strength when fired under laboratory conditions is markedly higher for all additives than in Practical Action's field test.

Facts and figures from the brickmaking industry

Brick production is concentrated along riversides in central Sudan. During the worst of the civil war, there was almost no brick production in the south of the country. High production along the Blue Nile indicates the strength of demand for bricks in Khartoum state and the central region. Fortunately in this regard, the soil along the Blue Nile is very suitable for brickmaking. By contrast, brickmaking is non-existent along the White Nile because the soil is wholly unsuitable for that purpose. In Khartoum state and the central region brickmaking constitutes some 8 per cent of all employment. Khartoum alone absorbs about 50 per cent of the total number of workers in the national brickmaking industry.

Table 5.8 Brick production along the Nile and its tributaries

Location	*Number of production units*	*Annual brick production ('000)*	*Percentage of annual national production*
Blue Nile	1,347	2,281,280	82.40
River Nile	170	261,920	9.50
River Gash	28	39,200	1.40
River Atbara	26	36,000	1.30
Total	1,571	2,618,400	94.60

Source: Hamid, 1994.

Table 5.9 Distribution of major brickmaking centres in Sudan

Location	*Number of production units*	*Annual brick production ('000)*	*Percentage of annual national production*
Khartoum	800	1,280,000	46.2
Sennar	404	775,680	28.0
Wad Madani	60	153,600	5.5
Atbara	38	54,720	2.0
Kassala	28	39,200	1.4
Nyala	30	33,600	1.2
Al Ubayyid	20	22,400	0.8
Total	1,380	2,359,200	85.1

Table 5.10 Employment in brickmaking industry, 1994

State/Region	*Average number of workers/unit*	*Number of production units*	*Total number of jobs*
Khartoum	22	800	17,600
Central region	21	654	13,080
Northern region	16	63	1,008
Eastern region	19	60	1,140
Darfur region	16	69	1,104
Kordofan region	16	59	944
Total		1,705	34,876

Source: Hamid, 1994.

A 1994 survey revealed in detail the quantities of raw materials - clay, additives, water and fuelwood - necessary for the production of 1,000 bricks (Hamid, 1994). The survey highlighted the well-known effect of the physical and chemical characteristics of clay on the firing energy requirement. Essentially, sandier and so more refractory soils require more energy to vitrify sufficiently for brick production. Also, the capacity of the soil for accepting the majority of additives is inversely proportional to its sandiness. At Al Ubayyid, for example, the 'clay' contains a high percentage of sand, some 67 per cent. This means that only a very small percentage of organic matter can be added before final brick quality is adversely affected, i.e. the bricks produced become crumbly and unusable. To vitrify such a refractory soil, moreover, requires a lot of energy and hence, of course, fuel. The lowest quantity of fuelwood required to fire 1,000 bricks is recorded in Khartoum and the central region i.e. along the Blue Nile. In general,

Table 5.11 Composition of clays at Gereif Shark, Khartoum

Component	*Percentage (by mass)*		
	Balabaty	*Zafota*	*Gurera*
SiO_2	44.21	49.09	75.04
Al_2O_3	17.03	15.68	8.23
Fe_2O_3	11.11	10.07	4.35
CaO	5.57	6.32	4.67
MgO	3.01	2.52	1.07
K_2O	1.75	2.53	1.26
Na_2O	0.95	2.10	0.73
LOI	12.82	8.08	5.58

the survey suggests that if bricks are to vitrify sufficiently, the combined proportion of sand and additives in the mix cannot be pushed above 70 per cent.

An analysis of the clays available at Gerief Shark, Khartoum state, may be illuminating. Firstly, as most brickmakers know, a range of soil types may be found in a relatively small area. In fact, the term clay can be a misnomer as it is used to cover a range of soil types, some of which contain much more sand than clay. The figure for SiO_2 is a direct indicator of the sandiness of the soil. So, by this measure alone we would not expect to use additives *in* Gurera 'clay'. This does not of course mean that residues could not be used as auxiliary fuels by other means. Gurera soil can be expected to require a lot of firing energy; we might even question whether it is suitable for brickmaking at all. The other soils, Balabaty and Zafota, on the other hand, look good for brickmaking and have potential for the incorporation of additives. Moreover, the presence of significant fractions of known fluxes, Fe_2O_3 and CaO, which aid the process of vitrification, indicates that bricks might be fired at relatively low temperatures, thereby demanding less fuel. (Note, however, that if too much CaO is present, particularly as lumps, it can cause problems with brick quality.) One concern might be the relatively high Loss On Ignition (LOI) of these soils, particularly Balabaty. LOI is an indicator of the organic matter in the soil. This organic matter burns when bricks are fired and can cause them to exhibit low density, low strength and high water absorption.

The data for fuel consumption is given per 1,000 bricks. As we have seen in case studies from Peru, this can lead to serious misconceptions when processes

Table 5.12 Annual fuelwood consumption of brickmaking industry, 1994

State/Region	*Fuelwood per 1,000 bricks (kg)*	*Production of bricks ('000)*	*Fuelwood (tonnes)*	*%age of total*	*Wood most often used*
Khartoum	50.67	1,280,000	64,858	35.40	*Acacia nilotica* & Talh
Central region	38.70–58.00	1,172,480	49,940	27.30	*Acacia nilotica* &Talh
Northern region	66.70–150.00	90,720	9,024	4.90	Misquite, Talh, Syal, Doam, Fruit trees
Eastern region	333.30–533.30	84,000	32,900	18.00	Misquite, Shaf, Kitir, Talh
Darfur region	66.67–140.00	77,280	8,027	4.40	Talh, Kitir, Sahab
Kordofan region	66.67–400.00	64,960	18,219	10.00	Misquite, Arad, Talh, Hashab, Kitir
Total national		2,769,440	182,968	100	

Source: Hamid, 1994

are compared. We know that brick size varies considerably from place to place, and even within one nominal location, in Sudan. Comparing 1,000 bricks from one site with 1,000 bricks from another probably means we are comparing very different masses of fired brick. That said, it is still worth noting that, from the data presented in Table 5.12, there is a huge variation in the fuelwood used to fire 1,000 bricks, i.e. from 38.7 kg to 533.3 kg. Apart from the soil type and how dry the bricks are when placed in the clamp, which we have mentioned, we must suspect that other influential factors are at work. We could speculate that, say, the condition of the firewood used might be very different from place to place. That is, the varieties listed may not only have very different essential calorific values, they may also be used in different conditions. At one location seasoned dry wood may be used, while at another small green wood with a high moisture content may be the supply. We do not, however, have sufficient data to engage in anything other than speculation, which at least raises awareness of some of the pitfalls of data collection. Such pitfalls were the reason that Practical Action developed its energy monitoring methodology.

The cost of the materials used in brickmaking represents between 45 and 64 per cent of the total production cost (Hamid, 1994). The single most expensive material input, moreover, is always fuelwood, which typically represents at least 25 per cent of production costs and can exceed 50 per cent in areas of scare supply and high demand. A 1996 study produced a breakdown of brick production costs in Khartoum (Table 5.13). Taken together, the cost of firewood

Table 5.13 Production costs for 100,000 bricks in Khartoum, 1996

Item	*Item cost (SD)*	*Cost (SD)*	*% of total cost*
A) Variable costs:		633,650	92.40
– Materials			
Animal dung	120,000		17.50
Firewood	195,000		28.40
Other	650		0.10
Total materials	315,650		46.00
– Total labour costs	318,000		46.40
B) Fixed costs		19,133	2.80
Tools			
Rent of land			
Water pump			
C) Overhead costs		33,333	4.80
Total production cost (A+B+C)		686,116	100.00

and cow-dung, which contributes as a fuel as well as a soil conditioner, make up a cost comparable with the cost of labour. A 1999 study in Kassala calculated the fuelwood cost at 44.27% of total production costs with labour and cow-dung contributing 24.59% and 7.78% respectively (Hood, 1999a).

Further potential for the use of agricultural residues and wastes

The British first introduced brick production to central Sudan, establishing the industry in the Khartoum area on the banks of the Nile and of Blue Nile. Because the soils in the area are high in clay and very plastic, the use of additives was soon introduced to minimize drying shrinkage, cracking and ultimately production losses. Although several additives, including sand, biomass materials, coal-dust and crushed broken bricks (grog), could have been selected, Sudanese brickmakers opted for cow-dung. Though it has a number of traditional uses, there was a huge surplus of cow-dung. Moreover, it was available for only the cost of transport. With time, firewood became scarce, the price soared, and brickmakers duly noted that cow-dung had another advantage over non-organic additives in that it served as a secondary fuel. From then on, this waste material attained a new value and soon had a price attached. As the price is lower than firewood, however, brickmakers tend to maximize the amount of cow-dung they incorporate in the clay mix. As we have seen, there can be an adverse effect on brick quality when cow-dung is overused.

The escalating cost of fuelwood together with technological limits on the use of cow-dung prompted research into the use of alternative wastes and agricultural residues. Sudan has vast reserves of agricultural and other residues, estimated in 2001 to amount to some 13.931 million tonnes per year (Table 5.15). The most promising of these residues for brickmaking are the stalks of various crops, peanut shells and, particularly, bagasse. In general, agricultural wastes must be processed into convenient forms for use as industrial fuel. If this is not done, high volume to weight ratios tend to make them prohibitively expensive to transport. When it comes to incorporating residues into the clay brick as an efficient way of burning them, peanut shells may need to be ground and stalks finely chopped. Though huge quantities of cow-dung are nominally available, free-range grazing of animals means that the collection of the vast majority of this waste is not economically viable. Residues not included in the table include sawdust and residues of threshing sorghum and millet (chaff).

Bagasse is a by-product of the sugar industry. It is the solid part of sugar cane that is rejected after extracting the juice. Freshly produced bagasse, which has a moisture content of around 50 per cent, is rough and coarse in texture. As it ferments naturally, however, it decomposes to soft and fine particles. In such condition it is termed 'rotted bagasse'. Heaps of bagasse are an inherent feature of the landscape around Sudanese sugar factories. Not only are these unsightly and unhygienic, encouraging rodents, the heat produced by fermentation means they tend to ignite spontaneously! Obviously, then, such heaps represent a

Table 5.14 Characteristics of some residues

Fuel/residue	*Moisture (%)*	*Volatile matter (%)*	*Fixed carbon (%)*	*Ash (%)*	*Calorific value (MJ/kg)*
Loose bagasse	9.41	66.23	29.34	4.42	19.17
Bagasse blocks (35% molasses)	6.73	62.41	27.99	9.6	18.66
Bagasse blocks (20% clay)	?	?	?	?	14.61
Bagasse blocks (20% filter cake)	?	?	?	?	17.46
Miskit wood	14.94	76.25	21.93	1.82	19.71
Miskit roots	6.80	72.22	25.81	1.97	19.54
Cow-dung	4.02	47.93	7.30	44.77	12.81
Fuelwood (*Acacia nilotica*)	13–20	50.2	50.0	0.64	19.40

Table 5.15 Annual availability of residues

Residue	*Sources*	*Quantity ('000 tonnes)*
Agricultural residues	Cotton stalks	373
	Sorghum stalks	7,821
	Wheat straw	776
	Millet stalks	11,206
	Groundnut shells	1,393
	Sesame stalks	2,120
Agro-industrial residues	Bagasse	327
Animal wastes	Cattle manure (cow-dung)	55,051

Source: Second National Energy Assessment, Forestry Resources, 2000.

Table 5.16 Bagasse produced annually by sugar factories, 1994/95

	Geneid	*Sennar*	*Assalaya*	*New Halfa*	*Kennana*
Bagasse (tonnes)	200,000	300,000	215,000	268,813	750,000
%age used for steam & electricity	31.0	60	35.0	60	75
% age used for electricity (off-season)	15.7	10	12.0	11	23
Other uses (%)	9.9	4	4.8	3	2
Available surplus (%)	43.4	26	48.2	26	0

significant fire hazard. In fact, sugar factories are frequently damaged by bagasse fires. The cost and nuisance associated with monitoring bagasse heaps is a burden for the sugar factories. Nationally, there are five operational sugar factories and, over time, four of these have accumulated enormous quantities of rotted bagasse.

The use of bagasse as a fuelwood substitute is facilitated by processing it into briquettes or blocks. In Sudan, bagasse has been turned into blocks using a press designed for the production of soil blocks. Although pit molasses emerged as the most appropriate binder in trials because it is effective and low priced, it is in short supply. Other binders have therefore been tested, in particular clay and filter cake. Filter cake is a residue from sugar factories. After juice has been extracted from the cane, the bagasse is filtered through lime. The by-product product of this filtration is a mud-like cake. Using either filter cake or clay, the potential annual output of bagasse blocks from Sudan's sugar factories exceeds 400,000.

Several bagasse block production facilities were actually established at different locations. Two sizes of blocks were produced, the average mass being either 1.5 or 2.0 kg. Though these facilities operated for some time, the relatively high price of fresh molasses used as a binder, transport costs and poor marketing combined to contribute to their eventual closure. The main brickmaking locations lie considerable distances from the sugar factories and ultimately bagasse blocks were unable to compete with fuelwood. When no cost is incurred for deforestation and subsequent degradation on all scales of conception of the environment, what economists term externalities, such an outcome is predictable

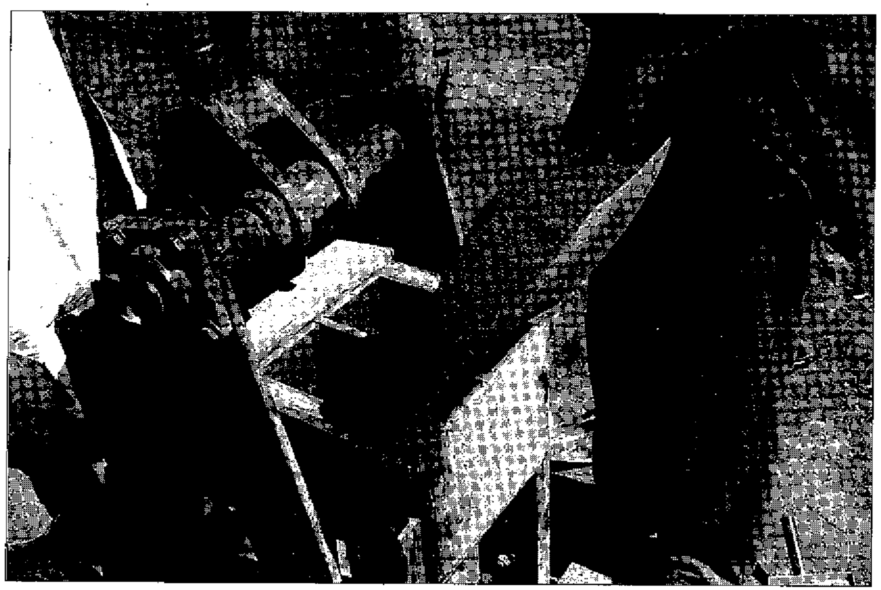


Photo 5.4: Block press. Credit: Practical Action/Zul

Table 5.17 Production of bagasse blocks at sugar factories

Enterprise/Location	*Established*	*Presses*	*Capacity (tonnes/year)*	*Production (tonnes)*	
				1994	*1995*
PDO./Assaalaya	Dec. 1994	2	500	80	NA
Muwafag/Sennar	July 1994	5	1,250	NA	NA
FNC/Guneid	July 1993	4	1,000	660	530
REC/SDC/Guneid	1995	10	2,500	290	-
Prison/New Halfa	1987	2	500	610	660
UNCHR/New Halfa	1995	10	NA	10	-
Private/New Halfa	1995	3	3,250	10	-
Total		36	9,000	1,660	1,190

Source: BENS, 1996.

and will no doubt be repeated elsewhere in the world; a false economics is thereby being employed to discredit renewable and alternative sources of energy, including wastes (Boulding, 1966; Daly, 1992; Daly, 1996; Daly, Cobb and Cobb, 1994; Ekins, 1999).

