounder basis for the choice of compression systems under various circumstances.

In view of conclusion 4 it is recommended that the compression potentials of the wheat straw be examined more closely.

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ANNEX 3

EXCERPTS FROM COMBUSTION CONSULTANT'S REPORT ON BRIQUETTES AS AN INDUSTRIAL FUEL FOR ETHIOPIA

CONSULTANT: Robert A. Chronowski

DATE: July, 1985

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<u>Assumptions and Constants Used for Financial Analysis</u>

- 1 US$ = 2.07 Birr

- Where fuelwood must be harvested, the harvesting cost is estimated as US$7.00 per tonne

- Fuelwood as used air-dried to 20-25% MCWB has a heat value of 14.3 MJ/kg

- Briquettes have an average as used heat value of 18.6 MJ/kg

- Fuel oil in Ethiopia has a heat value of 40.1 MJ/liter

- Ex-factory cost of briquettes US$/Tonne

Coffee (Addis Ababa)	- 31.22	(New Site)
Coffee (Dila)	- 37.04	
Cotton (Awash)	- 82.06	
Wheat (Diksis)	- 79.28	
Corn (Nekempte)	- 108.46	

- Combustion efficiency drop when substituting briquettes for fuel oil = -5 to -10%

- Combustion efficiency improvement when substituting briquettes for fuelwood = +5 to +10%

- 1 m^3 fresh cut green wood = 700 kg stacked for transport

- 1 m^3 air-dried fuel wood stacked = 500 kg at 25% mcwb

- All briquette transport costs vary according to road conditions but generally follow 0.22 Birr per tonne km on asphalt to 0.58 Birr per tonne km on poor gravel roads (based on 22 tonne trucks)

- Equivalent Cost: The term used in this report is simply the financial value of the fuel displaced divided by the tonnes of briquettes to be substituted

- Distances from briquette production sites to potential end use sites:

Production Site	Use Site	Distance (km)
Coffee (Addis)	Addis a/	
	Muger	100
	Ambo	120
	Nazareth	110
	Nura Era	150
	Awara Melka	220
	Dire Dawa	380
Coffee (Dila)	Addis Ababa	330
	Awasa	75
	Muger	430
Wheat (Dixis)	Addis Ababa	220
	Nazareth	90
	Muger	300
	Nura Era	130
	Awara Melka	200
	Dire Dawa	360
Cotton Residues (Awash)	Dire Dawa	130
	Awara Melka	100
	Nura Era	175
	Addis Ababa	270
	Muger	370
	Ambo	390
Corn (Nekempte)	Ambo	130
	Addis Ababa	260
	Muger	270

a/ Assume flat rate charge of 10.00 Birr per tonne for delivery within Addis Ababa metro area.

- All combustion calculations in this report are based on operations in the existing mode. Conservation initiatives which could easily save 20-30% or more are not considered when defining fuel requirements.

I. Summary of Findings

1.1 The potential users of briquette fuels were categorized as either Level 1 which would require no modifications to utilize the briquettes as fuel, and Level 2 which would require relatively simple modifications to accept the briquettes as fuel.

1.2 Main Conclusion: Because the existing fuelwood and charcoal shortages are causing significant procurement problems for industrial users of these fuels, there is sufficient demand for the briquettes in industrial applications to fully utilize the potential briquette output of the Energy I Pilot Projects. A total Level 1 demand of 21,000 tonnes of briquettes has been identified along with a Level 2 demand that ranges as high as 73,150 tonnes additional. The total potential demand identified thus far is therefore 94,150 tonnes.

1.3 There are definite least cost options for the briquettes that potentially will be produced. The prioritized list of potential consumers is given in Table 1.1. The intent of the list is to combine the users with least cost producers (including the transportation costs), to choose users who will reap the most financial returns, and to adequately cover the industry base such that after the Energy I Pilot Projects are completed, a rapid expansion of both production and industrial consumption of the fuels can proceed strictly on merit, with no further testing or demonstration required.

1.4 All of the industries identified as Level 1 candidates use grate or pile burning, and with the exception of the lime kilns, are best supplied with briquettes of at least 5 cm in diameter and up to 50 cm in length to simulate the dimensions of the fuelwood normally used. The lime kilns would best be served by say a 5 cm X 5 cm briquette to better simulate the charcoal normally employed.

1.5 The boiler modifications recommended to achieve a Level 2 status 1/ are based on retrofit with manually fed, solid fuel gasifier burners. The cement plants are more complex and require more extensive modifications. Several options exist for retrofitting the cement kilns and/or preheaters.

1.6 The Level 2 candidates presented in this report most likely do not represent the total potential market for the briquettes as not every industrial site could be identified and visited during the short mission. The market will make itself known as the briquette fuels become available and are successfully used. The "major" constraint to Level 2 conversions to briquette fuels is the electric boiler program which has made significant capital investments in hardware in such industrial applications as:

a. Pulp and Paper Plant
b. Brewery
c. Multiple Textile Plants
d. Tyre Plant
e. Hotels
f. Schools
g. Oil Mills

1/These would include ECAFCO, ETHARSO, St. George's Brewery, Addis Tyre Company, Akaki Textiles, Modjo Textiles, and Dire Dawa Textiles.

Table 1-1

Priority Sites for Industrial Use of Briquette Fuels

Industry	Fuel Displaced Type-Amount-Value ($)	Briquettes Substituted (tonnes/year)	Equivalent Cost Briquettes ($/tonne)	Delivered Price of Briquettes ($)	Cost of Modifications
National Alcohol Distillery	Fuelwood-5400m^3-193,801	2000	96.90	36.05-71.70	---
Two Private Brick Kilns	Fuelwood-8000m^3- 437,696 Fuel oil-288,000l- 74,435	3625	141.28	36.05-140.34	---
Awara Melka Tobacco Barns	Fuelwood-3440m^3 - 150,620 a/	1225	122.96	65.65-113.71	---
Ambo Lime Kilns	Fuel oil-561,000l-145,000	810	179.00	45.71-128.81	---
ETHARSO	Fuel oil-726,000l- 187,638 Fuelwood-1500m^3- 19,568	2180	95.05	36.05-71.70	100,000
United Oil and Soap Mill	Fuelwood-25,000m^3-N.A. Electricity-40 Gwh-1.2 million	7875 b/	115.03 based on electricity use	36.05-113.94	---
Dire Dawa	Fuel-1 millionl-258,460	2270	113.86	77.11-97.76	100,000

Total Briquette Demand for Priority Users: 19,985 tonnes/year

a/ As only 25% of the 3440m^3 can be obtained, the analysis underestimates the value of the fuelwood, as not being able to purchase causes direct and tangible losses.

b/ Not all of the 40 Gwh can be substituted for; full substitution would require 9900-10,000 tonnes.

1.7 There will be some resistance to additional capital investment to allow the use of briquette fuels regardless of the financial and economic implications. Using kWh charges of US$0.03 (LRMC) and US$0.06 (economic cost) results in the briquettes saving money at costs less than $115.03 and $230.06 per tonne respectively. If the new tariff for the industrial customers equals or exceeds the LRMC, there will be definite financial pressures to switch to less expensive fuels, hence briquettes.

1.8 It is also likely that additional Level 1 users will emerge who can utilize the briquettes with no modifications. One obvious class of use would be bakeries which are located in the major population centers and who could easily use briquettes in their wood-fired ovens. A bakery demonstration should be set up in Addis Ababa once the briquettes become available. The demonstration could be then publicized to motivate a demand from this sector that could approach 675 tonnes of briquettes per year in Addis Ababa. For an industrial program these smaller users should not be the project focus, but should be accounted for as potential demand as the briquette production is scheduled to expand following successful Energy I Pilot Project Demonstrations.

1.9 A visit to TNO in Apeldoorn, Holland to review the results of transportation and combustion tests confirmed that the physical and combustion characteristics of the briquettes are suitable for industrial applications. Relatively high net heating values were determined to range from 17.8 MJ/kg for cotton stalk briquettes to 19.3 MJ/kg for coffee parchment briquettes. Ash contents ranged from 0.33 to 3.45% with moisture contents between 5.36 and 5.88%.

II. Site Visits

2.1 Preliminary meetings were held with the appropriate ministries at the beginning of the mission and a priority list for plant visits was established from preliminary data available. The list prepared was as follows, and is graphically presented in Figure 2-1.