Experience of using alternative fuels

We have seen that more than 70 per cent of the energy consumed in Sudan is in the form of fuelwood, where this designation includes both firewood and charcoal. A 1994 survey of national forest products revealed that the total quantity of fuelwood consumed that year amounted to about 15.77 million cubic metres of standing wood (Hamid, 1994). Around 89.4% of this volume was consumed in the household sector, 6.8% in the industrial sector, 2.5% in the commercial and services sector and about 1.3% in Quranic schools. Firewood represents around 87.6 per cent of the total amount. The survey concluded that there was a need to conserve wood and encourage the use of alternative fuels. Although agricultural residues could play a major role in this respect, they currently contribute less than 2 per cent of national energy.

Investigating the use of bagasse as a fuel, BENS concluded that if it were compacted, it could be a viable alternative to fuelwood. It was found that applying a pressure of 48 kg/cm^2 to a mix of bagasse and an appropriate binder yields blocks of adequate strength for handling and transport. The optimum range of molasses added to bind bagasse blocks was found to be in the range of 33 to 40 per cent by mass. Other binders were also tested, filter cake and clay emerging as technically viable alternatives to molasses. With either of these binders, the recommended ratio is 20 per cent of the total mass of block. Though filter cake and clay are available at no cost, adding greater amounts to blocks has no practical advantage in terms of handling strength and it also reduces the calorific value of the block per unit mass.

The objectives of the BENS investigation then became to: 1) find the optimum level for substituting bagasse blocks for fuelwood in brick firing; and 2) investigate the effect of using raw bagasse as an alternative to cow-dung in clay mixed for making bricks. BENS carried out experiments at El Gereif Shark in Khartoum state. Two types of bricks were produced with the Blue Nile clay: bricks with cow-dung as the additive in the ratio 96 clay to 4 dung; and bricks with raw bagasse as the additive. A clamp with a capacity of 80,000 bricks was used for the experiments. Normally, such a clamp consumes around 2.7 tonnes of firewood. In addition to the additive tests, bagasse blocks were used as substitute for 50, 65 and 80 per cent of fuelwood in a series of tests. The calorific values of fuelwood and bagasse blocks were measured at, respectively, 19 and 17 MJ/kg.

Results suggest that the use of bagasse blocks as a substitute for fuelwood is technically viable and has no adverse effect on brick quality. In fact, brick quality seems to improve with the percentage of bagasse blocks used. This may be because the distribution of the blocks in the kiln gives a more favourable time–temperature firing condition, i.e. a greater percentage of blocks used as a substitute for fuelwood means that more of the fuel is in closer contact with bricks and so they are better fired. The BENS study did, in fact, conclude that the use of bagasse blocks as a substitute for fuelwood resulted in better heat distribution within the clamp. Firing bricks with fuelwood alone results in a hot but relatively brief blaze. Consequently, energy is lost in flue gases while bricks are not maintained at temperatures commensurate with vitrification for long enough. Bagasse blocks cannot 100 per cent replace firewood, however. They are difficult to light and do not burn well in the firing tunnels. If tunnels are maintained as the technology for primary ignition of the clamp, then a proportion of fuel suitable to burning in this manner must be used.

The limiting factor on this technological innovation, the BENS investigation concluded, would be the availability of affordable and sufficient supplies of molasses. At present the cost of molasses renders bagasse block technology economically non-viable. BENS recommend further work on the use of filter cake and clay as binders in bagasse block production. With respect to using bagasse as an additive in the clay mix in place of cow-dung, no adverse affect on

Table 5.18 Experimental design

Clamp no.	Additive	Firewood Tonnes	Firewood %	Bagasse blocks Tonnes	Bagasse blocks %	Firing time (hours)	Cooling time (days)
1	Dung	2.70	100	0.00	0	3.00	5.00
2	Dung	1.35	50	1.51	50	4.00	5.00
3	Dung	0.95	35	1.96	65	5.50	5.00
4	Dung	0.54	20	2.41	80	8.00	5.00
5	Bagasse	2.12	100	0.00	0	3.00	5.00

Source: BENS, 1996.

Table 5.19 Quality of bricks produced

Clamp no.	Additive	% firewood	Brick quality category: 1st class (%)	Under-fired (%)	Over-fired (%)
1	Dung	100	87	10.00	3.00
2	Dung	50	90	9.00	1.00
3	Dung	35	96	0	4.00
4	Dung	20	97	2.00	1.00
5	Bagasse	100	96	1.50	2.50

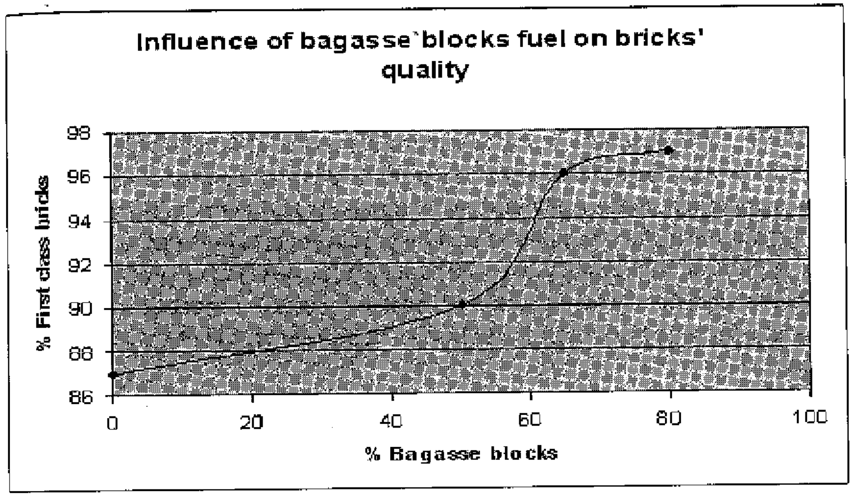


Figure 5.4 Influence of bagasse block fuel on brick quality. Contact Practical Action Sudan for further data.

Table 5.20 Physical properties of bricks produced

Clamp No.	*Additive*	*Brick dimensions (mm)*	*Water absorption (%)*	*Compressive strength (kg/cm²)*
1	Dung	191 x 95 x 48	33.30	31
2	Dung	192 x 91 x 48	23.80	33
3	Dung	189 x 93 x 48	34.90	37
4	Dung	198 x 98 x 48	31.10	29
5	Bagasse	199 x 96 x 48	33.90	33

Source: BENS, 1996.

higher than that of cow-dung (13.30 MJ/kg). As a fuel substitute, therefore, proportionally less mass can be incorporated into the clay mix for a similar firing regime. Alternatively, if brick quality could be maintained, the mass of additive could be kept constant and primary fuel use reduced.

In 1997, ITDG/Practical Action Sudan implemented an integrated technology project in Kassala State, Eastern Sudan (Hood, 1999a). A major component of the project concerned shelter and building materials. The work on building materials aimed at addressing two problems faced by producers, substantively brickmakers: 1) the high cost and scarcity of fuelwood; 2) poor or variable product quality. Hence, Practical Action set about investigating the use of furnace oil as substitute for firewood in firing bricks and the effect of cow-dung on the physical properties of bricks

In Kassala the combination of clearing land for mechanized farming schemes along with other economic activities, particularly charcoal production, has led to deforestation and southward desertification. Firewood scarcity means it must be hauled over long distances from the Ethiopian border and Blue Nile province. Previously, the Miskit tree (*Prosopis*) was introduced to combat deforestation and desertification. Unfortunately, this strategy turned out to be a big mistake. Miskit depletes scarce groundwater and has encroached arable land. It has become a weed and is an enormous nuisance. The government has made it policy to eradicate Miskit nationwide. Thus, it can be cut indiscriminately for use as firewood or in charcoal burning. It can also simply be burned in situ to no productive end. Nowadays, firewood and charcoal production from Miskit provides livelihoods for tribesmen around Kassala who have lost their livestock wealth during the successive periods of drought. Competition for Miskit between the brick industry and the household sector is manifest.

Practical Action in Sudan judged the traditional brick clamp unsuitable for oil firing. In Kassala, they therefore opted to conduct trials with a small down-draught or vault kiln. In 1995, the trial kiln was duly built. Initially, however, there were problems with both the compressed air system and also the electric motor required. In addition, the kiln design had to modified. Hence, trials could not begin in earnest until the following year. Results indicated that using furnace oil was some 1.2 times more expensive than firewood. As the price of furnace oil looked set to increase and secure supply was also becoming a problem, trials were discontinued (Bairiak, 1997).

With respect to the effect of using cow-dung as an additive, results for both slop- and sand-moulded bricks indicate similar trends. As the organic matter in cow-dung is consumed during firing it leaves voids in the brick. These voids increase porosity and hence water absorption. Density, mass and compressive strength are concomitantly reduced. The absence of a Sudanese technical standard on bricks makes it impossible to propose an optimum percentage value for the use of cow-dung. In practice, though, Practcial Action in Sudan estimates that, whichever moulding process is employed, including between 20 and 30 per cent of cow-dung in the mix yields bricks of still satisfactory quality.

Table 5.21 Effect of adding cow-dung on brick properties

Sample	% dung	Strength (N/mm²)	Water absorption (%)	Mass (kg)
A. Slop moulding				
1	9.09	3.13	25.11	2.03
2	16.67	1.99	28.07	1.80
3	23.08	2.10	29.64	1.68
4	28.57	4.25	22.52	1.74
5	33.33	2.26	30.53	1.60
6	37.50	1.50	35.13	1.66
7	41.18	0.61	32.20	1.46
8	44.44	2.61	25.00	1.51
9	47.37	0.88	40.55	1.44
B. Sand moulding				
1	4.76	6.16	24.56	2.0
2	13.04	4.25	23.28	1.90
3	20.0	3.24	28.45	1.76
4	25.93	1.75	32.54	1.64
5	31.03	1.6	34.17	1.68
6	35.48	2.5	24.96	1.65
7	39.39	1.42	38.23	1.49
8	42.86	2.58	30.56	1.45
9	45.95	2.23	31.82	1.60

Source: Bairiak, 1997.

yielded bricks with superior properties to slop-moulding throughout the range of tests.

Practical Action Sudan instigated trials on the use of loose rotted bagasse as an alternative to cow-dung in brickmaking (Bairiak, 1998) and the use of bagasse blocks as a substitute for firewood. In a typical test, 118,000 green bricks were built into two similar sized clamps. For ignition purposes, the tunnels of both were filled with firewood (Miskit wood). The control clamp was then fired using only Miskit wood burned in the tunnels. Firing continued for 26 hours and a total of 5.83 tonnes of wood were consumed, being added at intervals of between 0.5 and 1.5 hours. After ignition with wood, the second clamp was fired with bagasse blocks for 23 hours. In this time it consumed 1.44 tonnes of wood and 3.53 tonnes of bagasse blocks. The latter were fed into tunnels at time intervals of 3 to 4 hours. The trial was controlled via sets of Buller's bars being placed into both clamps at a comparable range of locations. Because deformation actually depends on a temperature being maintained for a sufficient time, Buller's bars which sag at nominal temperatures are commonly used in the ceramics

Table 5.22 Summary of clamp performances

Bricks	*Wood fired clamp*		*Bagasse block fired clamp*	
	Quantity	*%*	*Quantity*	*%*
Grade 1	35,700	64.91	42,040	66.73
Grade 2	9,000	16.36	9,520	15.11
Over-burned	2,850	5.18	3,470	5.51
Under-burned	6,000	10.91	7,000	11.11
Broken	1,450	2.64	970	1.54
Total	55,000	100.00	63,000	100.00
Firewood (tonnes)	5.83	1.44		
Bagasse (tonnes)	0.0	3.53		

Source: Bairiak, 1998.

17 bar sagged, indicating the attainment of a particular time–temperature function. By the time these bars sagged, physical indicators of complete firing were also visible: clamp height had dropped, the uppermost layer of bricks had taken on a whitish colour, emissions of smoke had all but ceased, and the insulating layer of mud had blackened and cracked. Clamps were left to cool for seven days before dismantling.

Using bagasse blocks as the principal fuel was a technical success. The percentages of Grade 1, Grade 2, over-burned and under-burned bricks produced in each clamp are very similar, while the percentage of broken bricks is somewhat lower in the clamp burning bagasse blocks. Where the technology flounders, once again, is when costs are compared. In short, the cost of transporting bagasse blocks from Halfa to Kassala, some 70 km, gives firewood a financial edge. Though it is only some SD2.62 per brick, on a 40,000 brick clamp this amounts to SD104,800 (approximately US$400). Brickmakers themselves concluded that loose bagasse was preferable to cow-dung as an additive in the clay mix. Bagasse is fine and does not have an offensive smell when wet. Dung smells and usually contains lumps that do not break down easily and leave voids in fired bricks. This effect can also mean that bricks with loose bagasse additive have smooth surface finish in contrast to that of bricks containing cow-dung, which appear pockmarked.

Having investigated options of fuel substitution and found these to be limited by financial and supply problems, Practical Action instigated trials with a different kiln technology (Hood, 1999c). The permanent, thermally insulating structure of a Scotch Kiln make it possible to achieve greater energy efficiency than when using a clamp. Furthermore, losses of under-burned bricks, which typically originate around the outer walls of the clamp, can be reduced in a Scotch Kiln for the same reason. The firing process in Scotch Kilns can also be made more controllable than it can with a clamp. Air intake can be varied and

Table 5.23 Energy consumption and costs compared

1. Energy Additive	*Wood fired clamp* Fuel Loose bagasse	Additive Miskit wood	*Bagasse block fired clamp* Fuel Loose bagasse	Additive Miskit wood	Bagasse blocks
Calorific value (MJ/kg)	19.17	19.35	19.17	19.35	18.66
Quantity used (kg)	6,286	6,827	7,200	1,039	3,325
Energy (MJ)	120,503	132,103	138,024	20,105	62,045
Total energy (MJ)	252,606	220,174			

	Wood	Bagasse block
(A) Cost/brick including transport of fuels (SD)	11.17	13.79
(B) Cost/brick excluding transport of fuel (SD)	6.56	4.21

Source: Bairiak, 1998.

if chimneys are incorporated, dampers can be used to attain even greater control. Practical Action constructed a Scotch Kiln in Kassala, the first in the area. Members of Shambob Bricks Production Co-operative, SBPC, trained in the operation of the kiln (Hood, 1999a,b,c). Very unfortunately, due to resource constraints on the project, it was only possible to test one kiln firing with what was then the new energy monitoring methodology; the results were promising, however.

Concluding remarks

From a technological point of view, the use of bagasse, both in block form as a replacement for fuelwood and as an additive alternative to cow-dung, is a success. Environmentally too, these technologies would seem to be valid measures to counteract deforestation at the local scale, desertification at the regional scale and greenhouse gas emissions on the global scale. Unfortunately, the high cost of transport combined with no effective restriction on cutting trees for fuelwood means the technology is not financially viable at brickmaking sites that are distant from the source of supply. In areas where Miskit wood is available,

Table 5.24 Annual fuelwood consumption by traditional industries

	Brick industry	*Lime burning*	*Bakeries*	*Other industries*	*Total*
Fuelwood consumption ('000 toe)	139.32	14.04	157.38	10.4	321.14
Forest cleared	2,429	243	2,738	181	5,591

Figure 5.5 Energy monitoring form, SBPC, Kassala

Name of producer: SBPC (Shambob)	Location/address: C/O IT-Kassala	Dates and time of firing: Start: 7 April 1999 at 14:00
		Finish: 8 April 1999, at 18:00
Type of kiln: Scotch	Type of fuel: 1) Firewood (Miskit wood) &	Mass of fuel used: Firewood: 15.62 tonnes
	2) Bagasse blocks	Bagasse blocks: 3.1 tonnes
Calorific values:	Number of bricks in kiln:	Average mass per brick:
Firewood: 19.71 MJ/kg	96,000	Green dry: 2.11 kg
Moisture content 25.8%		Fired: 1.91 kg
Bagasse block: 19.17 MJ/kg		
Dry brick moisture content:	Method of forming bricks:	Weather conditions:
2.2 %	Slop moulding	Very dry and hot summer, variable wind speed
Calculation of Kiln Efficiency:		Qualification information:
Mass of green (sun dry) bricks: 202,560 kg		Soil vitrification category:
Mass of dry bricks: 198,103 kg		Normal < 1000°C
Total moisture content: 4,456.3 kg		
Drying energy: 11,546,273.3 kJ		Buller's bar No: 17 (990°C)
Total energy used: 287,649,688.4 kJ		
Firing energy: 276,103,415.1 kJ		Average firing temperature
Mass of fired bricks: 183,360 kg		1,000°C
Specific firing energy: 1.51 MJ/kg		Firing time: 28 h

Notes: Firewood moisture content was quite variable (supply from different sources at different times) ranging between 6.53 and 37.1%; An average figure of 25.84% was used in calculations.

Comments: The quality of output bricks was quite satisfactory (more than 65% Grade 1). However, kiln firing time was very short because wood was fed to the kiln too rapidly. This led to the development of hot spots and bricks melting. Rapid firing also meant that the soaking period was short, which led to under-burned bricks at the top of the kiln. All these factors generated considerable losses (11.3%), mainly in the form of broken and over-burned bricks.

Recommendations: The firing time should be increased by reducing the firewood feeding rate, particularly on the first day of kiln firing. Also, the soaking period should be increased to a minimum of 12 hours after fire reaching the top of kiln.

Source: Hood, 1999 a,b,c

moreover, it is both government policy and an environmental necessity to reduce its prevalence.

Despite these macroscopic points, on the local level SBPC in Kassala are prospering. Through the operation of the Scotch Kiln and, when costs render it viable, replacing up to 75 per cent of their fuelwood with bagasse blocks, SBPC

creditworthiness. In the year following Practical Action's intervention income increased by 20 per cent. The following year it was up 60 per cent on the initial baseline. Practical Action's thoroughgoing training involvement has helped SBPC to produce bricks that are more regular in shape and better burned, and which therefore find a good market.

One lesson Practical Action Sudan have wholly taken on board is the benefit to both parties of deeply involving producers in research. Local skills and resources are vital assets that must be nurtured and built upon rather than rejected in favour of technologies from elsewhere. That is not to say there is no scope to consider exogenous technologies, but rather that these need to be appraised and adapted to the local context. In this particular project, bagasse had been tried elsewhere in Sudan and it was possible for brickmakers to appreciate and build on the knowledge of that history which Practical Action could offer. Replacing either fuelwood or cow-dung with bagasse does not involve incomprehensible or unrecognisable technical change. Brickmakers are quick to adapt to different methods and procedures as they see how the new material performs in practice. The Scotch Kiln is, by the same token, a clear development of clamp technology that can be readily appreciated.

CHAPTER 6
Trials with boiler waste in Zimbabwe

Lasten Mika

Land and climate

Covering an area of 390,000 km, Zimbabwe is a landlocked country with an estimated population of 11.87 million. The majority of people live in rural areas but around 40 per cent live in towns and cities. To the south Zimbabwe is bordered by South Africa, to the north-west by Zambia, to the south-west by Botswana and to the north-east, east and south-east by Mozambique. Zimbabwe

is divided into 10 provinces and 57 districts and the major cities are Harare, Bulawayo, Chitungwiza, Mutare, Masvingo and Gweru.

Access to the Indian Ocean is via the ports of Beira in Mozambique and Durban in South Africa. Communication systems are generally good and the road network is fairly good with major cities and towns connected by tarred roads. The national railway system runs for about 3,400 km and connects Zimbabwe with its neighbours.

Climatic conditions are substantially influenced by altitude and there are two characteristic seasons, cool and dry winters and hot and wet summers. The winter season runs from May through July, whilst the summer season lasts from August through April. The national average minimum temperature is 15°C and the maximum is 45°C. Annual rainfall varies quite widely from region to region, but the national average is 400 mm. Rainfall is highest on the High Veld with an average annual precipitation of up to 1,020 mm. The Middle Veld, meanwhile, receives 410 to 610 mm and the Low Veld less than 400 mm.

Zimbabwe has three distinct topographical regions, namely the High, Middle and Low Velds. Dominated by a limestone ridge known as the Great Dyke, the High Veld stretches from south-west to north-west and rises to between 1,200 and 1,600 metres above sea level. The Middle Veld has an elevation of between 900 and 1,200 metres. The Low Veld is below 900 metres and accounts for around 20 per cent of the land area. Major rivers are the Sabi, Lundi, Zambezi and Limpopo. Victoria Falls is located in western Zimbabwe, on the border with Zambia, and is one of the most spectacular waterfalls in the world.

Table 6.1 Land use in Zimbabwe

Land tenure	*Total area in hectares (1996)*	*Total area in hectares (2004)*
National parks	5,045,490	5,045,490
Forest land	1,335,157	1,335,157
State land	205,255	205,255
Communal land	15,445,686	15,445,686
Resettlement area	3,958,276	5,343,126*
Small Scale Commercial Farming Area (SSCFA)	1,122,781	1,122,781
Large Scale Commercial Farming Area (LSCFA)	11,893,668	10,508,418
Town	99,077	99,077
Total	39,000,000	39,000,000

* The figures are estimates from an unpublished report by Agritex. Hence the 400 Ha discrepancy.

Sources: Ministry of Lands Annual report for 2004, Ministry of Lands, Harare.

Unpublished data base sources from Ministries and Departments: Agricultural Research

People and nation

Zimbabwe has four main ethnic communities: Black Africans who account for the majority of the population; Whites or Europeans; Coloureds who are of mixed African and European or Indian descent; and Asians. Most Africans belong to one of two major tribal groups, the Shona who account for 71 per cent of the population and the Ndebele who constitute 16 per cent. The country's provinces are also divided along ethnic lines: Matabeleland being predominately Ndebele-speaking, Mashonaland Shona-speaking, the Midlands both Shona- and Ndebele-speaking, while Manicaland is home to a third tribal group, the Manica, and is predominately Chimanyika-speaking. Across the country a host of other minority tribal groups and languages are found, including Venda, Zulu, Sotho, Kalanga, and Tswana. Languages and cultures freely migrate across the nation-state borders that restrict the movement of people: Ndebele to the south is shared with people in South Africa and Botswana; in the east Ndau and Chimanyika are shared with people in Mozambique; and Tonga to the north crosses and re-crosses the border with Zambia. The official language nationwide in Zimbabwe is English, however. Around 45 per cent of the population are nominally Christians, while Muslims account for just 1 per cent, and the remainder follow either indigenous religions or a Syncretist faith, which is a synthesis of Christian and indigenous beliefs.

A former British colony, Zimbabwe was once ruled by a white minority who controlled the bulk of the economy, including industry, land, mines and commerce. During the 1960s the political movements Zimbabwe African National Union (ZANU) and Zimbabwe African Patriotic Union (ZAPU) launched guerrilla offensives, collectively known as Chimurenga (The Struggle), against the government. The major causes that they fought for were equitable land distribution and democracy. At the Lancaster House Conference in 1979, the warring parties agreed to the formation of a new government. On 18 April 1980 Britain recognized the country's independence as a Republic within the Commonwealth. Robert Mugabe, the ZANU leader, became Prime Minister and Rhodesia officially changed its name to Zimbabwe.

While ZANU was a mainly Shona movement and thence political party, ZAPU was principally an Ndebele organization. Political unrest in 1983 resulted in government troops cracking down on dissident activity in Matabeleland, allegedly the work of ZAPU supporters. Though the scale of the violence that followed is still contested, a great many Ndebele people were undoubtedly massacred by the largely Shona army acting on the authority of a mainly Shona government headed by a Shona Prime Minister. Some observers claim that this infamous military operation, known in Ndebele as Gukurahundi, amounted to ethnic cleansing or attempted genocide. Certainly, it is a terrible landmark in Zimbabwe's post-colonial history. Military action and opposition to it effectively ended with the signing of a peace agreement between ZANU and ZAPU in 1988.

In December 1990 legislation was passed that allowed for the confiscation of White-owned farms with compensation to be determined by the government.

To cut a very long, repressive and bloody chapter short, the country is currently characterized by bad governance and absolute official intolerance of opposition politics and any form of dissent. The government largely blames the West for the catastrophic political and economic situation. President Mugabe is particularly antagonistic towards Britain, which he accuses of attempting to re-colonize the country. Meanwhile, both the European Union and the United States have imposed economic sanctions on Zimbabwe, citing widespread and gross human-rights abuses.

Society and the economy

In the first decade after independence, poverty reduction was a priority for the government and the social sector received the lion's share of the budget. This resulted in the growth of education, health and agriculture. Through the 1990s, however, a combination of poor governance, corruption, inappropriate economic reforms (not least the IMF-imposed Economic Structural Adjustment Programme, ESAP, referred to by Zimbabweans as Even Sadza's A Problem, sadza being the nation's staple food derived from maize), and natural disasters turned back the clock on the nation's social achievements.

The Zimbabwean economy since independence is a tale of two contrasting periods. In 1980 the country inherited a dual economy characterized by a relatively well developed modern sector and a largely poor rural sector that employed 80 per cent of the labour force. This imbalance was addressed by the government through a number of plans and strategies such as Growth with Equity (1981), Transitional Development Plan (1982–85) and the First Five Year National Development Plan (1986–90). According to the *Zimbabwe Millennium Goals Development Report* (2004), policies were aimed at poverty reduction,

Table 6.2 Selected demographic and social indicators

Population (2002)	11.87 million
Population growth rate	1.1%
Urban population as %age of total population (2002)	39.8%
Population under 15 years of age (2002)	40%
Population 65+ years of age (2002)	3%
Average life expectancy (2005)	37 years
HIV/AIDS prevalence rate (2005)	21.3%
Infant mortality rate per 1,000 live births (2004)	78
Average household size (1999)	6.4 people
Literacy rate (age 15–24 years)	97.6%
Unemployment rate (2005)	>50%

Sources: Zimbabwe Millennium Development Goals Progress Report, 2004; Preliminary

improving rural infrastructure and addressing inequalities, particularly via a consensual programme of land reform.

The period 1980 to 1990 is marked by rapid gains in social and economic development. By contrast, the period from 1990 onwards is characterized by widespread and substantial erosion of all the progress achieved. Zimbabwe's catalogue of economic woes makes grim reading: plummeting GDP, upward spiralling unemployment and under-employment, hyperinflation, rapidly declining agricultural productivity, and the failure to implement economic reforms. Real GDP growth rate between 1991 and 1995 averaged 1.5 per cent per annum against a population growth of 2.2 per cent. Hence, there was no meaningful poverty reduction and no employment creation. Against this background, extreme poverty increased significantly during the 1990s. An estimated 35 per cent of households lived below the poverty line in 1995, up from 26 per cent in 1990.

Since 1999, Zimbabwe's economy has been ranked as one of the world's fastest shrinking. Overall, it is estimated that the economy has contracted by around 40 per cent. In 2005, shortages of basic commodities and key inputs, such as fuel and electricity, characterize the situation. These shortages undermine production and increase production costs. The unemployment rate in the formal sector rose to above 70 per cent, while the informal sector ballooned. Poverty levels rose sharply, with 80 per cent of the population living below the 'Total Consumption Poverty Line', according to an UNDP-MDG report. The UNDP ranks Zimbabwe 145th in an assessment of 175 countries.

Home-grown initiatives to salvage the economy, such as the Zimbabwe Programme for Economic and Social Transformation (ZIMPREST) in 1998, the Millennium Economic Recovery Programme (MREP) in 2001, and National Economic Revival Programme (NREP) in 2003, have all been in vain. Bad governance, resulting in the withdrawal of most of the donor community, international isolation, and a lack of resources, have contrived with recurring

Table 6.3 Key economic Indicators

Indicators	*1990*	*1995*	*2000*	*2002*	*2003*	*2004*
GDP growth (%)	7.0	0.2	–8.2	–14.5	–13.9	–2.5
Per capita GDP growth (%)	5.5	–1.3	–7.7	–14.7	–14.1	–
Inflation (%)	15.5	22.6	55.9	133.2	622.4	123.7
Overseas development aid (US$ million)	295.9	347.7	192.6	–	–	–
Net foreign investment (US$ million)	–12	98	16	–0.3	22.6	3.5

Source: Zimbabwe Millennium Goals Development Report, 2004 *(draft)* droughts and floods to undermine efforts at recovery. In curt summary, virtual economic collapse means Zimbabwe currently faces total societal breakdown while the spectre of mass famine looms large.