In and around Addis Ababa:

National Alcohol Distillery

Ethiopian Cement Corporation (Addis plant)

Ethiopian Hardwood and Softwood Board Plant (ETHARSO)

Ethiopian Chipwood and Furniture Plant (ECAFCO)

Ethiopian Plywood Plant

Edget Oil Mill

Two Private Brick Plants

Two Ethiopian Brick Plants (Government)

East of Addis Ababa:

Dire Dawa Cement Plant

Awara Melka Tobacco Barns

Awara Melka Fruit Canning Plant

Nura Era Tobacco Barns

West of Addis Ababa:

Muger Cement Plant

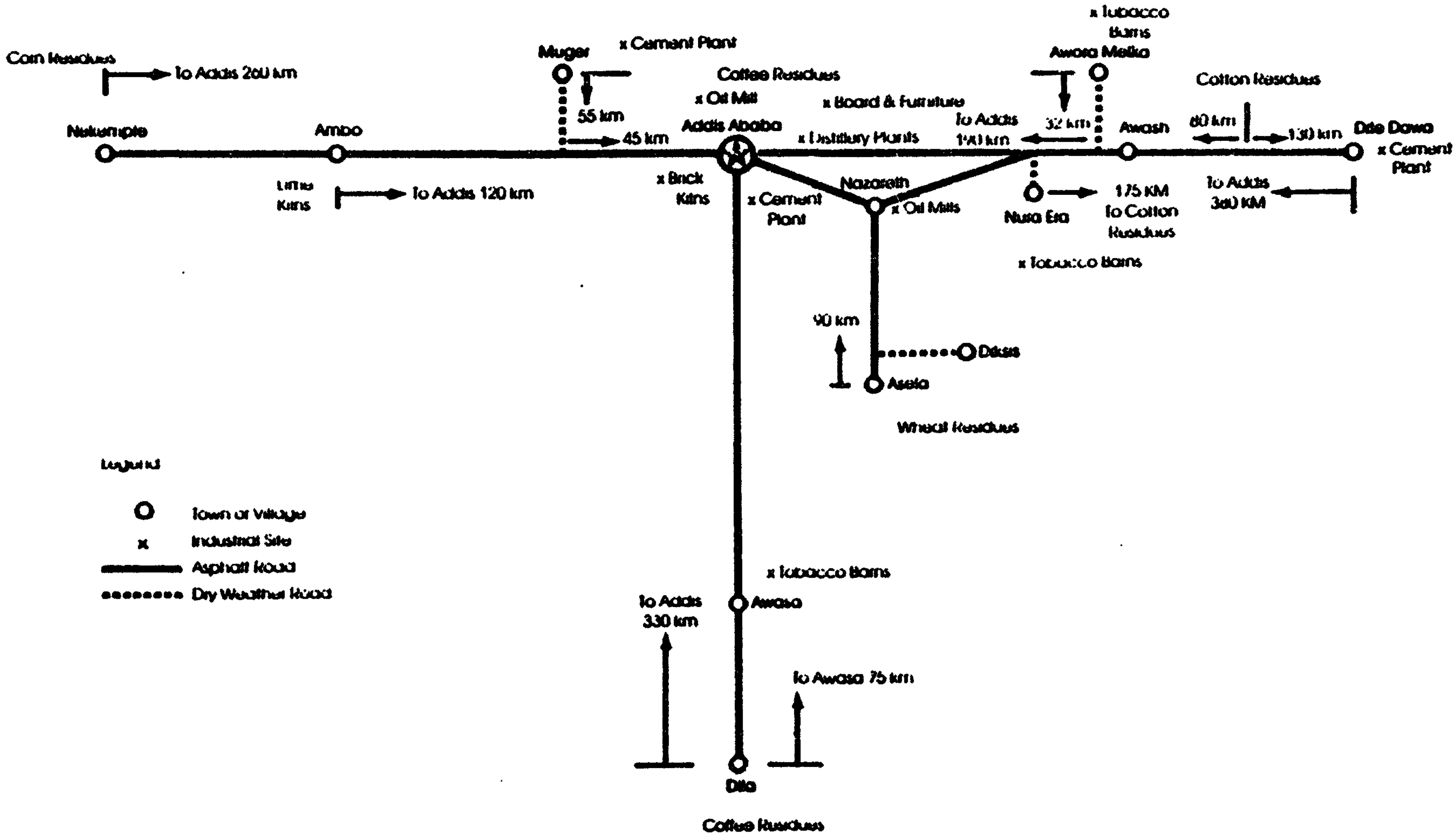
Ambo Lime Kilns

South of Addis Ababa:

Tobacco Curing Barns (Awasa)

2.2 As per the request of Matthew Mendis, made on a previous World Bank mission, the Ministry of Industry had prepared a list of the annual fuel consumption for those industries that currently utilize fuelwood. The above list of visits was prepared based on that available data. Upon visiting the respective plants, it was discovered that the fuelwood consumption data supplied to the Ministry by each plant was uniformly exaggerated by 20 to 100%. The explanation would appear to be that the obtaining of fuelwood is by means of a tedious and time-consuming permit process. Industrial users exaggerate consumption to either reduce the number of fuelwood procurements per year, or, more likely, to build up some amount of inventory during a time of unreliable supplies. The typical procurement process is as follows. The industrial user applies to the fuelwood authority for a certain amount of wood in m^3. The authority issues a permit for the industry to harvest a certain block of forest a specific distance from Addis Ababa ranging from 25 km to 600 km away, typically 200 to 300 km. Essentially a fee of 14 to 22 Birr is charged for the privilege of harvesting and the industry must then pay

ETHIOPIA
Potential Briquette Burning Industrial Sites



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for the wood to be cut, loaded, and transported to their plant. The cut fuelwood is transported at a density of about 700 kg per m^3 while air drying to a moisture content of 20-25% in the plant fuel storage area is a common practice before burning. As most do not have trucks, these must be rented, so that the whole process is cumbersome and expensive. The more fortunate smaller users are allowed to purchase already air-dried wood from government fuelwood depots in Addis Ababa, although this is not the norm for industry. All consumption data presented in this report is based on real consumption determined by examination of the hardware capacity, type of plant operations, number of historical operating days, and discussions with plant technical people.

2.3 The preliminary data suggested that sufficient industrial users could be found to directly substitute briquettes for fuelwood with little or no modifications, so a Level 1, Level 2 criteria was set up to characterize the potential users. Level 1 included those users whose wood-burning hardware can accept the briquettes directly with no modifications needed. These would be primarily manually fed systems that employed grate or pile wood-burning furnaces. Level 2 was envisioned as including automatic feed, wood burning systems (chip or powder feed systems) and heavy oil burning systems that could be retrofitted with gas producer/burners. Cement plants were included in as Level 2 candidates because of the large fuel oil substitution potential, the relatively simple oil burning mechanisms used to fire the kilns, and the success of burning supplemental fuels in cement kilns elsewhere in the world. (Details regarding the technical and economic feasibility of briquette use at specific industries visited by the consultant are presented in the Consultant's report which can be obtained from the Energy Department of the World Bank. Summary Tables have been excerpted for the purpose of this Annex).

2.4 The industrial market for agricultural briquette fuels for the Energy I Pilot Project and beyond can be clearly defined by aggregating the data in Tables 2-1 and 2-2. The annual briquette demand can be projected to be from 23,400 tonnes to 32,200 tonnes with 11,000 tonnes needed for Level I applications requiring no modification capital. The next section investigates supplemental industrial customers for the briquettes based on published material, although no visits were made to the sites.

Table 2-1
Level 1, No Modifications Needed

Industry	Location (From Addis)	Current Fuel (Type & amount m3/4-liters/year)	Current Fuel (Cost per year US$)	Briquette Substitution (Tonnes per year)	Cost of Briquettes (Annual cost US$)
National Alcohol Distillery	Addis Ababa	Fuelwood $5400m^3$	193,801	2000	72,100
Ethiopian Hardwood and Softwood Board Plant (ETHARSO)	Addis Ababa	Fuelwood $1500m^3$	19,560	535	19,287
Edget Oil Mill	Addis Ababa	Fuelwood $1380m^3$	49,527	660	23,793
Private Brick Kilns	Addis Ababa	Fuelwood $8000m^3$ + Fuel oil 288,000 liter-	437,696 TOTAL = 512,131 74,435	3625	130,681
Tobacco Barns (Awara Melka)	220 km east of Addis Ababa	Fuelwood a/ $3440m^3$	150,620	1225	119,719
Tobacco Barns (Nura Era)	150 km east of Addis Ababa	Fuelwood $1150m^3$	43,059	410	42,131
Lime Kilns	120 km west of Addis Ababa	Fuel oil 561,000 liters	145,000	810	100,570 from NeKempte
		Charcoal (525 tonnes est.)	78,262 b/		61,709 from Addis Ababa
Tobacco Barns (Awasa)	255 km south of Addis Ababa	Fuelwood $5000m^3$	141,190	1700 11,000	78,387

Total Level 1 Annual Demand: 11,000 tonnes per year

a/ $3440m^3$ is demand; actual supply is $860m^3$ so that leaves rot in field.
b/ Price of charcoal in bulk in Ambo reported by Lime Kiln Plant manager to be $149.07 per tonne. While this seems low, it is used for the analysis.

Table 2-2

Level 2, Modifications Required

Industry	Location (from Addis)	Cost of Modification (US$)	Fuel Oil Displaced (liters/year)	Fuel Oil Savings (US$ per year)	Briquette Substitution (tonnes/year)	Cost of Briquettes (US$ per year)
Cement Plant	Addis Ababa	A. 135,000	20% - 1.68 million	434,203	4000	144,200
		B. 1,000,000	50% - 4.2 million	1.08 million	10,000	538,800
Ethiopian Hardwood and Softwood Board Plant (ETHARSO	Addis Ababa	100,000	A. 726,000	187,638	1645	59,302
		100,000 (current rate of consumption)	B. 726,000 liters Fuel oil plus 750 tonnes fuelwood	187,638	2180	78,589
					207,206	
				19,568		
		100,000	C. 1.4 million	361,836	3170	114,279
Ethiopian Chipwood and Furniture Factory Plant (ECAFCO)	Addis Ababa	70,000	324,000	83,739	750	27,038
Cement Plant	Dire Dawa - 380 km east of Addis Ababa	100,000	20% - 1 million	258,460	2270	221,915
Cement Plant	Muger - 100 km NW of Addis Ababa	A. 250,000-400,000	20% - 6.5 million	1.68 million	15,000	1.28 million
		B. 250,000	10% - 3.25 million	840,000	7500	640,000
		C. 135,000	5% - 1.625 million	420,000	3750	320,000
					12,400 - 31,200	

Total Level 2 Annual Demand: 12,400-31,200 tonnes per year

III. Supplemental Industrial Users for Briquette Fuels

3.1 During the length of the mission, it was not possible to investigate each potential user in the appropriate geographical areas. In this section, two additional cases will be dealt with: i) the case of comparing operating costs for briquette fired boilers to electric boiler operating costs, and ii) the case of comparing operating costs for briquette fired boilers to fuel oil fired boilers.

3.2 For the electric boiler case, the assumption is made that all current and future electric boiler users will pay at least the marginal cost for electricity of US$0.03 per kwh for Ethiopia's hydro-based power supply. Assuming a 95% efficiency for electric boilers, a boiler rated at 5 million Btu/hr (6.33 million kJ/hr) output will require an electrical input of 1.85 mw or 1850 kw per hour. The hourly fuel cost for operating the electric boiler at capacity would be $55.50 or $1332 per day for a three-shift operation. For a 300-day working year, the annual charge would be a maximum of $399,600. Assuming a combined use factor of 50%, the annual power cost would be about $200,000. A briquette-fired boiler using briquettes with an 18.6 MJ per kg heat value and operating at 75% overall boiler efficiency would use 454 kg/hr of briquettes, or 11 tonnes per day. At maximum capacity this would be 3300 tonnes for 300 working days, or, at a 50% combined use factor, 1650 tonnes. Using the annual cost of the electricity, i.e. $399,600 minus an O and M differential of $20,000 (4 man years per year of labor + $14,000), and dividing by 3300 tonnes, an equivalent briquette cost of $115.03 is obtained. The obvious conclusion is that if the briquette cost is below $115.03 per tonne delivered, which it will be for almost all cases, the cost of operations will be less for briquettes. If the backup boiler to the electric boiler is already wood capable, this is the ideal case where no modification costs will be experienced and the backup role can revert to the electric boiler. If, however, the backup boiler is only fuel oil capable, then a modification cost must be incurred. Using the existing case, a modification could be completed at $70,000. Assuming briquettes were delivered to the plant for $100 per tonne, the simple payback would range from one to two years depending on the combined use factor of the boiler, assuming somewhere between 50% and 100%. At a delivered briquette cost of $80.00 per tonne, the payback falls to between six months and one year, a very attractive situation. This does not consider the economic value of the fuel oil and the resulting foreign exchange savings. In terms of new installations, electric boilers should not be considered, if briquette fuels are available below a delivered cost of $115.03 per tonne. Dual fuel capable (oil and briquettes) installations can be installed to be competitive with an electric boiler installation with fuel oil backup.

3.3 For the fuel oil boiler case, the cost of the fuel oil to the user is assumed as 0.535 Birr per liter or US$0.2585 per liter. Assuming an 82% boiler efficiency for a fuel-oil fired boiler, the boiler rated at six million Btu/hr output (6.33 million kJ/hr) will require a fuel oil input of 193 liters per hour of fuel oil with a heating value of 40.1 MJ/liter. The maximum fuel oil demand is therefore 4632 liters/day at a cost at $1197 per day or 1.39 million liters per year at a cost of $359,100. For a 50% combined use factor this would be 700,000 liters per year at a cost of $180,000. The equivalent briquette cost at rated capacity would therefore be \$105.79 per tonne assuming 18.6 mJ/kg, a 75% boiler efficiency, and an O and M differential of \$10,000 (2 man years labor per year plus \$7,000) a little less attractive than for the electric boiler case. For some cases, however, the delivered briquette cost will be below \$105.79 per tonne so that fuel savings will accrue and foreign exchange will be saved. If a modification to use briquettes is required, a delivered cost of \$80 per tonne of briquettes results in a 9-18 month simple payback, and if the delivered cost is \$70 per tonne, this drops to 6.5-13 months. The conclusion is that at the delivered costs projected by other World Bank staff and/or consultants, almost all industrial boiler operations found in Ethiopia are both technically and financially viable for consideration of using agricultural briquettes as fual sources.

3.4 Potential industrial users, not surveyed, where briquette firing might be advantageous are listed in Table 3.1.

Table 3-1

Supplemental Industrial Briquette User List

Level 1 Candidates

Industry	Current Fuel (type and annual amount)	Current Fuel (cost per year)	Briquette Required (tonnes per year)
United Oil and Soap Mill	Fuelwood, 21,000m^3 (Electric BLR)	N.A.	7875
Akaki Oil Mill	Fuelwood, 3300m^3 150 tonnes fuel oil (Electric BLR)	N.A.	1200
Nazrawi Kiba Novg Oil Mill	Fuelwood, 2400m^3	N.A.	860
Arsina Mirta Oil Mill	Fuelwood, 1200m^3	N.A.	430

Total Supplemental Annual Level 1 Briquette Demand: 10,365 tonnes per year

Level 2 Candidates

Industry	Annual Amount and Cost of Fuel Oil ($)	Modification Cost ($)	Annual Briquette Demand (tonnes)
St. Georges Brewery	1450 tonnes at 392,850	180,000	3500
Addis Tyre	3000 tonnes at 813,000	180,000	7250
Akaki Textiles	5000 tonnes at 1.25 million	270,000	12,000
Modjo Textiles	900 tonnes at 225,350	100,000	2200
Dire Dawa Textiles	7000 tonnes at 1.75 million	360,000	17,000

Total Supplemental Annual Level 2 Demand: 41,950 tonnes per year

IV. Prioritization of Industrial Applications - Least Cost Solutions

4.1 In order to determine the least cost solutions, both the need for modifications to burn the briquettes and the value of the fuel displaced must be considered. The financial value (cost to user) of the competing fuels is listed in Table 4-1 along with an equivalent delivered briquette cost.

4.2 It is most desirable to have the briquettes used against as many of the conventional fuels as possible during the Energy I Pilot Project. With successful demonstration of briquettes in multiple applications, a widespread implementation can occur without further testing as the briquette production potential is expanded. Table 4-2 presents the priority industrial applications to both take advantage of the best financial situations while obtaining maximum market type coverage.

Table 4-1

Competing Fuel Values

Fuel	Energy Value mJ/kg, mJ/liter, or mJ/kwh	Use Efficiency (%)	Equivalent Briquette Cost US$/tonne (18.6 mJ/kg at 75% off)
Fuelwood ($50/tonne)	14.3	65-70	68.46 - 72.26
Fuelwood ($75/tonne)	14.3	65-70	102.69 - 108.39
Fuelwood ($100/tonne)	14.3	65-70	136.92 - 144.52
Fuelwood ($125/tonne)	14.3	65-70	171.14 - 180.65
Charcoal ($150/tonne)	29.0	75	96.21
Charcoal ($180/tonne)	29.0	75	115.45
Charcoal ($200/tonne)	29.0	75	128.28
Charcoal ($250/tonne)	29.0	75	160.34
Fuel Oil (25.85/liter)	40.1	80	113.91 a/
Electricity (3 cts/kwh)	3.6 mJ/kwh	95	115.03
Electricity (6 cts/kwh)	3.5 mJ/kwh	95	230.06

a/ For the special case at the Ambo Lime Kilns that have a 50% reject rate using fuel oil and a 5-10% reject rate for charcoal (and briquettes assumed), the equivalent price for briquettes is $179.00 per tonne.