Environment matters

The major environmental problems facing Zimbabwe are water supply, loss of biodiversity, land degradation and soil erosion. In part at least, these problems are associated with Zimbabwe's colonial past. The Rhodesian era was characterized by social engineering that saw black Africans not needed as industrial labour or domestic servants confined to designated communal lands. These areas were most often marginal lands, not required by the white commercial farmers. Environmentally vulnerable communal lands became overpopulated and under-resourced, resulting in loss of biodiversity, deforestation, land degradation, soil erosion and, in some areas, desertification. In the communal lands, poor farming practices, such as overgrazing and excessive tree felling, exacerbate the natural vulnerability associated with 'thin' or shallow topsoils and slow rates of soil formation. Due mainly to human activity, some 500 million tonnes of soil are reckoned to be displaced annually. This translates to an estimated 50 to 75 tonnes per hectare of soil loss.

In the upheavals through the 1990s and into the new millennium, settlers on land the government has acquired by one means or another have had a significant environmental impact. They have cleared land for agriculture, to obtain wood for building houses, and for domestic fuelwood. Patently, this is exacerbating deforestation and land degradation nationally. While exact figures are unknown, estimates suggest that deforestation ranges between 100,000 and 320,000 hectares per year. This impact is not, however, solely down to land reform and resettlement. In some parts of the country, particularly the eastern highlands, commercial forest plantations are a major industry. In an attempt to meet wood supply needs, the introduction of exotic species, such as eucalyptus, has put further pressure on indigenous species. These exotic trees tend to be fast-growing and demand a lot of water. This leads to a decline in the water table and groundwater supplies, which most affects the less aggressive indigenous species.

Nationwide, there are a number of other environmental impacts worthy of consideration. Droughts and floods degrade cultivated land and rangelands in some parts of the country. This has an impact on plant cover, livestock numbers, and consequently agricultural productivity. In national parks, meanwhile, food shortages have led to an increase in poaching and the decimation of certain species of wildlife. These days, not only are elephants illegally shot for their tusks, but all manner of smaller mammals and birds are shot for meat. Elsewhere, mining operations, including small-scale gold and diamond mining, are also insensitive to environmental impacts. Effluent from mining waste dumps has polluted surface water and the sector has also been responsible for the build-up

impact on the social environment, displacing communities from the ore-rich areas where companies wish to operate. Zimbabwe's main source of carbon emissions is coal burning. Apart from in Harare, air pollution is not considered a serious problem. When there is the fuel to run them, vehicle emissions are a significant contributor to both air pollution and carbon emissions.

The Environmental Management Act (Chapter 20: 27 No 13/2002) of 2004 provides a framework for mainstreaming environment into national policies and programmes. The challenge remains to build capacity at both the national and local levels to ensure effective implementation of the Act as well as link EMA with other legal instruments, such as the Traditional Leaders Act, to make environmental management more effective. Other institutional initiatives that should provide support for operationalizing the principal of sustainable development include:

- consultative and planning forums of the Convention to Combat Drought and Desertification;
- District Environmental Action Plan (DEAP);
- Communal Area Management Programme For Indigenous Resources (CAMPFIRE);
- Water Act;
- Rural Electrification Programme;
- urban and peri-urban councils.

The energy situation

The main sources of energy in Zimbabwe are coal, wood, electricity and petroleum fuels. Fuelwood is estimated at providing the bulk (53%) of the total supply, followed by coal (20%), liquid fuels (14%) and electricity (13%). The energy supply situation is characterized by liquid fuel shortages and intermittent power cuts.

According to the Zimbabwe Power Company, the nation's peak electricity demand is projected to have increased from 2,000 MW in 2004 to over 2,600 MW by 2007. Access to electricity is estimated nationally at around 40 per cent on average, but access in the rural areas is much lower at about 19 per cent. The

Table 6.4 Percentage of households having access to energy sources in Zimbabwe

	Energy for cooking					
	Urban areas		*Rural areas*		*National*	
	Poor	*Non-poor*	*Poor*	*Non-poor*	*Poor*	*Non-poor*
Electricity	73.1	81.9	2.1	11.0	19.0	52.8
Kerosene	39.7	33.7	1.0	13.5	10.2	25.4
Wood or Coal	12.7	5.4	98.6	80.6	78.1	36.3

country currently imports more than 40 per cent of its electricity from neighbouring countries. A shortage of hard currency has meant Zimbabwe defaulting on payments for electricity imported from South Africa, Zambia, Mozambique and the Democratic Republic of Congo (DRC). The resultant power shortage has forced the government to introduce load-shedding, i.e. scheduled power cuts. Load-shedding has impacted negatively on the productive and service sectors, threatening their viability at a time when the economy needs them most. In the long term, in any event, Zimbabwe cannot rely on meeting its needs by importing regionally. By 2007, forecasts indicate that the other countries in the region may not even be able to meet their own needs. Meanwhile, lack of investment and the economic crisis generally means that Zimbabwe is largely unable to maintain or renew its aged power stations and electrical infrastructure. So desperate is the economic situation that thieves have taken to stealing the cooling oil from substation transformers to use in vehicle engines.

The traditional biomass energy sector has continued to play an important role in the energy economy of Zimbabwe. Seventy five percent of the rural population meet 80–90 per cent of their energy requirements from traditional fuels, principally wood. Almost all rural households use wood as their main source of fuel for cooking. In urban areas, as the economic crisis bites ever deeper, wood has re-emerged as a key energy resource for both the poor and also the affluent. This is the direct consequence of shortages of kerosene and LPG along with intermittent load-shedding and a lack of access to electricity, especially in peri-urban settlements. Small enterprises and industry are also significant users of fuelwood. In the informal food industry, wood is the main source of energy with LPG and electricity used only to a very limited extent. In traditional brickmaking, wood is far-and-away the most significant fuel. The main fuel used to cure tobacco, formerly an export mainstay of the economy, is also, predictably, wood.

Annual deforestation in Zimbabwe is estimated at 1.5 per cent of all woodland areas. Principal causes are the clearing of land for agriculture, the extraction of fuelwood for domestic and agro-industrial purposes, timber felling for construction, and forest fires, particularly in times of drought in susceptible areas. Considered on the national scale, there is not yet a shortage of fuelwood. In some rural 'communal areas', however, shortages can be acute. Obviously, these shortages are related to population density and the time period over which the area has been settled.

Zimbabwe does not have known oil reserves. The transport sector relies totally on imported liquid fuels brought in by pipeline from Beira in Mozambique. Kerosene is used mainly in the household sector, but also to a limited extent by industry. The effect of the shortage of foreign exchange has been manifest most dramatically in the petroleum fuels subsector. From about 2000, petroleum fuel supplies have been erratic. Long queues of motorists at fuel outlets have been all too frequent, and images of these epitomize Zimbabwe's

Coal is a major energy resource for Zimbabwe, with extensive reserves to be found at Hwange in particular. Coal provides the bulk of industrial energy and also fuels power stations to produce about 70 per cent of the nation's electricity. Large-scale commercial farmers use coal for curing tobacco. In medium- to large-scale industry, coal is used extensively to fire clay bricks. There is scope for increased coal use in small-scale processing industries such as brickmaking, food preparation and manufacturing. There is little household consumption of coal: the high sulphur content of the indigenous resource makes it particularly unsuitable for use as a fuel for domestic cooking on open fires.

The housing situation

Traditional housing in most of Zimbabwe was built with pole and *dagga*. This material matrix consists of mud and cow-dung plaster spread over a framework of upright poles and interwoven saplings. The roofs of traditional houses are roughly thatched with straw. Brick construction was introduced well before independence, however, and is an established building technology. Even in rural areas, bricks are, or would be, the walling material of choice for many people. The demand for bricks in urban areas has long outstripped supply because there is a critical shortage of housing. In 1985 it was estimated that the urban housing backlog stood at over 1 million units. To alleviate this backlog, the government targeted constructing 162,500 units per annum from 1985 to 2000. Actual annual construction was only in the region of between 15,000 and 20,000 units, however. Since 2000, the construction rate has declined still further. In 2002, for example, only 5,500 house stands were serviced, i.e. provided with water and sewage connections and electricity. According to the *Zimbabwe Millennium Development Goals 2004 progress report*, a quarter of a million houses need to be constructed and serviced annually.

Homelessness is widespread across the country, especially in urban areas. The result is squatter camps or illegal settlements, massive overcrowding in high density suburbs where the majority of poor urban people live, and the proliferation of illegal backyard shacks – 'tangwenas' - that do not have any direct services. This situation has strained the capacity of both central and local government to breaking point. They simply cannot cope with the demands on the infrastructure of towns and cities. The number of people deemed to be living in slums is estimated at 157,000. In 2005, a programme of demolishing dwellings that the government judges illegal has exacerbated the problem. Politically motivated, the programme was an attack on urban supporters of the main opposition party, the Movement for Democratic Change (MDC). People made homeless, often having been forced to demolish their own homes, have been directed by government to return to their traditional homes in the communal lands. This does not approach any sort of solution to the housing crisis, however. Communal lands do not have the resources to house or employ the influx of refugees, which was why many people migrated to cities in search of work in

The government's urban slum demolition drive in 2005 drew more international condemnation. The president said it was an effort to boost law and order and development; critics accused him of destroying slums housing opposition supporters. Either way, the razing of 'illegal structures' left some 700,000 people without jobs or homes, according to UN estimates. (BBC, 2005)

Brick production

The fired brick industry has been dominated by large-scale plants. Bricks are heavy and so the cost of transport plays a part in the location of these plants. Hence, most are located in areas with suitable soils that are fairly near urban centres of demand. The early 1990s witnessed the emergence of some medium- and small-scale producers, complementing rather than competing with large-scale plants. Demand for bricks in 1991–92 stood at 800 million bricks while annual production was only 350 million. At that point in time, moreover, demand was increasing at the rate of 15 per cent annually. The shortfall in production obviously meant a shortfall in supply and the price of bricks increased dramatically, attracting the interest of entrepreneurs on a range of scales. One of the barriers to market penetration by small-scale producers has been the punitively high standards put in place before independence. These are based on British standards and are inappropriate for many indigenous construction needs. In 1992 the Mugabe government finally relaxed the standards applying to building materials that can be used in urban areas. This opened up a market for so-called 'farm bricks' from small-scale peri-urban producers.

The brickmaking industry in Zimbabwe can be broadly classified into three scales of enterprise. Large-scale plants are categorized as those that produce, or could produce, over 30,000 bricks per day. Production of bricks on this scale is quite mechanized, employing mechanical diggers in the excavation process, mechanized crushing and size screening, extruding plant, and conveyor belts and motorized vehicles in the handling process. Manual labour is typically restricted to loading and offloading kilns. Most large-scale producers use beehive kilns, though some employ Hoffman Kilns, tunnel kilns and even large clamps. The most common fuels used are coal and coal-dust. Major brickworks are situated near the capital, Harare, and also near the largest city in Matebeleland, Bulawayo.

Medium-scale plants are considered to be those that produce between 10,000 and 30,000 bricks per day. Generally, the equipment used is similar to that used by large-scale producers, the differences being the age and condition. This scale of enterprise usually relies on second-hand equipment and is therefore prone to frequent breakdowns that obviously have an adverse effect on productivity. Clamps or scove kilns (i.e. a brick clamp that has firing tunnels built into it) are the principal firing technology because they require no capital investment in infrastructure. Once again, the main fuels used are coal and a limited quantity of

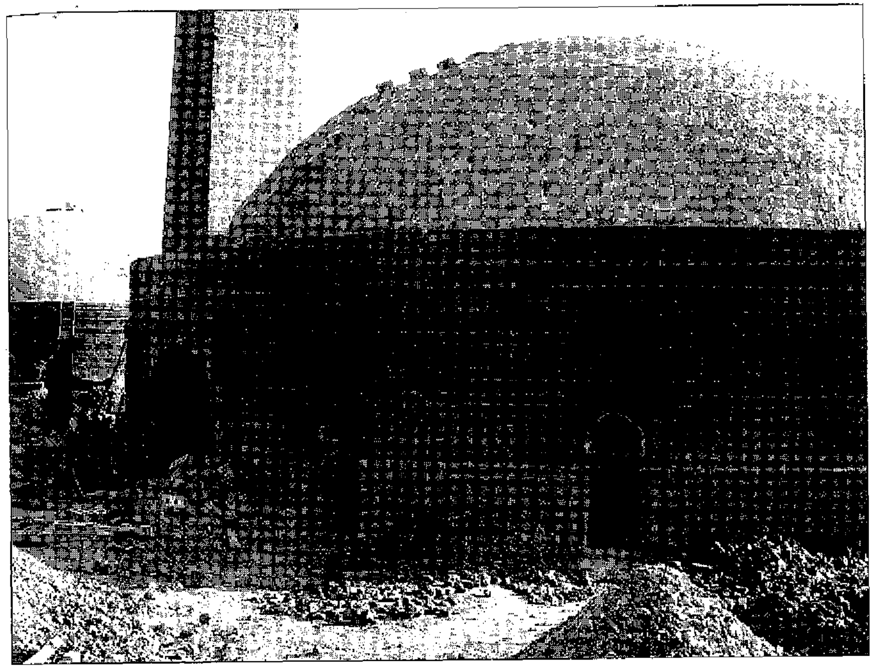


Photo 6.1 Zimbabwean beehive kiln. Credit: Lasten Mika.

coal-dust. Production is continuous throughout the year, with green bricks and unfired clamps being covered with plastic sheets during the rainy season.

Small-scale brickmaking enterprises are those that produce less that 10,000 bricks per day. Operations are characterized by being labour-intensive from excavation through to offloading of the clamps. A typical clamp would contain about 30,000 bricks, but they range in capacity from only perhaps 5,000 to 50,000 bricks. Some mechanization can be observed in the moulding process, where a few enterprises have introduced manual presses. In the main, though, the traditional slop moulding method is employed. The moulds used vary in size, resulting in bricks of somewhat variable dimensions being produced in different parts of the country. Typically, bricks are fired in scove kilns. The main source of fuel is wood, though, in a limited number of cases, coal, coal-dust and boiler waste are employed. The number of people involved in the production of bricks in each enterprise varies from just two up to perhaps ten workers. Brickmaking is seasonal with production typically suspended during the rainy season, a long lay-off that for many brickmakers may well last from November to March.