Table 4-2

Priority Sites for Industrial Use of Briquette Fuels

Industry	Fuel Displaced Type-Amount-Value ($)	Briquettes Substituted (tonnes/year)	Equivalent Cost Briquettes ($/tonne)	Delivered Price of Briquettes ($)	Cost of Modifications
National Alcohol Distillery	Fuelwood-5400m^3-193,801	2000	96.90	36.05-71.70	---
Two Private Brick Kilns	Fuelwood-8000m^3- 437,696 Fuel oil-288,000l- 74,435 512,131	3625	141.28	36.05-140.34	---
Awara Melka Tobacco Barns	Fuelwood-3440m^3-150,620 a/	1225	122.96	65.65-113.71	---
Ambo Lime Kilns	Fuel oil-561,000l-145,000	810	179.00	45.71-128.81	---
ETHARSO	Fuel oil-726,000l- 187,638 Fuelwood-1500m^3- 19,568 207,206	2180	95.05	36.05-71.70	100,000
United Oil and Soap Mill	Fuelwood-25,000m^3-N.A. Electricity-40 Gwh-1.2 million	7875 b/	115.03 based on electricity use	36.05-113.94	---
Dire Dawa	Fuel-1 millionl-258,460	2270	113.86	77.11-97.76	100,000

Total Briquette Demand for Priority Users: 19,985 tonnes/year

a/ As only 25% of the 3440m^3 can be obtained, the analysis underestimates the value of the fuelwood, as not being able to purchase causes direct and tangible losses.

b/ Not all of the 40 Gwh can be substituted for; full substitution would require 9900-10,000 tonnes.

4.3 Two Level 2 cases are included in the priority list. The ETHARSO modification is the easier of the two, with no costly pre-engineering required. All engineering will be routinely done by the retrofit burner supplier based on specifications and drawings of the boiler plus layout drawings of the boiler room. Other information required for control purposes would be average steam rates and the type and duration of boiler load swings caused by process needs. The cement plant modification is a little more complex and should be approached with a specialized cement industry consultant performing the pre-engineering design work and preparing the specification and bid documents to complete the modification. While a formal feasibility study is not required, an expert should be utilized to design the briquette storage, transfer, grinding and injection system plus interfacing of controls, if desirable. It is recommended that only the 20% potential modification be considered (although all hardware should be designed for 30, possibly 40%) which would pneumatically inject ground-up briquettes into the oil flame zone, and that this be done in the smallest plant, in Dire Dawa. Based on the operations at this plant, optimized designs could be prepared for the Addis Ababa and Muger plant, if desirable and briquette production allows.

Annex 4

SPECIFICATIONS FOR MAJOR EQUIPMENT

Contents

Equipment Specification

Plant:	for all (4) Screw and Piston Briquetting Plants
Flow Sheet:	dwg. no. 850506, 07, 08
Layout Plan:	dwg. no. 850510 and 11
Plot Plan:	dwg. no. 850512, 13, 14

Item no. 13, 15, 16 (correspond with item nos on flow sheets)

Unit:	Piston Briquettor
Qty:	4
Intended use:	to produce fuel briquettes with 75 mm diameter with a density of 1,0 - 1,2 kg/dm^3
Capacity:	500 - 700 kg/h depending on the type of raw material
Construction:	the plant consists of the briquettor with feed hopper comprising a vertical screw with variable speed drive, The housing is made of heavy mild steel plates in welded construction. The motion of the piston is made by means of a crank drive with flywheels, flat belt drive and electric motor on tensioning slide rails. The motor has 75 kW. A cooling water system to cool the lubrication oil and the briquettor housing must be supplied with the unit. 10 different dies must be included. An inclined cooling line 12 m long is attached to the die head, height of discharge point 3,5 m above floor level.

Equipment Specification

Plant: for all (4) Screw and Piston Briquetting Plants

Flow Sheet: dwg. no. 850506, 07, 08

Layout Plan: dwg. no. 850510 and 11

Plot Plan: dwg. no. 850512, 13, 14

Item no. 8, 10, 11 (correspond with item nos on flow sheets)

Unit: Screw Briquettor

Qty: 4

Intended use: to produce fuel briquettes with 28 mm diameter, with a density of 1,2 - 1,4 kg/dm^3

Capacity: 500 - 700 kg/h depending on the type of raw material, the capacity should not be less than 500 kg/h

Construction: the unit consists of the briquettor with feeding system comprising a small bin with level indicator to start and stop the discharge screw of the silo, with a vibrating chute between the bin and the briquettor inlet. With a reduction gear, an elastic coupling and a variable speed AC electric motor of 75 kW. With a briquettes cutting device and a cooling system for the lubrication oil and the briquettor housing. The briquettes fall into an outlet chute which is suitable to discharge onto a belt conveyor, the chute must be provided with a suction hood for the removal of the smoke.

The unit must be supplied with 10 die heads and 10 dies with various lengths

Equipment Specification

Plant: for all (4) Screw and Piston Briquetting Plants

Flow Sheet: dwg. no. 850506, 07, 08

Layout Plan: dwg. no. 850510 and 11

Plot Plan: dwg. no. 850512, 13, 14

Item no. 10, 12, 13, 15, 17, 18 (correspond with item nos on flow sheets)

Unit: Bagging Station

Qty: 8

Intended use: to hold bags in position suitable for filling with shovels and to weigh the filled bags

Capacity: each station must hold 2 bags in an upright position leaving full access to the opening of the bag

Construction: the units must be mobile on wheels so they can be moved along the cooling heaps. A suitable clamping device must hold the bag during filling. The exchange of bags must be easy. A weighing device must be incorporated in the station.

Equipment Specification

Continuation General Requirements

Electric Motors

All electric motors must be according to the IEC standard. They must be the squirral cage type T.E.F.C. (totally enclosed fan cooled). Degree of protection IP 54 according to IEC. Insulation class B according to VDE 0530 (German electric standards). They must be suitable for continuous operation (around the clock).
All gear motors to be from SEW. No drum type motors are desired for belt conveyors.

Motor Controls

All motor controls must be supplied with the equipment. Motor starters, fuses, push buttons, indicating lamps and relais with spare I/O's to incorporate some logic interlocks from other plant components must be supplied in a panel. Starters for motors with more than 10 kW power rating must be of the star-delta type.
Push buttons will generally be installed at sight distance from the corresponding equipment. However the motor controls of some equipment will be incorporated in the L.V. switchboard. The motor control components will be standardized as much as possible during the detail planning to facilitate the spares requirement.

Guards

Belt drives and other rotating parts must be protected with guards according to DIN 31001 (German General Standards). Sight contact to the rotating parts should be allowed by using wire mesh surfaces.

Manuals

The suppliers must provide operating and maintenance manuals, spare part lists and drawings in English after receipt of the order.

Equipment Specification

List of Equipment which can only be specified at a later stage:

- Transformer and high voltage switch gear
- low voltage switch board (after knowing the exact power ratings of the installed motors)
- electric cables and cable trays (after completion of the final layout plan with the exact dimensions of the equipment which will be purchased)
- general supporting structures, ladders, walkways and platforms for operation and maintenance for the plant.

Item no.: 21

Unit: **Workshop and storage equipment for maintenance of collecting equipment and plant for coffee residue briquetting**

1 set of each section

Qty.	Description
	Section 1:
1	Bench drilling machine
3	Electric portable hand drills
1	Double ended grinding machine
1	Portable grinding machine with accessories.
1	Thread cutting tools
1	Stud removers
1	Measuring tools
3	Vices
1	Kerosine blow lamp
	Section 2:
1	Arc welding machine
1	Oxy-acetyline welding & cutting equipment
1	Tin smith tools
1	Manual shear bench
1	Manual bending machine
1	Long leg vice
	Section 3:
1	Hydraulic floor crane
1	Hydraulic jacks

Qty.	Description
1	Engineering measuring instruments
1	Expanding reamers
1	Pullers
2	Maintenance tools in locked boxes
1	Socket wrenches set in locked boxes
	Section 4:
1	Electrician tools and equipment
	Section 6:
1	Storage racks with drawers etc.

Specifications of Agricultural Machinery for Cotton Stalk Collection

Item : 6

Unit : 2 wheeldrive Tractor

Qty. : 7 units

Type : The tractor shall be agricultural rear wheel drive. A test report from a recognized testing centre, preferably in accordance with the O.E.C.D. or Nebraska standard code will be submitted with the tender.

Engine : Engine shall be of the diesel type-4-stroke cycle- developing about 40 - 45 KW (55-60 HP), at rated speed of about 2000 RPM
Cylinders in line with replaceable sleeves.
Direct fuel injection. Engine to be suitable for ambient temperatures of up to 45 degrees "C" and dusty conditions.
The air cleaner of a heavy duty oil-bath type with precleaner. Engine to be equipped with a heavy duty water cooling system, large tropical radiator, centrifugal pump and large fan.
The lubrication system must be forced feed, equipped with gear type pump and oil strainer in sump. The fuel filters to be of dual stage system with replaceable elements.

Electrical System:

To be 12 V, precharged battery of about 85 AH, starter motor and alternator. An ample lighting system has to include 2 headlights, sidelights, tail and plough lights. Standard instrument panel equipped with hour meter, engine speed, temperature, oil pressure, fuel meter, light indicators, etc.

Transmission:

Dry type dual clutch with a largest possible diameter however not less than 11 inches. Multipower or powershift transmission with 12-16 forward and 4-8 reverse speed.

Hydraulics:

Three-point linkage cat. II with adjustable lift arms live draught and position control. Minimum lift capacity 1,800 kg. at the end linkage, swinging drawbar.

Track & Wheels:

Wheeltracks must be adjustable between 1.60 and 1.80 mtrs.
Tractors to be equipped with regular agricultural tyres of natural rubber and innertubes. The following approx. tyre sizes are required.

Front : 6.50 x 16 - 6 PR

Rear : 12.4 x 28 - 8 PR

Brakes: Foot operated differential lock with automatic disengagement device. Multiple plate oil cooled brakes and parking brake.

Power take off:

An independent PTO with 6 splines 35mm (1.38 inch) speed 540 rpm.

Steering: Power steering.

Miscellaneous:

Fully cushioned seat with height adjustment, overhead safety guard with sunshade.

Tools, special equipment and accessoires:

Set of tools, to be included with each machine, also fire extinguisher, grease gun, and hydraulic jack. Special tools, equipment and accessoires should be offered.

Others : Operators manual, parts catalogue, workshop manual for each unit in English to be received after ordering.
Pamphlets to be sent with the offer and country of origin has to be stated.

Spare parts:

A comprehensive list of fast and slow moving spare parts recommended for two years must accompany the tender.
Prices should be quoted separately for each item to a total not exceeding 20% of C & F value of units.

Item No : 7

Unit : Cotton stalk chopper

Quantity 5 units

Type : PTO driven mounted on small trailer

Capacity: 5 tons chopped material per hour

Description :

The unit will be used to chop cotton stalks with diameters of up to 0.04 mtrs. and length up to 1.70 mtrs.
The stalks will be cut manually and fed to the chopper by hand from a swath 3.60-5.40 mtrs. Moisture content of the stalks at time of chopping will not exceed 15% (MCWB) and stalk production will reach about 3800 Kgs:HA. The chopper will be connected to the wheeltractor of para. 1 and is driven via the P.T.O. shaft of that tractor.
The unit is provided with a drawbar hook to pull the forage trailer of para. 3 during chopping operations.

The chopper has to cut the stalks in chips having dimensions not exceeding 15x10x5 mm.
The capacity of the unit at maximum chip length should not be less than 2.5 tons/hr.

Execution :

The unit has to be provided with:

- Adjustable number of wear resistant knives, up to 12 pcs. to adjust chip dimensions.
- Blower of sufficient capacity to blow the chopped material into the forage trailer.
- Blower discharge chute should be adjustable from the drivers seat.
- Shearbolts and/or safety pins/systems to ensure a safe operation of the unit.

Others: Operators manual, parts catalague, workshop manual for each unit to be received after ordering. Pamphlets to be sent with the offer and country of origin has to be stated.

Spare Parts :

A comprehensive list of fast and slow moving spare parts recommended for two years must accompany the tender. Prices should be quoted separately for each item not exceeding 20 per cent of C & F value of units.

Item : 8

Unit : Self discharging forage trailers.

Quantity 7 units

Type : PTO driven unloading system.

Capacity: 25 m^3 chopped cotton residue with a weight of about 4 tons.

Frame : Rigid construction, hot rolled steel.

Description :

The unit will be used to receive chopped material from the chopper of para.2, to transport this to the plant and to discharge it by means of a built in conveyor system.
The trailer will be connected to the a.m. chopper during loading operations and directly to the wheeltractor of para.1 during transport and unloading operations.

The trailer of the tandem axle type having a wheeltrack of 1.80 mtrs. should be freestanding (to facilitate connection and disconnection to chopper and tractor) and designed for a total carrying capacity of 4 tons and a net volume of about 25 m^3, having a total height not exceeding 3.25 mtrs.
Unloading will be arranged by means of a moving floor and cross conveyor discharging the material sideways at either the front or rear end of the trailer.
Discharge operations and rates are to be controlled from the tractor driver's seat.

The unloading system may be driven by means of the hydraulic system or the P.T.O. drive of the tractor.

The trailer, of all steel construction consisting of hot rolled channel steel chassis and frame members is provided with heavy duty bottom chains with detacheable transport hooks.

All walls of the forage box are to be of the closed, reinforced type, with either front or rear wall, depending on the discharge system, opening and closing from the drivers seat. All provisions to prevent loss of chopped material are to be included in the design.

The unit is furthermore provided with:

- Suitable drawbar with shockabsorber device and turnable draweye.
- Rear pulling hook for rescue operations.
- Front and rear reflectors.
- Radial tyres of not less than 11.5 x 15 - 8 PR.
- The required hydraulic hoses, pump, P.T.O. shaft etc. for connection to the tractor.
- Overrun expanding brakes coming into operation when the tractor brakes are applied.
- Having duty square shaped high tensile steel axles of not less than 55 mm.

<u>Others:</u> Operators manual, parts catalogue, workshop manual for each unit to be received after ordering. Pamphlets to be sent with the offer and country of origin has to be stated.

<u>Spare parts:</u>

A comprehensive list of fast and slow moving spare parts recommended for two years must accompany the tender. Prices should be quoted separately for each item not exceeding 20% of C & F value of units.

Item no.:	10
Unit:	**Workshop and storage equipment for maintenance of collecting equipment and plant for cotton stalk briquetting**

1 set of each section

Qty.	Description
	Section 1:
1	Bench drilling machine
3	Electric portable hand drills
1	Double ended grinding machine
1	Portable grinding machine with accessories.
1	Thread cutting tools
1	Stud removers
1	Measuring tools
1	Power hack saw
1	Hydraulic floor press
3	Vices
1	Kerosine blow lamp
	Section 2:
1	Engine driven Arc welder
1	Oxy-acetyline welding & cutting equipment
1	Tin smith tools
1	Manual shear bench
1	Manual bending machine
1	Long leg vice

Qty.	Description
	Section 3:
1	Engine stand
1	Hydraulic floor crane
1	Hydraulic trolly Jacks
1	Hydraulic jacks
1	Piston and ring service equipment
1	Cylinder head service equipment
1	Injector tester with injector service equipment
1	Valve and seat grinder
1	Engineering measuring instruments
1	Expanding reamers
1	Pullers
1	Torque wrenchs
2	Maintenance tools in locked boxes
1	Socket wrenches set in locked boxes
	Section 4:
1	Heavy duty battery charger
1	Electrician tools and equipment
	Section 5:
1	Air compressor with accessoires
1	Vulcanising unit
	Section 6:
1	Storage racks with drawers etc.

Specifications of Agricultural Machinery for Straw Collection

Item No. 1

Unit : 2 wheeldrive tractor

Qty. : 5 units

Type : The tractor shall be agricultural rear wheel drive tractor. A test report from a recognized testing centre preferably in accordance with the O.E.C.D. or Nebraska standard code will be submitted with the tender.

Engine : Engine shall be of the diesel type- 4-stroke cycle- developing about 40 - 45 KW (55-60 HP), at rated speed of about 2000 RPM.
Cylinders in line with replaceable sleeves.
Direct fuel injection. Engine to be suitable for ambient temperatures of up to 45 degrees C and dusty conditions.
The air cleaner of a heavy duty oil-bath type with precleaner. Engine to be equipped with a heavy duty water cooling system, large tropical radiator, centrifugal pump and large fan.
The lubrication system must be forced fed, equipped with gear type pump and oil strainer in sump. The fuel filters to be of dual stage system with replaceable elements.

Electrical System:

To be 12 V, precharged battery of about 85 AH, starter motor and alternator. An ample lighting system has to include 2 headlights, sidelights, tail and plough lights. Standard instrument panel equipped with hour meter, engine speed, temperature, oil pressure, fuel meter, light indicators, etc.

Transmission:

Dry type dual clutch with a largest possible diameter however not less than 11 inches. Multipower or powershift transmission with 12-16 forward and 4-8 reverse speed.

Hydraulics:

Three-point linkage cat. II with adjustable lift arms, live draught and position control. Minimum lift capacity 1,800 kg. at the end linkage, swinging drawbar.

Track & Wheels:

Wheeltracks must be adjustable between 1.60 and 1.80 mtrs.
Tractors to be equipped with regular agricultural tyres of natural rubber and innertubes. The following approx. tyre sizes are required:

Front : 6.50 x 16 - 6 PR

Rear : 12.4 x 28 - 8 PR

Brakes: Foot operated differential lock with automatic disengagement device. Multiple plate oil cooled brakes and parking brake.

Power take off:

An independent PTO with 6 splines 35mm (1.38 inch), speed 540 rpm.

Steering: Power steering.

Miscellaneous:

Fully cushioned seat with height adjustment, overhead safety guard with sunshade.

Tools, special equipment and accessoires:

Set of tools, to be included with each machine, also fire extinguisher, grease gun, and hydraulic jack. Special tools, equipment and accessoires should be offered.

Others : Operators manual, parts catalogue, workshop manual for each unit in English to be received after ordering.
Pamphlets to be sent with the offer and country of origin has to be stated.

Spare parts:

A comprehensive list of fast and slow moving spare parts recommended for two years must accompany the tender.
Prices should be quoted separately for each item to a total not exceeding 20% of C & F value of units.