'Farm bricks' is the generic term used to describe the type of brick produced by small-scale enterprises in Zimbabwe. Brickmakers obviously choose their working sites because the clay available there is suitable to purpose. With very small-scale rural producers, the site chosen is often close to an anthill. Soil from

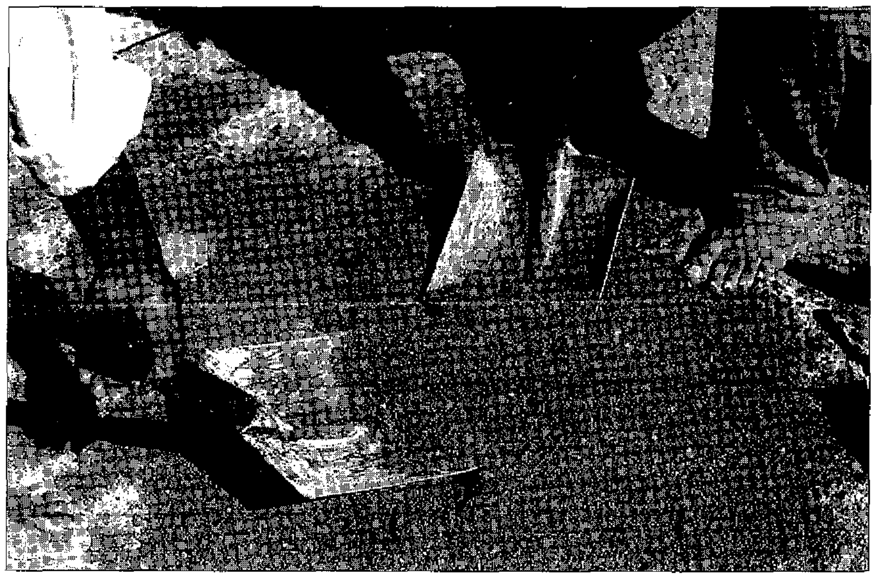
Table 6.5 Relative brick quality and energy requirement

	Large-scale	*Medium-scale*	*Small-scale*
Avg. density green bricks (kg/m³)	1,775	1,760	1,600
Avg. density fired bricks (kg/m³)	1,700	1,600	1,550
Water absorption by mass (%)	14.00	16.50	17.00
Avg. compressive strength (MPa)	14.00	13.50	6.00
Relative energy requirement	2.00	1.04	1.00

Source: Practical Action Zimbabwe.

soils that tend to have the right proportions of sand and clay because that is what is required to build their homes. Moreover, the soil in anthills is homogenized, free from lumps and stones. Traditionally, testing the suitability of soils for brickmaking is a process of trial and error whereby a few sample bricks are moulded and baked in an open fire. At some sites, in rare instances, it is necessary to modify the clay/sand balance of the soil. In general, this is only worthwhile when soils contain too much clay but there is an available source of river or pit sand not too far away.

Before moving on to Practical Action's project intervention, it is worth considering the processes involved in small-scale production in a little more detail. Brickmakers excavate soil using simple hand-tools, picks and shovels. The clay then is transported in wheelbarrows to the mixing place where water is added. There is no crushing, sieving or tempering of the soil. Moulding



typically involves placing a wet mass of clay in a wooden mould with three brick compartments. The moulder stands in a pit up to the waist and moulds bricks on the ground. Excess clay is removed from the top of the mould with a wooden scraper. A labourer then carries the mould to a clean and level drying area where the bricks are demoulded. Wet bricks are spaced to allow for air circulation and are left to dry for between three and five days, depending on weather conditions. The half-dry or green bricks may then be stacked to dry more fully. Traditional brickmakers may, however, begin to build the half-dry bricks into a scove kiln after only a few days of drying. The scove kiln has firing tunnels built into its base and when complete is 'scoved', i.e. plastered with soil and water mixture. Sometimes brick rubble from the breakages of previous firings is used to cover the top of the scove kiln. The kiln is then fired with wood burned in the tunnels. Ideally, a slow fire is maintained for some time to fully dry the bricks. The intensity of the blaze is then increased and maintained for a period. Finally, brickmakers stop feeding wood to the fire and the kiln is allowed to cool naturally before being dismantled, typically after a week or more.

The environmental impacts of brickmaking include the land and landscape degradation that can result from clay extraction, local air pollution and the emission of carbon dioxide. A concern with small-scale brickmaking is the open pits left when brickmakers vacate a site. These are a danger to people and animals. Moreover, small-scale brickmaking certainly contributes to deforestation, which is particularly critical in the fragile ecosystems where such operations tend to be sited. As Table 6.6 indicates, the contribution to air pollution and carbon dioxide by small-scale brickmakers appears negligible when compared nationally to that of large- and medium-scale producers. Local environmental impacts are perceived as most severe where there is a high concentration of production units on the fringes of an urban area.

The intervention of Practical Action

One impact of IMF-imposed economic structural adjustment programmes in the early 1990s was to increase unemployment, with many jobs cuts occurring in Zimbabwe's still extensive civil service. This forced many people to seek alternative work outside the formal sector. Given the shortage of bricks and the opportunity for income generation, brick production was one sector that attracted a number of people, both entrepreneurs and labourers. New and augmented small-scale production facilities encountered a number of obstacles,

Table 6.6 Environmental impacts of the brickmaking industry

	Large-scale	*Medium-scale*	*Small-scale*
Emission of carbon dioxide per annum (kg x 10^6)	3.5	1.25	<0.25
Sulphur dioxide emissions per			

Box 6.1 Assessment of brickmaking at Price Busters

An assessment was carried out at Price Busters Brick Company in 1996. The assessment was made to determine the pollution levels and the energy efficiency of the kilns and other processes. Emission levels measured included carbon monoxide (CO), carbon dioxide (CO_2), sulphur dioxide (SO_2), nitrogen oxides (NO_x) and particulate emission (PM-10).

The company employed 450 workers who worked two shifts per day. It has two extrusion machines each producing 60,000 bricks per shift. Three types of burning kilns are used: beehive, Hoffman and field clamps. Coal is the energy source.

On-site observations showed that the raw materials were not well defined and the lack of specifications was contributing to high losses. The extrusion machines were too old (over 50 years) affecting productivity due to frequent breakdowns.

Test results

Beehive kiln	*Measured value*	*Standard*
PM-10	87 mg/m³	115 mg/m³ (Zimbabwe)
SO_2	0.422 ppm	0.03 ppm (NAAQS)
CO	230 ppm	9.0 ppm (NAAQS)
CO_2	2215 ppm	35 ppm (NAAQS)
NO_x	0.153 ppm	0.053 ppm (NAAQS)
Field clamp	*Measured value*	*Standard*
PM-10	87 mg/m³	115 mg/m³ (Zimbabwe)
SO_2	0.51 ppm	0.03 ppm (NAAQS)
CO	180 ppm	9.0 ppm (NAAQS)
CO_2	1840 ppm	35 ppm (NAAQS)
NO	0.215 ppm	0.053 ppm (NAAQS)

- Efficiency of coal combustion was quite high
- Dust emissions higher than level permitted by National Ambient Air Quality Standards (NAAQS)
- Gas pollutants were higher than allowed limits

however. Inappropriate standards meant that, if they wished to supply the potentially lucrative urban market, these enterprises were obliged to produce bricks that could be classified as 'commons'. In general, producing bricks with the compressive strength and water absorption demanded by the commons standard is not beyond small-scale brickmakers. Production of commons does mean a step change in technology, however, particularly with respect to quality control.

At the time, interest rates were high, discouraging brickmakers from taking loans to make capital investments in, for instance, moulding machines or kilns. Intermediate technologies were potentially an appropriate means of production for small-scale producers. Characterized in part by relatively low investment costs, such technologies presented the possibility of making the step-up from conceptualization of a Practical Action building materials project in Zimbabwe. The project focused on three main areas of small-scale brick production:

- increasing brick quality;
- introducing alternative fuels;
- improving firing techniques.

The economic rationale for improving brick quality at the time has been outlined already. Practical Action staff also recognized from the project's inception that increased brick production on the scale required nationally would mean an untenable burden on forests and woodlands. If wood continued to be the main fuel used by the small-scale sector, the predicted increase in demand could critically exacerbate the already acknowledged environmental problem of deforestation, subsequent land degradation and soil erosion. Domestic demand for fuelwood meant that these problems would tend to be most acute in exactly the areas where brickmakers worked. Thus, the project focused on identifying alternative fuels. Much the same reasoning vis-à-vis deforestation, gave rise to the focus on improving firing techniques, i.e. increasing energy efficiency as well as ensuring bricks were sufficiently fired to meet the quality standard. Traditional small-scale brickmaking technology tends to be very inefficient and thus energy-intensive and damaging to the environment, specifically in terms of deforestation and carbon dioxide emissions.

The project was implemented both via training centres and through existing brickmaking enterprises. At the training centres, improved brickmaking was integrated into construction-related courses. This was a deliberate strategy designed to ensure that graduating students disseminated the technology when they returned to their home areas. A number of training centres across the country became active project partners: Fambidzanayi (Harare), Mupfure (Chegutu), Kaguvi (Gweru), AVOCA (Plumtree), Hlekweni (Bulawayo) and Chipiku (Bikita). The other strand of the project was work with existing brickmaking cooperatives, notably Kuwirirana, located in a high-density suburb of Harare, and Kurehwasekwa, situated in Epworth, a largely illegal settlement on the fringe of Harare. The objective of this strand of the project was to pilot small-scale brickworks capable of supplying the urban market and doing so as viable businesses, capable of record-keeping and ultimately formalizing their operations. In other words, enterprise development was as important an element of the work as technology change.

As a first step, studies were made with small-scale brick producers to identify the causes of inferior brick quality. One conclusion was that the method of moulding needed to change in order to meet the required common standard. Slop-moulding made it extremely difficult to reach the required compressive strength, water absorption and dimensional accuracy. Manually operated brick-moulding machines were therefore imported for trials, with a long-term view to their local manufacture. The first institution to adopt such technology was Mupfure College, located south of Harare. The first machine extensively tested

to be performed at a comfortable working height. A clot of prepared soil is thrown into a chamber lubricated to facilitate release of the moulded brick. Closing the chamber lid and giving the clay a forming press via the mechanism of a foot pedal ensures the brick is dimensionally accurate with sharp edges and corners.

It is good soil preparation prior to moulding and effective firing that exert most influence on the brick's compressive strength and water absorption, however. The results of trials at Mupfure led Practical Action to design, make and test a table for sand-moulding that had no moving parts to wear out. Once appropriate local materials had been identified, this moulding table design proved durable and affordable. Meanwhile, a second moulding machine was imported for test. The Belgian Ceratec press was actually designed for the production of soil blocks, including stabilized soil bricks, SSBs, which are soil-stabilized with a binder, usually lime or cement. Unlike the IT Workshops machine, then, the Ceratec is a bona fide press. Consequently, the soil mixed used to make bricks has to be quite dry; it is not possible to press water. The Ceratec press yielded very good-looking and dimensionally accurate bricks. However, unless the soil used had been thoroughly mixed and moistened beforehand, as well as allowed to dry sufficiently before pressing, there was a tendency for the final product to be rather brittle.

When the project turned its attention to alternative fuels, fuelwood was so scarce around many urban centres that brickmakers either had to buy wood brought in from rural areas or steal from nearby farms and managed woodland. Typically fuelwood from rural areas would travel more than 200 km. Practical Action's first initiative was to pilot the coal-fired clamp as an alternative to the scove kiln in areas, specifically around Harare, where coal was available. Rather than being fired via tunnels at its base, the coal-fired clamp has coal laid between layers of bricks. Otherwise the clamp shape, capacity, building technique and scoving were familiar to brickmakers, so the technology change was manageable. Once the bottom layer of coal is ignited utilizing a temporary external grate, clamp-firing proceeds automatically, though air flow can be controlled somewhat and the clamp can be shielded from winds.

This technology was quickly adopted by Practical Action's cooperative partners and thence, via a programme of peer-to-peer visits and training, to a good number of peri-urban brickmakers nationwide. The main problem with the coal-fired clamp was not technological, in fact, but financial. Dealing with formal coal merchants meant brickmakers had to pay for supplies in advance of firing. Previously, they had, in many instances, been able to pay informal sector suppliers of fuelwood after selling the bricks produced. Though many small-scale enterprises could manage this cash-flow problem, it remained the case that coal was expensive, offering at best only a marginal saving over fuelwood. The main benefit of coal was its relatively constant availability rather than its economic viability. So, Practical Action began to look for other alternative fuels. The huge quantities of boiler ash from Harare's thermal power station presented charge to anyone who wanted to take it away. Luckily for brickmakers, if not for society and the environment in general, the power station is old and inefficient. The boiler ash therefore retains a percentage of unburned carbon and so a calorific value. Practical Action's partners first experimented successfully with using the ash instead of a proportion of coal in the clamp. Thereafter, they also had some success with incorporating boiler ash into the body of bricks.

Table 6.7 Typical calorific values of fuel in Zimbabwe

Fuel type	Calorific value (kJ/kg)
Wood	15,000–18,000
Coal	30,000–32,000
Coal boiler waste	10,000–15,000

In 2005, it was common for peri-urban brickmakers to use both coal and also coal boiler waste when these fuels were available. Apart from thermal power stations, boiler waste is available from tobacco farms and other industries that utilize steam. Unfortunately, suppliers have recognized its value and boiler ash is no longer freely available. It is, though, the cost of transport, and indeed the availability of fuel for transport, that discourages the use of coal.

Practical Action's work in monitoring and thence increasing energy efficiency was cut short by the combination of the crisis in the country and a lack of project funding. A first series of tests using the energy monitoring methodology that was so successful in Peru yielded the results set out in Table 6.8. Fieldworkers recorded: 'There was a large variation in the results obtained

Table 6.8 Results of energy monitoring

Parameter	*Epworth Kiln 1*	*Epworth Kiln 2*	*Epworth Kiln 3*	*Epworth Kiln 4*	*Epworth Kiln 5*
Avg. mass green brick (kg)	3.56	3.60	3.28	4.84	3.55
Avg. mass fired brick (kg)	3.33	3.40	2.93	4.63	3.30
Moisture content green bricks (%)	6.91	7.00	0.50	4.54	0.50
Type of fuel	Eucalyptus	Eucalyptus & boiler waste	Boiler waste	Mix of hard woods	Boiler waste
Mass of fuel (kg)	3,580	1,693 & 1,595	5,093	3,005	5,093
No. of bricks	20,000	20,000	23,245	8,000	18,000
Specific firing energy (MJ/kg)	0.47?	0.50?	0.65?	1.04?	1.17?