Item : 2

Unit : Flat bed trailer

Quantity: 4 units

Type : 4 wheels, 2 axle, turntable, carrying capacity 5 tons.

Size : Platform 2.50 x 7.25 mtrs.

Frame : Rigid construction, hot rolled steel.

The unit is provided with:

- Suitable drawbar with shockabsorber device and turnable draweye
- Rear pul`ing hook for rescue operations
- Front and rear reflectors
- Radial tyres of not less than 12.5 x 15 - 8 PR
- Overrun expanding brakes coming into operation when the tractor brakes are applied
  Heavy duty, square shaped, high tensile steel axles of not less than 55 mm.

Note: Please observe that axle springs and a lighting system are not required.

Others: Parts catalogue and workshop manual for each unit to be received after ordering. Pamphlets to be sent with the offer and also country of origin has to be stated.

Spare parts:

A comprehensive list of fast and slow moving spare parts recommended for two years must accompany the tender. Prices should be quoted separately for each item not exceeding 20%, of C & F value of units.

Item : 3

Unit : Square straw baler

Quantity : 3

Type : suitable to produce square bales with size of aprox. 0.35 x 0.45 x 0.85 - 1.15 metre

Description :

The unit will be used to bale wheat straw laying in swaths after harvesting of the crop by combine harvesters. The swaths (covering a harvested area of about 5.00 mtrs. wide) are about 1.20 mtrs. wide and the recoverable straw production is estimated at 2,100 kgs/HA at a moisture content of less than 15 per cent at time of baling.

The baler will be operated by the P.T.O. drive of the tractor as described in parea "1". The gathering width of the unit should not be less than 1.50 mtrs., with tine spacing of the pick-up device not exceeding 70 mm. Number of ram strokes between 75 and 100 per minute at 540 R.P.M. of the P.T.O. shaft.

Execution:

The unit has to be equipped with:

- Double twine system, with direct driven knotters;
- Twine box;
- Drawbar and P.T.O. shaft for connection to the tractor;
- Trailer hitch;
- Flywheel of suitable dimensions to even out power surges;
- Adjustable pick-up heihgt to be controlled from the operators seat;
- Bale density adjusters;
- Power overrun device by slip-clutch or similar;
- Tyres at pick-up side of not less than 7.00 x 12 -6 PR and balecase side of not less than 10.00 x 15 - 6 PR.

The delivery should include sufficient baler twine to produce in total 360,000 bales with an average length of 1.00 mtr.

<u>Others</u> : Operators manual, parts catalogue, workshop manual for each unit to be received after ordering. Pamphlets to be sent with the offer and country of origin has to be stated.

<u>Spare Parts</u> : A comprehensive list of fast and slow moving spare parts recommended for two years must accompany the tender. Prices should be quoted separately for each item not exceeding 20 per cent of C & F value of units.

Item no.: 5

Unit : **Workshop and storage equipment for maintenance of collecting equipment and plant for straw briquetting**

Quantity: 1 set of each section

Qty.	Description
	Section 1:
1	Bench drilling machine
3	Electric portable hand drills
1	Double ended grinding machine
1	Portable grinding machine with accessories.
1	Thread cutting tools
1	Stud removers
1	Measuring tools
1	Power hack saw
1	Hydraulic floor press
3	Vices
1	Kerosine blow lamp
	Section 2:
1	Engine driven Arc welder
1	Oxy-acetyline welding & cutting equipment
1	Tin smith tools
1	Manual shear bench
1	Manual bending machine
1	Long leg vice

Qty.	Description
	Section 3:
1	Engine stand
1	Hydraulic floor crane
1	Hydraulic trolly Jacks
1	Hydraulic jacks
1	Piston and ring service equipment
1	Cylinder head service equipment
1	Injector tester with injector service equipment
1	Valve and seat grinder
1	Engineering measuring instruments
1	Expanding reamers
1	Pullers
1	Torque wrenchs
2	Maintenance tools in locked boxes
1	Socket wrenches set in locked boxes
	Section 4:
1	Heavy duty battery charger
1	Electrician tools and equipment
	Section 5:
1	Air compressor with accessoires
1	Vulcanising unit
	Section 6: storing equipment
1	Storage racks with drawers etc.

Specifications of Agricultural Machinery for Maize Residue

Item No: 11

Unit : 2 wheeldrive Tractor

Qty. : 8 units

Type : The tractor shall be agricultural rear wheel drive. A test report from a recognized testing centre preferably in accordance with the O.E.C.D. or Nebraska standard code will be submitted with the tender.

Engine : Engine shall be of the diesel 4-stroke cycle developing about 40 - 45 KW (55-60 HP), at rated speed of about 2000 RPM.
Cylinders in line with replaceable sleeves. Direct fuel injection. Engine to be suitable for ambient temperatures of up to 45 degrees C and dusty conditions.
The air cleaner of a heavy duty oil-bath type with precleaner. Engine to be equipped with a heavy duty water cooling system, large tropical radiator, centrifugal pump and large fan.
The lubrication system must be forced feed, equipped with gear type pump and oil strainer in sump. The fuel filters to be of dual stage system with replaceable elements.

Electrical System:

To be 12 V, precharged battery of about 85 AH, starter motor and alternator. An ample lighting system has to include 2 headlights, sidelights, tail and plough lights. Standard instrument panel equipped with hour meter, engine speed, temperature, oil pressure, fuel meter, light indicators, etc.

Transmission:

Dry type dual clutch with a largest possible diameter however not less than 11 inches. Multipower or powershift transmission with 12-16 forward and 4-8 reverse speed.

Hydraulics:

Three-point linkage cat. II with adjustable lift arms, live draught and position control. Minimum lift capacity 1,800 kg. at the end linkage, swinging drawbar.

Track & Wheels:

Wheeltracks must be adjustable between 1.60 and 1.80 mtrs.
Tractors to be equipped with regular agricultural tyres of natural rubber and innertubes. The following approx. tyre sizes are required.

Front : 6.50 x 16 - 6 PR

Rear : 12.4 x 28 - 8 PR

Brakes: Foot operated differential lock with automatic disengagement device. Multiple plate oil cooled brakes and parking brake.

Power take off:

An independent PTO with 6 splines 35mm (1.38 inch), speed 540 rpm.

Steering: Power steering.

Miscellaneous:

Fully cushioned seat with height adjustment, overhead safety guard with sunshade.

Tools, special equipment and accessoires:

Set of tools, to be included with each machine, also fire extinguisher, grease gun, and hydraulic jack. Special tools, equipment and accessoires should be offered.

Others : Operators manual, parts catalogue, workshop manual for each unit in English to be received after ordering.
Pamphlets to be sent with the offer and country of origin has to be stated.

Spare parts:

A comprehensive list of fast and slow moving spare parts recommended for two years must accompany the tender.
Prices should be quoted separately for each item to a total not exceeding 20% of C & F value of units.

<u>Item</u> : 12

<u>Unit</u> : Single Row Maize chopper

<u>Quantity</u> 5 units

<u>Type</u> : PTO driven

Capacity: 4 tons chopped material per hour

Description :

The unit will be used to recover the maize stalks that are left in the field after the cobs have been picked by hand. The chopper may be supplied from a swath with stalks already cut by hand or will be used to cut and chop one single row of stalks at a time.
Moisture content of the stalks at time of chopping will be less than 20% (MCWB) and stalk production will reach to about 3000 kgs./HA.
The chopper will be connected to the 3 point linkage of the wheeltractor of para.1. and driven by the P.T.O.
The unit is provided with a drawbar hook to pull the forage trailer of para. 3 during chopping operations.

The chopper has to cut the stalks in lenghts adjustable between 25-30 mm. and 70-75 mm. by either changing the number of knives and/or changing the knife-speed.

Execution :

The unit is equipped with:

- Adjustable number of wear resistant knives, up to 12 pcs. to control chip length
- Blower of sufficient capacity to blow the chopped material into the forage trailer.
- Blower discharge chute should be adjustable from the drivers seat.

- A dual purpose gearbox to allow the operation of either the chopper or the discharge of the trailer without disconnecting one of the units.
- Shearbolts and/or safety pins/systems to ensure a safe operation of the unit.

<u>Others:</u> Operators manual, parts catalogue, workshop mannual for each unit to be received after ordering. Pamphlets to be sent with the offer and country of origin has to be stated.

<u>Spare parts:</u>

A comprehensive list of fast and slow moving spare parts recommended for two years must accompany the tender. Prices should be quoted separately for each item in total not exceeding 20%, of C & F value of units.

Item No : 13

Unit : Self discharging forage trailers.

Quantity 8 units

Type : PTO driven unloading system.

Capicity: 25 m^3 chopped maize residue with a weight of about 4 tons.

Frame : Rigid construction, hot rolled steel.

Description :

The unit will be used to receive chopped material from the chopper of para.2, to transport this to the plant and to discharge it by means of a built in conveyor system. The trailer will be connected to the a.m. chopper during loading operations and directly to the wheeltractor of para.1 during transport and unloading operations.