Table 6.9 Production cost comparison (Zimbabwe dollars, Z$)

	Wood	*Wood & boiler waste*	*Boiler waste*	*Coal*
Clamp parameters				
Monthly production rate	40,000	40,000	40,000	40,000
No. of clamps fired per month	1	1	1	1
Bricks per month	20,000	20,000	30,000	25,000
Breakage rate per clamp	12	8	2	2
No of bricks available for sale per month	17,600	18,400	29,400	24,500
Fuel input				
Amount of fuel (wood) per clamp	3,580	1,693	–	–
Amount of fuel (waste) per clamp	–	1,597	5,093	–
Amount of fuel (coal) per clamp	–	–	–	2,000
Cost of fuel (wood)	8,950,000	4,232,500	–	–
Cost of fuel (waste)	–	343,200	1,092,000	–
Cost of fuel (coal)	–	–	–	15,500,000
Transport cost (wood)	1,200,000	1,200,000		
Transport cost (waste)		1,200,000	1,200,000	
Transport cost (coal)				1,200,000
Total cost of fuel	**10,150,000**	**6,975,700**	**2,292,000**	**16,700,000**
Labour input				
Cost of 5 people per month	4,000,000	4,000,000	4,000,000	4,000,000
Subtotal costs (direct Inputs)	14,150,000	10,975,700	6,292,000	20,700,000
Fuel as percentage of direct costs	72%	64%	36%	81%
Overheads				
Estimated at 10% of subtotal costs	1,415,000	1,097,570	629,200	2,070,000
Summary				
Cost of brick production	15,565,000	12,073,270	6,921,200	22,770,000
Unit production cost	884	656	235	929
Selling price per brick	1000	1000	1000	1000
Profit per brick	116	344	765	71
Profit margin	**13%**	**52%**	**325%**	**8%**

Source: Practical Action Zimbabwe.

for specific firing energy... This could not give conclusive results and thus further investigations are recommended.' The results for specific firing energy attained in the Epworth tests were so low that they were instantly suspect. For one thing, fieldworkers did not systematically record how well-fired the bricks from the five trial kilns were. Hence, they could make no relative judgement about whether, for example, bricks from Kiln 1 were under-fired compared to Kiln 5. The tests indicated that the builders and operators of the kilns had a major influence on the specific firing energy required. Moreover, fieldworkers suspected significant errors in the data recorded by brickmakers, particularly with respect to the masses of fuels used. Unfortunately, for the reasons given, there was no further opportunity for investigation or for fieldworkers to familiarize themselves with the methodology.

In 2005, Practical Action in Zimbabwe performed a rapid appraisal of the financial implications of using different fuels in brickmaking. The results are recorded in Table 6.9. The indication is that profit margin will vary considerably according to fuel choice. Analysis suggests that wood, a small volume of which was purchased at commercial rates in Harare in 2005, is the most expensive fuel option and boiler waste the cheapest.

Practical Action in Zimbabwe report that a nationwide survey conducted in 2005 shows there is a high level of awareness among brickmakers about the use of coal and boiler waste as alternatives to fuelwood. Many brickmakers were familiar with both coal-fired clamp technology and also the potential for integrating a proportion of the fine fraction of boiler waste as fuel into the body of the brick. As expected, the survey indicated that the factors determining which fuel is used are availability, the cost of fuel, and the cost of transporting it. Practical Action's project intervention has increased the fuel choice options of small-scale brickmakers, which may help to ensure their viability in the harsh socio-economic conditions that prevail in Zimbabwe. There is still much to be done to help brickmakers produce better quality bricks that will command a better price, however. The same is true of increasing energy efficiency, which would benefit both livelihoods and the environment.

CHAPTER 7
The view from Europe

Ray Austin

As a glimpse into the potential future development of some small-scale brickworks in the majority world, it may be illuminating to look at the waste application technologies being used and researched in 'the West'. This chapter reviews what is going around the world, focusing particularly on Europe. It concludes by assessing a number of waste application technologies with current or future interest to small-scale brickmakers and those working to support the sector. Over the years the success of a brickmaking unit, regardless of size, has generally been dependent on the following criteria:

1) the ability to provide an acceptable building material appropriate to meeting the needs of the user and the requirements of local standards;
2) close proximity to the market and supplies of raw materials and resources;
3) acceptable standards achieved at the lowest manufacturing cost.

We could summarize these criteria as product, proximity and price; all must be right. For small-scale brickmakers, using appropriate technology and requiring the minimum of capital outlay are usually determinants of producing bricks at a saleable price. Even in areas of Europe where there has been a long tradition of brickmaking and enterprises are typically larger, it has not been easy to achieve a viable brick plant when there are almost constant changes in markets: competitors innovate and undercut, labour is drawn to other industries where wages are higher or conditions better, there are swings in demand for bricks and competition for resources. To achieve a viable unit, achieving product quality at a saleable price has meant being adaptable and opportunistic, no more so than in the search for raw materials, fuels and usable waste materials. The addition of environmental standards in more recent times has made providing an acceptable product at a competitive price an even more challenging task.

An early example of a viable system with a claim to environmental sustainability was the manufacture of bricks along the southern shore of the Thames Estuary. These bricks were used in the construction of London in the 1800s and early 1900s. They were delivered to the capital city in as many as eighty 'sailing barges', vessels that could sail up the Thames and also navigate the canals and rivers flowing into the Thames. On the return journey the barges would load up with refuse from a site in East London and take this back to the combustible material and added to the clay mix as a fuel source. Also added to the clay mix was the waste from the local factory producing 'whiting'. This waste contained chalk and mica and was beneficial in the brickmaking process. Barges would also go out into the estuary and dig sand from the sandbanks at low tide. This sand was used for de-moulding bricks. The brick-earth itself was dug locally in such a way that the fields were reinstated with topsoil: the field would end up lower but still capable of growing crops. Originally, bricks were made by hand and dried in outdoor 'hacks'. As demand grew machinery was installed and driers built. This system of using waste and local resources continued for nearly a century and the low cost of manufacture enabled affordable housing for Londoners and the tide of people swelling its suburbs.

Unfortunately there is not always such a range of low-cost resources available. Moreover, the increasingly high demand for bricks through most of the 20th century has heralded mass production techniques that are designed to burn conventional fuels. Such fuels have been quick and convenient to burn, requiring little or no preparation. For most of the century in Europe they have also been available affordably and without the stricture of regulation applying to greenhouse gas emissions.

Table 7.1 Costs (UK, 2006) of fuels and wastes

(a) Fuel	*Cost per MJ (pence)*	*Relative cost (coal = 1)*
Natural gas	0.570	2.19
Oil	0.720	2.77
Coal (ex pit)	0.260	1.00
Metallurgical coke (ex works)	0.510	1.96
Wood	0.220	0.85
Electricity	2.220	8.54
(b) Waste-as-fuel		
Rice husk	0.077	0.30
Bagasse	0.088	0.34
Town ash (high calorific value)	0.089	0.34
Paper waste	0.107	0.41
Town ash (low calorific value)	0.129	0.50
Coal slurry	0.142	0.55
Sawdust	0.177	0.68
Straw	0.203	0.78
Metallurgical coke	0.517	1.99
Boiler ash	0.417	1.81
Fly ash	2.000	7.69

Every fuel listed in Table 7.1(a) can be used as a direct fuel in either a continuous or batch kiln with the aid of burners or trickle feed hoppers. Coal and coke can also be used as additives in the clay mix. In most kilns, thus incorporated fuels can supplement the direct-fired fuel. In the case of a clamp, Scotch Kiln or Vertical Shaft Kiln (VSK), coal and coke in the clay mix can provide the entire energy requirement. With the exception of the VSK, which has a high efficiency, the body-added fuel is only 35 to 60 per cent as effective as the direct-fired fuel in usefully using its heat. Effectiveness cannot be directly equated with thermal efficiency, however. Thermal efficiency can be boosted by the incorporation of wastes in the clay mix.

Table 7.1(b) does not include the cost of transporting the waste product from its source to the brickworks. This can add considerably to the cost per MJ when estimating the feasibility of its use. As we have previously noted elsewhere, with some waste materials there are benefits other than being a source of energy. They can also reduce wastage when drying the bricks by reducing shrinkage and by opening up the clay to enable the moisture in the brick to migrate to the surface. This reduces differential shrinkage within the brick and reduces the risk of cracking. Really sticky, highly plastic clays in particular are prone to drying cracks and up to 10 per cent of the dried bricks can be unsuitable to progress to the firing stage. Boiler ash, fly ash, sawdust and shredded paper in particular can improve the drying process.

European brickmakers have a long history of adapting to available fuels and have moved from wood to coal, to heavy oil and most recently gas. Sometimes these changes have been of necessity, as in the instance of wood scarcity. Otherwise changes in fuel choice have been due to environmental concern, i.e. the change from oil or coal to natural gas. Natural gas prices in Britain have recently doubled, however, and the quest for alternative fuels is once again underway. Bearing in mind that climate change is an increasingly significant factor, the search has focused on waste gaseous fuels because these burn with less carbon dioxide emissions. Already, 'coal-mine methane' has been used successfully. This gas can be extracted from either working or abandoned mines. If the methane were vented directly to the atmosphere as a waste, it would have

Box 7.1 Incorporation of wastes

Body-added fuels can be used more efficiently by optimizing the way bricks are loaded into the kiln, ensuring there is accessibility of oxygen to the fuel. Recent trials carried out in clamps have reduced the firing time by 22% and wastage has decreased from 8.7 to 7.8%. This has been achieved with a reduction of body fuel energy from 4,346 MJ per 1,000 bricks to 4,028 MJ per 1,000 bricks. The bricks have been set in a vertical straight pattern, allowing oxygen to reach the bricks from the top to the bottom. Any loose sand was removed from the bricks before setting in the clamp to prevent sand affecting the oxygen accessibility. The fuel bed on which the clamp is set burns cleaner and quicker if it is a fuel with a low ash content.

twenty times the effect as the same amount of carbon dioxide on the greenhouse effect. Another gas source exploited by brickmakers has been landfill gas. This is produced by the decomposition of domestic, industrial and agricultural waste dumped in the worked out areas of the clay pit adjoining the brickworks. In both instances location – proximity – is a critical factor with respect to viability. It is not generally viable, for example, to extract, store and transport coal-mine methane by road. Meanwhile, electricity generating enterprises also find these gases an attractive alternative and so are in competition with brickmakers.

Another change affecting the brickmaker is the trend towards clay bricks and blocks with properties that reduce heat loss in buildings and minimize the use of mortar. This trend has focused on the manufacturing of lightweight units, which are structurally sound and have excellent thermal insulation characteristics. German brickmakers in particular have undertaken extensive research into using sawdust and also shredded polystyrene foam derived from used packaging. Such materials are added to the clay and bricks are extruded using a die. After firing, the result is a light-weight brick or block that has many small pores where the sawdust and polystyrene foam has burnt away. The sawdust also contributes energy to the firing process, of course. The use of clay is minimized, moreover, thereby reducing the energy requirement to fire each square metre of walling material. Paper sludge is also used to similar effect. Unfortunately, a conventional direct-fired kiln is required to fire these products at present, rendering them of little current interest to small-scale brickmakers in the majority world.

Mining waste has often found a use in brickmaking, especially heaps of coal-mine waste such as the 'bings' of southern Scotland and the waste heaps of the Midlands, the Ruhr and Poland. These shales have a high content of carbonaceous material and, in some instances, this may even be sufficient to fire bricks without further fuel addition. Meanwhile, South African gold mining gives rise to waste known as mine slimes which, when added to clays, enhance the fired product at virtually no cost.

It cannot be over-stressed that the cost of transporting waste any distance can make its benefit marginal. Frequently, though, the person creating the waste material has problems with storing and disposing of it, and disposal can often be equally expensive. In some circumstances, such as with fly ash, boiler waste, mine waste, paper waste and sawdust in some regions of the UK, the waste producer may deliver the waste to a local user free of charge. The partnership of waste producer and waste user can prove extremely beneficial to both parties.

As circumstances change and a waste may become more valuable for generating electricity or fuelling boilers, a pragmatic approach is needed. Competition is almost inevitable as all industries look to cut costs. Apart from being used as fuels and additives in brickmaking, for example, sawdust and wood waste can also be converted into board. Fly ash can be used to make lightweight concrete blocks, moreover. The search for waste products to improve

numerous trails. Very often, however, there is an alternative market prepared to pay more for the waste as, say, a boiler fuel or an animal feed additive. Vigilant brickmakers are constantly on the lookout for 'spoil heaps' where useful materials have been (poorly) incinerated, buried or dumped. Those civil projects that require large excavations, for instance, can be disposing of usable clay at no benefit to anyone. Some years ago, thanks to the keen eye of the owner of a brickworks who noticed it was being dumped, the clay excavated from a London underground railway project was diverted to a brickworks at no cost.

If they are situated adjacent to a brickworks, the waste heat generated by other industries can be diverted and used in brick driers. Naturally, this is especially welcome in the wet season. A brickworks near Bristol was located next to a factory producing 'carbon black', which is used to as a reinforce products such as tyres, tubes, conveyer belts, cables and other rubber goods. The factory flared off 'Jones gas', a by-product of the production process that contained carbon dioxide, carbon monoxide, hydrogen and water. This gas was readily piped to the brickworks and fuelled the kiln there for many years.

Environmental concerns

European brickmakers are very conscious of four areas of environmental concern:

1. greenhouse gas emissions, notably (i) carbon dioxide which is generated from the combustion of carbon fuels such as coal and (ii) methane generated from bacterial decay of organic matter (agricultural waste, forestry waste, landfill and coal mines);
2. dioxin and furan (a group of colourless, volatile, heterocyclic organic compounds containing a ring of carbon atoms and one oxygen atom) emissions from the combustion of certain plastic waste, such as PVC and other chlorinated plastics, which can pose a risk to human health;
3. heavy-metals and pathogens found in sewage sludge that can cause them to be unsuitable for spreading on agricultural land and can be a health hazard if handled without due care;
4. leachates from landfill waste sites that can seriously pollute watercourses and aquifers.

There are instances when using waste can reduce negative environmental impacts. The use of methane as a fuel, for example, is preferable to allowing it to escape into the atmosphere as methane. The carbon dioxide produced in methane combustion contributes much less to the greenhouse effect. Though more research is required, there is the potential for toxic heavy metals to be used as additives in brickmaking. As we noted in Chapter 3, it may be that these heavy metals can be chemically locked into the brick during firing, thus rendering them harmless.

There are other areas of concern such as smell, which may be harmless to paper waste and agricultural waste in particular, can be a significant, though usually local, problem. Water run-off from sites that store waste in the open can contaminate watercourses and wherever possible should be stored on higher ground and covered.

Waste materials and brickmaking technologies

Biogas is a mixture of methane and carbon dioxide. It is produced by bacterial digestion of organic matter and can be used as a fuel. Anaerobic digestion involves placing biodegradable organic materials, the feedstock, in an environment absent in oxygen. Depending particularly on the nature of the feedstock, the process can give variability in the gas produced. Wastes are usually digested anaerobically in a closed fabricated container such as a drum. Gas production is temperature-dependent and requires a minimum of 10°C. Up to a limit, increasing temperature accelerates natural digestion and gas is produced and stored, usually in a chamber designed to maintain a constant pressure. Despite being associated with small-scale domestic gas supply in China and also dairy farming in Europe and USA, where the gas is often used in electricity generation, this technology appears underdeveloped in many regards. Research in India has investigated the use of anaerobic digesters in generating gas to assist the drying of clay tiles.