The trailer of the tandem axle type having a wheeltrack of 1.80 mtrs. should be freestanding (to facilitate connection and disconnection to chopper and tractor) and designed for a total carrying capacity of 4 tons and a net volume of about 25 m^3, having a total height not exceeding 3.25 mtrs.
Unloading will be arranged by means of a moving floor and cross conveyor discharging the material sideways at either the front or rear end of the trailer.
Discharge operations and rates are to be controlled from the tractor driver's seat.

The unloading system may be driven by hydraulic system or the P.T.O. drive of the tractor.

The trailer of all steel construction consisting of hot rolled channel steel chassis and frame members are provided with heavy duty bottom chains with detacheable transport hooks.

All walls of the forage box are to be of the closed reinforced type, whereas either front or rearwall, depending on the discharge system, opening or closing from the drivers seat. All provisions to prevent loss of chopped material are to be included in the design.

The unit is provided with:

- Suitable drawbar with shockabsorber device and turnable draweye.
- Rear pulling hook for rescue operations.
- Front and rear reflectors.
- Radial tyres of not less than 11.5 x 15 - 8 PR.
- The required hydraulic hoses, pump, P.T.O. shaft etc. for connection to the tractor.
- Overrun expanding brakes coming into operation when the tractor brakes are applied.
- Having duty square shaped high tensile steel axles of not less than 55 mm.

Others: Operators manual, parts catalogue, workshop manual for each unit to be received after ordering. Pamphlets to be sent with the offer and country of origin has to be stated.

Spare of parts:

A comprehensive list of fast and slow moving spare parts recommended for two years must accompany the tender. Prices should be quoted separately for each item not exceeding 20% of C & F value of units.

<u>Item no.:</u> 15

<u>Unit:</u> <u>Baling press for chopped maize stalks</u>

<u>Qty:</u> 2 units

<u>Type:</u> Fully automatic self binding.

<u>Capacity:</u> 2500 kg material per hour or 125 bales per hour chopped maize stalks with a bulk density of 160 kg/cbm.

<u>Dimensions of bales:</u>

About 50 cm width, 40 cm height and a length of 80 to 120 cm variable.

<u>Weight per bale:</u> 20 - 25 kilos at a bulk density of 180 - 350 kg/cbm.

<u>Binding:</u> Preferable with plastic or sisal rope.

<u>Description:</u> The unit will be used to press chopped maize stalks to bales. The material will be fed into a chopper after which it will be pressed fully automatic. The bales leave the machine double twined.

The delivery should include sufficient baling rope to produce in total 250.000 bales with an average length of 1,00 metre.

<u>Tools, special equipment and accessoires:</u>

Set of tools, to be included with each machines, such as, grease gun etc. Special tools, equipment and accessoires should be offered.

<u>Others:</u> Operators manual, parts catalogue, workshop manual for each unit in English to be received after ordering.
Pamphlets to be sent with the offer and country of origin has to be stated.

<u>Spare parts:</u> A comprehensive list of fast and slow moving spare parts recommended for two years must accompany the tender.
Prices should be quoted separately for each item not exceeding 20% of C & F value of units.

Item no.: 18

Unit: **Workshop and storage equipment for maintenance of collecting equipment and plant for maize residue briquetting**

1 set of each section

Qty.	Description
	Section 1:
1	Bench drilling machine
3	Electric portable hand drills
1	Double end grinding machine
1	Portable grinding machine with accessories.
1	Thread cutting tools
1	Stud removers
1	Measuring tools
1	Power hack saw
1	Hydraulic floor press
3	Vices
1	Kerosine blow lamp
	Section 2:
1	Engine driven Arc welder
1	Oxy-acetyline welding & cutting equipment
1	Tin smith tools
1	Manual shear bench
1	Manual bending machine
1	Long leg vice

Qty.	Description
	Section 3:
1	Engine stand
1	Hydraulic floor crane
1	Hydraulic trolly Jacks
1	Hydraulic jacks
1	Piston and ring service equipment
1	Cylinder head service equipment
1	Injector tester with injector service equipment
1	Valve and seat grinder
1	Engineering measuring instruments
1	Expanding reamers
1	Pullers
1	Torque wrenchs
2	Maintenance tools in locked boxes
1	Socket wrenches set in locked boxes
	Section 4:
1	Heavy duty battery charger
1	Electrician tools and equipment
	Section 5:
1	Air compressor with accessoires
1	Vulcanising unit
	Section 6:
1	Storage racks with drawers etc.

Equipment Specification

Plant: Maize Stalks and Wheat Straw Screw and Piston Briquetting

Flow Sheet: dwg. no. 850507

Plot Plan: dwg. no. 850513

Item no. 2 (corresponds with item no on flow sheet)

Unit: Bale Breaker

Qty: 2

Intended use: To break bales made of chopped maize stalks and wheat straw. The bales are fed by means of an inclined belt conveyor. Strings are removed by hand before the bales are fed onto the belt conveyor.

Capacity: up to 2000 kg/h of bales, size 0,4 x 0,5 x 0,85 - 1,15 m, weight of each bale up to 25 kg, i.e. up to 80 bales per hour

Construction: drum type rotor with exchangeable teeth, rotor shaft to be supported with grease lubricated spherical roller bearings, housing made of welded mild steel plates. With enclosed inlet chute preferably leading bales with a 45 degree angle into the bale breaker. The inlet chute must be provided with a by-pass to feed loose cotton stalks directly onto the discharging conveyor. With suction hood for dust removal. With flywheel and v-belt drive, with electric motor. Access for maintanance must be easy. The unit must be supplied with 3 sets of teeth. The machine must be provided with a vibration sensor to signal unblanced rotor due to uneven wear on teeth.

Equipment Specification

Plant:	for all (4) Screw and Piston Briquetting Plants
Flow Sheet:	dwg. no. 850506, 07, 08
Layout Plan:	dwg. no. 850510 and 11
Plot Plan:	dwg. no. 850512, 13, 14
Item no.	7, 9, 10 (correspond with item nos on flow sheets)
Unit:	Silo
Qty:	4
Intended use:	Intermediate puffer store for dried residue, ready for briquetting, to even out fluctuations in the material flow and to make the operation of the briquettor more independant from the other plant sections
Capacity:	storage capacity approx 6 m^3, discharge capacity up to 750 kg/h for each discharge screw, up to a maximum of 4 independant discharge screws.
Construction:	mild steel metal sheet housing with structural steel supports down to the floor level. Hight of discharge port 2,8 m above floor level. At the beginning the silo will only be equipped with one discharge screw, with fixed speed electric drive for the screw. The floor of the silo must be prepared to receive up to 3 additional screw conveyors at a later stage. The interior of the silo must be provided with a rotating agitator to distribute the material even over the discharge screws. High and low level sensors must be included, preferable of the rotary type. The silo must be equipped with an access ladder and a man hole in the cover plate.

Equipment Specification

B. Plant: for all (4) Screw and Piston Briquetting Plants

Flow Sheet: dwg. no. 850506, 07, 08

Layout Plan: dwg. no. 850510 and 11

Plot Plan: dwg. no. 850512, 13, 14

Item no. 2, 4, 5, (correspond with item nos on flow sheets)

Unit: Hammer Mill

Qty: 4

Intended use: to reduce the size of the residues without producing excessive dust. The milled fraction is removed by means of pneumatic conveyors and some of the conveying air can be sucked through the mills.

Capacity:

Residue:	kg/h:	kg/m^3:
coffee husks	2500	250 - 350
chopped cotton stalks	2000	100 - 120
chopped maize stalks	2000	80 - 100
wheat straw	2000	60 - 80

Construction: rotor with free swinging hammers supported in grease lubricated spherical roller bearings, housing made of welded mild dteel plates, discharge closed with perforated screens, access to hammers and screens must be easy for maintenance and for exchanging, with enclosed inlet chute suitable for feeding with belt conveyor, with a suction funnel at the bottom to be connected to a pneumatic conveying pipe, with 5 sets of hammers and 5 sets of screens with different perforations.
The hammer mill must be provided with a vibration sensor to signal if the rotor unbalanced due to uneven wear on hammers.

Equipment Specification

Plant:	for all (4) Screw and Piston Briquetting Plants
Flow Sheet:	dwg. no. 850506, 07, 08
Layout Plan:	dwg. no. 850510 and 11
Plot Plan:	dwg. no. 850512, 13, 14
Item no.	4, 6, 7, (correspond with item nos on flow sheets)
Unit:	Three Deck Screen
Qty:	4
Intended use:	to divide the residues into three fractions: Fraction 1: Overflow of first screen and third screen for piston briquettor Fraction 2: Overflow of second screen for screw briquettor Fraction 3: which passes through all three screens for disposal
Construction:	preferably slow motion type screen with crank drive over a v-belt drive for easy adjustment as required. With stainless steel wire screens tensioned in an enclosed mild steel frame. Maintenace and changing of screens must be easy. Each unit must be supplied with ten sets of screens with various mesh sizes, with square holes ranging from 1 to 8 mm.
Capacity:	see pneumatic conveyors items 3, 5, 6

Annex 5

LIST OF RECOMMENDED EQUIPMENT SUPPLIERS FOR BRIQUETTING PLANTS

1. Bale breakers and hammermills

(a) Pallman KG, D-666 Zweibrucken, W. Germany

(b) Condux-Werk, D-6451 Wolfgang, W. Germany

(c) Buehler Brothers, CH-9240 Uzwil, Switzerland

2. Silos

(a) Weiss Brithers KG, D-6343 Frohnhausen, W. Germany

3. Screens

(a) Allgaier-Werke GmbH, D-7336 Uhingen, W. Germany

(b) The Orville Simpson Company, Cincinati, Ohio 45223, USA

4. Piston Briquettors

(a) Rosenmund AG (Hausmann presses), CH-4410 Liestal, Switzerland

(b) Gebr. Hofmann, D-8701 Eibelstadt, W. Germany

(c) J. Mared AB, Huskvarna, Sweden

5. Screw Briquettor

(a) Biomass Development Europe SA, B-1040 Bruxelles, Belgium

6. Belt conveyors

(a) HEFO AG, CH-4222 Zwingen, Switzerland

(b) Jost Brothers AG, CH-3527 Heimberg, Switzerland

7. Pneumatic Conveyors

(a) Keller Lufttechnik GmbH, D-7312 Kirchheim, W. Germany or Keller & Co., CH-8105 Regensdorf, Switzerland

(b) Ventilator Staefa AG, CH-8712 Staefa, Switzerland

ANNEX 6

SUPERVISING ENGINEER: TERMS OF REFERENCE

Scope of Work

1. A supervising engineer will be hired to facilitate the implementation of all pilot plants and to initiate a technical monitoring and evaluation program over a period of three crop seasons. The engineer will have several sets of responsibilities which will occur during (1) the detailed planning phase, (2) training and construction, (3) installation and commissioning, (4) the start-up period, and (5) over three crop seasons of plant operation. In addition, the supervising engineer will play a monitoring role for the World Bank throughout the project. The component tasks for each of these responsibilities are listed below.

Terms of Reference

2. During the design and tendering phases, the engineer will be responsible for:

(a) reviewing all designs, tender documents, and equipment specifications to ensure acceptability and compatibility;

(b) travelling overseas to inspect major equipment components at their manufacturing site prior to shipment to Ethiopia;

(c) after seafreight but before local transport, checking the condition of crates and of uncrated major equipment to see if the consignment is complete and intact according to the packing list;

(d) checking the condition of crates and equipment after arrival at the site and making sure that the shipment is complete according to the packing list;

(e) in the case of damaged crates and equipment, ensuring that claims are filed with the appropriate insurance company;

(f) coordinating between equipment suppliers to ensure proper interface of plant components;

(g) checking equipment design with regard to ease of maintenance and operation within Ethiopia;

(h) reviewing maintenance and operating instructions to ensure that they are applicable specifically to the equipment supplied, and incorporating all individual instructions into one common manual;

(i) studying spare part proposals to make suggestions for standardization in order to limit the need for specialized spares; and

(j) reporting periodically to the World Bank, especially if a Bank intervention is anticipated.

3. During the training and construction period, the engineer will undertake the following:

(a) designing, reviewing and coordinating training programs for skilled local labor in conjunction with equipment suppliers;

(b) supervising, whenever possible, the installation and assembly of key equipment;

(c) regarding site construction, making at least two check-ups during the execution phase and one final check-up after completion to compare the size of buildings, foundations and site works for power supply to see if they are in accordance with drawings, specifications and instructions; and

(d) reporting regularly to the World Bank, especially if a Bank intervention is anticipated.

4. During installation and commissioning, the engineer will be responsible for the following tasks:

(a) checking the proper execution of equipment erection, installation, test runs and commissioning;

(b) ensuring that future operators and maintenance staff assist overseas erection personnel during erection and installation;

(c) preparing standardized fault protocols for the performance reports during the breaking-in period and the first year of production;

(d) instructing the operating and maintenance staff on how to fill in the protocols; and

(e) reporting periodically to the World Bank, especially if a Bank intervention is anticipated.

5. During the breaking-in period, the supervising engineer will undertake the following assignments:

(a) making sure that fault protocols are properly completed by staff;

(b) assisting the operating staff in solving operational problems and the maintenance staff in conducting repairs;

(c) informing equipment suppliers about recorded faults and deficiencies to get their advice and assistance; and

(d) reporting periodically to the World Bank, especially if a Bank intervention is anticipated.

6. During the three crop season production period, the engineer will be responsible for the following activities:

(a) visiting each plant periodically to make sure that the operating and maintenance staff continue to record deficiencies in the fault protocols;

(b) informing equipment suppliers about the recorded deficiencies to get their advice;

(c) assisting the operating staff with problem-solving and implementing the advice of equipment suppliers;

(d) ensuring that production rates are properly recorded;

(e) connducting quality control exercises; and

(f) reporting periodically to the World Bank, especially if an intervention is anticipated.

7. In addition, the engineer will conduct a series of checks whenever equipment is procured. Specifically, these include:

(a) After seafreight but before local transport, checking the condition of crates aud of uncrated major equipment to see if the consignment is complete and intact according to the packing list;

8. After arrival at the site, checking the condition of crates and equipment, and making sure that the shipment is complete according to the packing list;

(a) Regarding site construction, making at least two check-ups during the execution phase and one final check-up after completion to compare the size of buildings, foundations and site works for power supply to see if they are in accordance with drawings, specifications and instructions; and

(b) in the case of damaged crates and equipment, ensuring that all matters are reported to and followed up by the appropriate insurance company.

ENERGY SECTOR MANAGEMENT ASSISTANCE PROGRAM

Activities Completed

Energy Assessment Status Report	Date Completed
Papua New Guinea	July, 1983
Mauritius	October, 1983
Sri Lanka	January, 1984
Malawi	January, 1984
Burundi	February, 1984
Bangladesh	April, 1984
Kenya	May, 1984
Rwanda	May, 1984
Zimbabwe	August, 1984
Uganda	August, 1984
Indonesia	September, 1984
Senegal	October, 1984
Sudan	November, 1984
Nepal	January, 1985
Zambia	August, 1985
Peru	August, 1985
Haiti	August, 1985
Paraguay	September, 1985
Morocco	January, 1986
Niger	February, 1986

Project Formulation and Justification

Panama	Power Loss Reduction Study	June, 1983
Zimbabwe	Power Loss Reduction Study	June, 1983
Sri Lanka	Power Loss Reduction Study	July, 1983
Malawi	Technical Assistance to Improve the Efficiency of Fuelwood Use in Tobacco Industry	November, 1983
Kenya	Power Loss Reduction Study	March, 1984
Sudan	Power Loss Reduction Study	June, 1984
Seychelles	Power Loss Reduction Study	August, 1984
The Gambia	Solar Water Heating Retrofit Project	February, 1985
Bangladesh	Power System Efficiency Study	February, 1985
The Gambia	Solar Photovoltaic Applications	March, 1985
Senegal	Industrial Energy Conservation	June, 1985
Burundi	Improved Charcoal Cookstove Strategy	September, 1985
Thailand	Rural Energy Issues and Options	September, 1985
Ethiopia	Power Sector Efficiency Study	October, 1985
Burundi	Peat Utilization Project	November, 1985
Botswana	Pump Electrification Prefeasibility Study	January, 1986
Uganda	Energy Efficiency in Tobacco Curing Industry	February, 1986
Indonesia	Power Generation Efficiency Study	February, 1986
Uganda	Fuelwood/Forestry Feasibility Study	March, 1986

		Date Completed
Project Formulation and Justification (cont.)		
Sri Lanka	Industrial Energy Conservation-Feasibility Study	March, 1986
Togo	Wood Recovery in the Nangbeto Lake	April, 1986
Rwanda	Improved Charcoal Cookstove Strategy	August, 1986
Institutional and Policy Support		
Sudan	Management Assistance to the Ministry of Energy & Mining	May, 1983
Burundi	Petroleum Supply Management Study	December, 1983
Papua New Guinea	Proposals for Strengthening the Department of Minerals and Energy	October, 1984
Papua New Guinea	Power Tariff Study	October, 1984
Costa Rica	Recommended Tech. Asst. Projects	November, 1984
Uganda	Institutional Strengthening in the Energy Sector	January, 1985
Guinea-Bissau	Recommended Technical Assistance Projects	April, 1985
Zimbabwe	Power Sector Management	April, 1985
The Gambia	Petroleum Supply Management Assistance	April, 1985
Burundi	Presentation of Energy Projects for the Fourth Five Year Plan	May, 1985
Liberia	Recommended Technical Assistance Proj.	June, 1985
Burkina	Technical Assistance Program	March, 1986
Senegal	Assistance Given for Preparation of Documents for Energy Sector Donors' Meeting	April, 1986
Zambia	Energy Sector Institutional Review	November, 1986
Jamaica	Petroleum Procurement, Refining & Dist.	November 1986