As feedstock for anaerobic digestion, dung, sewerage and many agricultural wastes are good. Sawdust and straw are not so good. Typically digesters need daily attention and conditions inside should be kept reasonably stable. Due to potential explosion risk and lack of breathable oxygen, care is necessary when carrying out any cleaning or maintenance to digester vessels.

Producer gas consists of a mix of mainly nitrogen and carbon monoxide. It has a low calorific value because the large nitrogen constituent is inert. Producer gas is made in a furnace or generator. Air is forced upward through a burning fuel. Although the fuel is introduced from the top, no air is admitted there.

Box 7.2 Biogas, producer gas and landfill gas

Biogas

Analysis: 57–70% CH_4, 30–40% CO_2, 1–10% N_2, 0–1% H_2, traces of O_2 and H_2S.
Calorific value of raw biogas: 23 MJ/m³.

Producer gas

Analysis: 40–50% N_2, 22–27% CO, 10–15% H_2, 10–15% CO_2, 2–3% CH_4.
Calorific value: 4–6 MJ/m³.

Landfill gas

Analysis: 57% CH_4, 42% CO_2, 0.5% N_2, 0.2% H_2, 0.2% O_2, traces of H_2S.
Calorific value: around 19 MJ/m³ at its peak.

Carbon in the fuel is oxidized by the oxygen in the air to form carbon monoxide. The nitrogen in the air is unchanged. When steam is introduced with the air, the producer gas will also contain hydrogen. Producer gas is quite widely used in industry because it can be made from inexpensive fuels and is more versatile. The only well-documented example of the use of producer gas in brickmaking, it seems, comes from Finland. There, a tunnel kiln used extruded peat (densified) in step grate converters to produce gas to fire clay blocks. Such a process requires considerable investment and technology development, however.

Waste biomass is quite widely used on all continents, especially when conventional fuel is in short supply or expensive. The calorific value typically ranges between 14 and 19 MJ/kg, comparable to fuelwood. Handling and storage are safe and reasonably straightforward. It being a potentially renewable source of energy, burning biomass is relatively environmentally friendly. Generally, the ash content and emissions of sulphur are low, and burning reduces the natural methane that evolves from rotting crop waste. When in a granular or powder form, such as sawdust, coffee husks, shredded paper or crushed shell, biomass can be used as an additive to the clay mix.

Alternatively, it can be formed into fuel briquettes, either by hand, by pressing or extruding. Typical sources of biomass for briquetting are crop waste or forest debris. The density of briquettes varies depending on the method of making. Generally denser briquettes are preferred. With low-pressure briquetting, either by hand or pressing, it is often difficult to attain a product that holds together, particularly when using springy biomass. In such cases a binder is necessary and an appropriate substance is not always easy to source cost-effectively. Some binders, such as clay, leave a substantial residue to deal with; others, such as cement, are relatively expensive for such a use.

Fluxes are used in a fine dust grading and added to the clay mix to reduce the maturing temperature of the brick. They are usually a waste by product of a process such as mining or quarrying. Recently, ground waste glass has been used with some success. It is rarely economically viable to grind fluxes for use in brickmaking, however, as the mechanical energy used exceeds the thermal energy saved. Fortunately, many mines and quarries create dust, which they are obliged to dispose of. In particular, road-stone material, such as granite and basalt, when added to the clay mix as dust mean that a lower firing temperature is needed to achieve a satisfactory brick. These additives can, in some instances, also reduce the drying shrinkage and waste from drying cracks. Wood ash is one flux that offers this advantage.

Using a flux addition can affect the vitrification range. If this range is small, there is a risk of the bricks being either under-fired or over-fired. The top temperature in a clamp could be anything from 950°C to 1,050°C and if the vitrification range of the clay/flux mix is 1,000°C plus or minus only 20°C, there could be a poor yield of good bricks. Fluxes are especially useful when the only clays available are refractory and have a very high firing temperature. Furthermore, if the fired bricks are to be used in a very cold climate and are therefore susceptible to frost damage, then the use of fluxes is beneficial.

One tonne of degradable rubbish can produce 400 to 500 cubic metres of landfill gas, although this is only some 20 per cent of the potential energy that could have been recovered if the waste had been incinerated. Due to clays tending to be being impervious, when 'worked out' brickwork quarries have become a favoured location to dispose of municipal solid waste. Very soon after this means of disposal was employed, however, it was noticed that methane was being evolved and harming trees. Future landfill sites were arranged in such a way that this methane could be flared off and so rendered harmless, in respect to local flora at least. As this was frequently occurring adjacent to brickworks, the practical use of this methane was investigated. Following trials, it was used in the hot zones of the brick kilns. An alternative is to burn methane to generate electricity for use either on or, indeed, off the site.

Some sites in the UK have now been using landfill gas from the original dump site for 20 years. The volume and calorific value of the gas varies over the years. The volume reaches a peak and then declines to zero when all the organic material has been digested anaerobically. The calorific value also reaches a peak and then tends to stabilize until the site stops producing. Present-day landfill sites are designed with great care, being laid with a network of pipes to collect as much gas and as little air as possible. The pits are lined and the waste capped with plastic sheet after water has been added to aid decomposition. This results in a leachate, which must be collected and treated to neutralize its potentially contaminating effect on aquifers and streams. Landfill gas is corrosive and any metal pipe-work, valves and regulators require regular examination, maintenance and replacement. Extraction of landfill gas also requires constant monitoring and attention by an operator.

Shredded paper is commonly used as an additive to assist brick drying by 'wicking' moisture to the brick surface. Moreover, paper additive bulks out the clay and provides a source of energy during firing. As detailed previously, the addition of paper can also improve the thermal insulation properties of lightweight clay blocks and this technology is employed in Germany, Switzerland and Austria, in particular.

Also used as an additive is 'incinerated paper ash', which is the residue after waste paper has been burnt in a boiler or incinerator. Though it has virtually no residual energy, paper ash does assist drying and, even in small additions such as 2 per cent by mass, can reduce the tendency of the brick to crack during drying. Many types of incinerated paper contain calcium carbonate, kaolin and titanium oxide, which can affect the fired colour of the brick by bleaching red to a lighter colour and also giving white spots. Although harmless, customers may perceive such 'blemishes' as indicative of poor quality.

Paper recycling is now commonplace and paper fibres can be reused several times before they become brittle and unsuitable. The fibres are extracted from the recycling process and the residue is known as paper sludge. This sludge can be further refined into dry fibre or dry filler (calcium carbonate, kaolin, titanium oxide and ink residues) and even compacted into dry fibre briquettes. The fibrous material has a gross calorific value approaching that of wood and when added

Box 7.3 Dioxins

Dioxins are a family of toxic chlorinated organic compounds that bioaccumulate in humans and wildlife over time because they are soluble in lipids (fat). The most notorious of those is 2,3,7,8-tetrachlorodibenzo-p-dioxin, often abbreviated as TCDD. Even at low exposures, dioxins can accumualte to dangerous and even lethal levels.

Source: Wikipedia, http://en.wikipedia.org/wiki

to clay reduces the risk of cracking during drying. The combustion of the fibre in the clay body happens at relatively low temperatures and, unless the clay has a very low vitrification temperature, it needs to be supplemented with other fuels, typically coal-dust or screened ashes. Extruded briquettes are at present only available in North America and Europe due to the cost of the high-pressure equipment required.

Refuse Derived Fuel (RDF) has a high paper and cardboard content and is derived from domestic waste. RDF is converted to briquettes and pellets, usually by extrusion, and is then a convenient form of solid fuel. Caution is required if there is any plastic content as this may give off harmful fumes when burnt. The caloric value varies from 12 to 17 MJ/kg, depending on the source waste and the nature of processing.

Plastic Fuel Pellets are formed in municipal waste recycling units where the disposed items are split into paper, glass, metal and plastic. The plastic fraction is shredded and extruded into pellets, which can be used as fuel. These have been tried in the high-temperature zones of brick kilns with a limited degree of success. The pellets are fed through the roof of the kiln and combust at temperatures in excess of 1,000°C in the firing dykes. Due to the handling involved and the lack of control, however, this method is not entirely satisfactory. There is concern that dioxins and furans are formed at lower temperatures (300/400°C) and, although 'destroyed' at 1,000°C, they can reform if cooled quickly. Both dioxins and furans are persistent and potentially harmful to humans. Plastic should not be used as a fuel unless constant monitoring and control is exercised in the feedstock used, the process of combustion and emissions.

Sludge from waste-water treatment plants is normally treated with lime, dewatered and disposed of on land. Sewage sludges may contain heavy metals and so disposal on land is controlled. They may also contain pathogens, which can be harmful if handled without adequate protective equipment. In dense population areas, particularly, sewage sludge poses a significant disposal problem. Hence, there is some research into using dried sludge or sludge ash in building products. As an additive to fired bricks, up to 40 per cent of dried sludge and 50 per cent of sludge ash are the limits, with ash yielding the higher-strength product. Benefits are an increase in clay plasticity and, in some instances, reduction in drying shrinkage. On firing there is a tendency for shrinkage to increase, however. (Fired bricks typically shrink twice, at the drying and the firing stages, the former almost always being most significant.) The process of increase in water absorption and lower compressive strength, as well as a tendency to effloresce. When mixed with clay, sludges with a high lime content will have a short firing range and it is not advisable to use a firing process that has a high temperature variation. The caloric value of raw sewage sludge is around 23 MJ/kg.

Burning used tyres directly is neither permissible, advisable nor convenient, particularly not in contemporary brickmaking in Europe. Burning tyres cause air pollution, endangering human health, flora and fauna in the vicinity. Hence, such a process is prohibited by the environmental legislation pertaining in EU countries. Moreover, tyres are not a form that would be convenient for use as a fuel at most brickworks. There are currently at least two companies investigating the feasibility of converting old tyres into a high-carbon granulated fuel, a type of char. Over the last three years, they have come close to achieving a feasible operation. The product is still not on the market, however, and the chemistry of the process is still under development.

Wastes with potential for small-scale brickmaking

It is suggested that, for burning waste to be a beneficial technology for small-scale brickmakers, a number of criteria must be met:

1) The cost of the waste in a usable form to the point of use is economically viable.
2) The capital cost of any equipment required is low.
3) The technology is simple, repeatable and safe.
4) The supply of the waste material is guaranteed over a reasonably long term.
5) The quality of bricks produced is good and there is a high yield of saleable bricks.
6) The net environmental impact is negligible, beneficial or can be mitigated.

Granulated agricultural and forestry waste added to the clay mix meets most, if not all of these criteria. This is reflected by the fact that such fuels have indeed been adopted in many brickworks worldwide. For many years, rice husk has been used with considerable success in developing countries as a supplement with wood for direct firing and as a body additive in clamp firing. It has also been used to manufacture a lightweight refractory insulating brick for use in kiln and furnace construction.

Fuel briquettes and pellets derived from agricultural waste, forestry waste or waste paper may also meet our criteria and are very promising technologies. In some part of the world such fuels have found favour in the direct firing of kilns or in the fuel bed of a clamp. Sawdust, rice husk and cotton stalks are difficult wastes to use as energy sources. Whilst they can be fed into a hot kiln fire-hole, they have to be used sparingly to prevent smothering the fire. There are burners that will blow air and pulverized fuel such as sawdust into a kiln when it has

are ineffective, however, and they also require an electricity supply. Compacting these agro-forestry wastes into briquettes means these problems can be overcome and they can be used for direct firing kilns, either independently or supplementing other fuels. With clamp firing, they can be used on the clamp bed. The calorific value is similar to that of wood and, depending on the waste used, burning can give very little ash.

There are numerous briquetting machines available, many developed in India and China. Apart from manual presses, extrusion by a reciprocating ram or an Archimedes screw are the usual alternatives. The use of binders is not always necessary when high pressure and a heated die are used to extrude the agricultural residue, especially if sawdust is added. The alternative to high pressure is adding a binder such as clay, though this usually results in inferior combustion. In spite of biomass briquettes being used successfully in many regions, there is a need for 'best practice' to be shared to perhaps simplify and improve the reliability of the briquetting equipment. High wear on the screw and the die are not easily resolved in a low-technology environment. With high energy prices hitting Europe and East Asia, along with international commitments to reducing greenhouse gas emissions, biomass briquettes and pellets are seen as serious alternatives to coal and oil. There is a strong case for examining existing technology and highlighting opportunities to make these briquettes feasible in both low- and high-technology environments. What, for instance, are the best shape and size and density of the briquettes for different applications? And which conditions give the most efficient combustion?

In many majority world countries, not only could this fuel briquetting technology benefit brickmakers, it could also be employed to produce suitable fuel for domestic cooking. Initially, the briquettes would be simply made by hand, possibly using paper soaked in water as a binder. In the future, as appropriate technologies are developed, briquette quality and economic viability could be improved and the market expanded. There is a strong case for making bricks and fuel briquettes on the same site, as both processes require similar skills and the latter could generate additional employment and community income.

Boiler ash and mature domestic waste, which from a health and safety point of view should be more than thirty years old, can also meet most of the criteria. Shredded paper or paper sludge can largely be regarded as renewable sources of energy. The cost of processing along with the care required in handling and use make such wastes mainly unsuitable for consideration by small-scale brickmakers. There is some scope for developing anaerobic digesters and landfill gas extraction for use in small-scale brickmaking in the not too distant future. Indeed, these are technologies that deserve planning and initial implementation as soon as possible.

CHAPTER 8
The feasibility, sustainability and viability of using wastes

Kelvin Mason

> Sustainability is an ultimate, perfect condition, which we will almost certainly never attain: a perfect condition in which the human species manages to live within the (planetary) limits that we've got in a way that enhances and protects the diversity of what we've got... Sustainability's also a world in which societies are stable, where there's a high level of social equity, where societies are peaceful... And it's also a place where there's an economy for all; there is enough for all people. So, it's a highly idealistic notion of the way that we could live. But as a vision, it's worth holding up. (Rod Aspinwall, UK Sustainable Development Commissioner, quoted in Mason, 2005)

In this final chapter we will assess the technical feasibility of using wastes in brickmaking. We will also ponder whether doing so is more or less environmentally sustainable than alternatives. Some of this technical and environmental ground will have been provisionally covered in our country case studies. Herein, then, we will attempt to develop what we have already noted. We will also consider the institutional conditions under which the use of wastes is, or could be, economically viable and so boost the livelihoods of brickmakers. Such conditions will be influenced by the political support that might be won for the technologies under consideration. Finally, taking all these issues together, we will speculate upon the actions that policymakers, NGOs, fieldworkers and brickmakers could take in the light of our deliberations.

Technical feasibility: we can do it

In the main, we have considered using agricultural residues and industrial wastes as fuels in brickmaking. Whilst we have touched upon the use of such materials as fluxes, grogs and bulkerizers, and also upon using brickmaking as a means of waste disposal, our conclusions must largely be confined to fuel substitution. It is apparent, both from the literature we have reviewed and also Practical Action case studies from around the world, that the use of wastes and residues as fuel substitutes in brickmaking is, generally speaking, technically viable. Though one conclusion of our investigation must be that each instance context, it is safe to confirm the enormous potential energy available from wastes and residues.

Although some wastes can be burned in fires beneath clamps or kilns in a similar manner to fuelwood, other means of combustion offer significant advantages in many cases. Incorporating finer residues in bricks, for example, is a way of putting the fuel in intimate contact with the clay. It can, therefore, be a more efficient means of combustion than burning the residue remote from the bricks, minimizing the heat loss associated with transfer over distance. Another advantage is that the bricks produced will be lighter because the fuel fraction of the waste will have been burned away. Lighter bricks with more voids are cheaper to transport, easier to handle and offer improved thermal insulation.

The limit on how much fuel can be incorporated into bricks is set by the effect on both the handling strength of the green brick and also the required properties of the final product. When considering incorporating wastes, the mouldability of the clay, the green strength of the brick and the durability of the final product are particular concerns. The addition of most wastes reduces the plasticity of the clay mix and thence the green strength and ultimately the durability of the brick. In general, though, the finer a residue, the greater the amount of it that can be incorporated. Results from the Sudan case study suggest that, as a rough practical guide for fieldworkers, the final mix must contain at least 30 per cent clay by mass. Other studies have indicated that the production of sufficiently durable bricks means the fuel fraction of the mix will be between 5 and 10 per cent by mass. It should not be forgotten that the appearance of the final brick, its acceptability to customers, may be more important than its physical properties when brickmakers' livelihoods are at issue. I suspect many a frustrated engineer has, like me, solved technical problems only to confronted by the fickleness or conservatism of consumers: people just don't know what's good for them!

In some cases too, it is the producers who baulk at technologically sound innovation. In Zimbabwe in the early 1990s, for example, the design, testing and production of a sand-moulding table offered brickmakers the opportunity to produce bricks that reached 'common' quality. By virtue – or otherwise – of the restrictive standards in force, such bricks could be sold to the more lucrative urban market of the time. The moulding table was made from local materials using local skills and was therefore available and affordable. The technology of using the table was certainly not too alien for brickmakers to adapt to. Although the bricks produced could compare favourably with the output of the IT Workshops moulding machine, for example, the perception of brickmakers was that the technology as a whole was inferior to such imported alternatives. So, they did not adopt the moulding table readily and en masse, as might have been the case had they judged the matter wholly rationally, i.e. in the way that engineers and scientists like to think these things are decided.

The psychological perception that imported products must be better than locally made ones and that mechanization is always superior to processes that

of the benefits of the Western model of industrial modernization are pervasive and persuasive: fast cars, cheap air travel, consumerism... The jury is out on whether any of us will successfully make the transformation to ecological modernization. What that model will look like is still being contested, in fact, though many of us believe the time for argument about formative initiatives such as the Kyoto Protocol is long past.

Returning to our central theme of technological effectiveness, placing waste-as-fuel in layers between rows or columns or bricks in clamps or kilns is another means of bringing the fuel closer to the brick. In this case, however, there is no unavoidable effect on clay or brick properties. One limit on using waste-as-fuel in this way is likely to be the danger of insufficient air-flow and hence incomplete combustion. Finer wastes, in particular, may well compact to the extent that airflow is restricted. This may lead to burning in a reduced oxygen environment and thence to reduction spots on the bricks, possibly lowering their sale value. Incomplete combustion also tends to increase air pollution. Another limit, particularly with respect to clamps, is the structural integrity of the stacked green bricks. Generally, brickmakers are known to build clamps that sag inwards as any fuel contained within them burns away. If, as the waste-as-fuel burns away, any resultant movement in the stack of bricks is not controlled, then there may be a risk of total or partial collapse and hence loss of production and possibly accidents involving staff. With certain wastes, notably the by-products of rice production, a high ash content may present technical problems with both combustion and ash disposal.

One promising means of preparing certain wastes for optimal burning falls under the label of low-pressure briquetting. In Peru, coal-dust and clay were formed into spherical 'briquettes' by hand. The amount of clay used is just sufficient to bind the coal-dust so that the briquettes hold their shape and can be handled when dry. The construction of rudimentary grates made from bricks makes it possible to burn these briquettes in tunnels below the kiln. This means the technology is not significantly altered from burning fuelwood and no capital investment is required. Burning briquettes in this manner is combined with both using coal-dust between layers of bricks and also distributing briquettes at known 'cold spots' to promote even firing of bricks throughout the kiln. It is worth noting here that, in another Practical Action collaborative project, brickmakers in Ecuador developed the technique of placing fuelwood in their kilns at similar peripheral locations where bricks tended to be under-fired.

In Sudan, meanwhile, rotted bagasse was made into blocks with the aid of a manually operated press. Technically, this operation too falls into the category of low-pressure briquetting. A range of binders was identified and tested. Unfortunately, molasses, the most promising binder technically, was not available in the quantities and at the price that would have made its use in block production commercially viable on a mass scale. It was acknowledged that more research on clay and filter cake was required. As filter cake is available as a residue from sugar factories, it would seem potentially ideal as a binder for in its loose form in close proximity to a brickmaking site, then there would evidently be a ready supply of clay to use as a binder for fuel briquettes. Given the appropriate soil properties and processing technology, a machine such as the Ceratec press tested by Practical Action in Zimbabwe could be employed to press both bricks and also the fuel briquettes to fire them. Press machines of a similar design are available from other manufactures. The main drawback for small-scale brickmakers in much of the majority world, though, would consistently be the purchase price of an imported piece of hardware.

Overall, the briquetting of wastes offers a number of benefits. Loose and low density wastes-as-fuels can be rendered easier to handle and to transport. Moreover, briquettes can be burned more readily, and generally with less technological change, than can powdery residues and wastes. They also offer a way of overcoming the limit on how much powdery waste can be burned by incorporating it into bricks. The combination of burning a powdery waste incorporated into clay, formed into briquettes and also distributed in the kiln may well be a technological route to the complete substitution of traditional fuels such as wood or coal. It is also a means of securing substantial gains in energy efficiency.

Environmental sustainability: we should do it

From the outset we proposed a quite complex definition of environment that is doubly inclusive, i.e. that both includes and also is included in humanity. Part of what makes us human is nature, and nature is in part humanity. Philosophically, this leads us away from an econometric view of the environment. Nature may provide us with, in the economist's terms, goods and services, but the stewardship ethic means we have a duty of care to ensure that nature is not destroyed or degraded. This ethic holds whether or not the element of nature considered renders goods and services that are valuable to, or rather valued by, humanity. There is a difference. For example, the greenhouse effect is extremely valuable to humanity but it becomes a problem, some critics would say, because it is not valued by us. Measures such as carbon taxes literally put a value on the greenhouse effect. The stewardship ethic therefore encompasses the principle of intrinsic value. Though it can be problematic to put into practice, intrinsic value need not mean that all change is taboo. Rather, it is a route to considering the environment beyond that which can be measured quantitatively in units that reflect only short-term, transient anthropocentric value.

Sustainable development is essentially a matter of space and time. Conscious of the needs of brickmakers and their families in today's world, we must also try to take account of the needs of their descendants and, indeed, our own. It is, as the popular contemporary phrase runs, a very big task. Through Finn Arler's typology of resources and adapting the methodology of Environmental Impact Assesement (EIA), we came up with a means of considering changes in brickmaking technology. Our grandchildren or great-grandchildren may judge

Box 8.1 Goliath

They chop down 100 foot trees
To make chairs
I bought one
I am six foot one inch.
When I sit in the chair
I am four foot two.
Did they really chop down a 100 foot tree
To make me look shorter?

(Milligan, 1973)

Even when we consider only the economic microcosm of small-scale brickmaking, all these resources are potentially affected. Brickmaking may be using up exchangeable resources in the form of fossil fuels, degrading unique landscapes, or contributing to the destruction of the critical ecological service rendered by the greenhouse effect.

When we considered the sustainability of small-scale brickmaking in Chapter 2 we prioritized a number of changes in our strategic EIA, namely deforestation, emissions of carbon dioxide, emissions that pollute air and affect air quality, the incineration of wastes, and flora and fauna. As long as brickmaking is not degrading a unique landscape, I suggest that this list holds good in the light of what we have gleaned from the intervening chapters. Applying our adopted typology of resources, we can see that deforestation, emissions of carbon dioxide and air pollution pertain to critical resources, as might the incineration of waste. Flora and fauna may be considered either unique or exchangeable resources, meanwhile, depending on their individual characteristic.

As a benchmark, I propose that, from an environmental point of view, the best possible source of fuel for brickmaking would be biomass from a sustainably managed local source. If this biomass were the by-product of an agricultural process that produced a primary crop for consumption or use by humanity, so much the better because I believe this would make our duty of care to dispose of that waste in an environmentally friendly fashion even clearer. My proposal, however, ignores the fact that wastes and residues have already been produced as a result of unsustainable production, e.g. boiler ash from an inefficient power station in Harare and sawdust from commercial operations in Peru. Until the nature of such production has been amended, it may well be that one of the best ways of disposing of wastes and residues is via brickmaking. Before we get too general, though, let us consider three examples from our case studies and assess the environmental impact of their dissemination on the national scale.

The case of rice husks in Peru can, I propose, be considered as fairly representative of agricultural residues. As we have discussed, the use of each residue in each context must be assessed on its individual impacts. Nevertheless, considering the environmental impact of using rice husks according to the

On the national scale, the use of rice husks as a substitute for at least a proportion of fuelwood would have a positive environmental impact on deforestation. Trees are a critical resource, serving as carbon sinks that can help ensure the greenhouse effect is life-giving rather than life-threatening. Burning rice husks is also carbon neutral in that emissions of carbon dioxide can be no more than that which the plant absorbed whilst growing. Moreover, rice is an annual crop and so is, in that sense at least, sustainably produced. If rice husk is incorporated into bricks and burned in layers in the kiln, the process will tend to be more efficient thus further reducing carbon emissions. All in all, then, the dissemination of using rice husks as a fuel in brickmaking on the national scale would have a positive impact on the global and regional environment.

With respect to emissions into air, the overall quantity of emissions is unlikely to change significantly. Rice husks have a similar calorific value to fuelwood and so a similar amount will be burned to produce the energy required. In terms of air quality, however, it may be that burning rice husks emits proportionally more acid gases and particulates in smoke than wood. Generally, this effect on the local and regional environment would need to be assessed on a case-by-case basis, comparing a particular wood with a particular agricultural residue. Certainly, the nature of rice husk will make it more technically difficult to burn cleanly, i.e. to approach complete combustion. If rice husks were used as a substitute for coal rather than fuelwood, the environmental impact on both air pollution and net carbon dioxide emissions would be likely to be positive, depending on how cleanly and efficiently the fuels were burned.

Vis-à-vis disposing of waste, rice husk is a residue with a limited number of alternative uses. Although it does not seem to present a major disposal problem in most instances, rice husk can be incinerated in brickmaking. Moreover, the energy released is used productively. If rice husk is used extensively in brickmaking, however, there may be an increase in heavy vehicle traffic for its transport. This is likely to have a negative impact on roadside flora and fauna, though the magnitude of change will probably be small. Assessing the impact on the local environment would mean balancing the benefits of productive waste disposal against any damage caused by increased traffic. Mitigating the extent of such damage may be possible via reasonably straightforward measures. Were it the case that rice husk was transported extensively by road, the increase in emissions of carbon dioxide and air pollutants from delivery vehicles would have to be considered.

Let us now consider the environmental impact of disseminating the use of boiler ash in brickmaking on the national scale in Zimbabwe. To an extent, the following discussion will give us insights into the use of similar industrial wastes – other ashes and coal-dust – in alternative national contexts. As with all alternative fuels considered, provided that it is fuelwood that would otherwise be burned, using boiler ash in brickmaking has a positive environmental impact, reducing deforestation. Burning boiler ash is not carbon-neutral on the same time-scale as burning biomass, however, whether that biomass is fuelwood or

to be balanced against the carbon emissions from burning boiler ash. In the short to medium term, boiler ash would not degrade and emit carbon dioxide if left to stand. On the other hand, using boiler ash in layers between bricks is likely to be more efficient than burning fuelwood beneath a clamp or kiln, and increased efficiency would reduce carbon emissions from the process. Overall, although it is better to burn wood from a sustainable supply, I suggest that burning boiler ash has a less negative environmental impact than burning wood from other sources.

Considering emissions into air, boiler ash and similar fuels will tend to produce more acid gases and particulates than fuelwood. Oxides of sulphur and nitrogen are of particular concern, contributing to not only local environmental pollution but also to acid rain on a regional scale. There may be ways of mitigating these impacts. Developments in clean coal technology could be employed to wash impurities out of boiler ash before burning and also perhaps clean – or 'scrub' - exhaust emissions (BBC, 2005). In general, however, such technologies are currently beyond the reach of the small-scale brickmaking sector.

In Zimbabwe at least, boiler ash is a local landscape pollutant. Initially, it was a waste disposal problem for Harare power station, whose site was simply being overwhelmed with piles of ash. The use of boiler ash as a fuel in brickmaking served to help solve these problems. With respect to burning boiler ash in brickmaking on a national scale in Zimbabwe, the direct impact of road transport on flora and fauna would probably be small. If the ash were transported over long distances by trucks that billow black smoke, as is typically the case in Zimbabwe, then the increase in emissions of carbon dioxide and air pollutants would be a significant impact. There is a rail network in Zimbabwe that reaches a number of population centres, including previously designated 'growth points'. The use of this network to transport a proportion of boiler ash would reduce the impacts due to road transport. Overall, burning boiler ash seems to have the potential to have a less negative impact than continuing to use fuelwood.

Our analysis of the use of bagasse in Sudan actually follows most of the arguments that applied to case of rice husks in Peru. Like rice husks, bagasse is as an agricultural residue. Burning it is carbon-neutral in the immediate term and sugar cane is an annual crop. The use of bagasse as a substitute for some proportion of fuelwood would serve to reduce both deforestation and carbon emissions. In this regard, the regional as well as global environmental impact is positive. There is likely to be little change in air pollution compared to burning fuelwood. If bagasse replaces coal, however, the net impact is most likely to be positive. There is an acknowledged problem with the disposal of bagasse as a waste in Sudan. Thus, the environmental impact of burning bagasse in brickmaking is positive in this respect also. Overall, the case study of bagasse is even more positive than that of rice husks. It seems that the only significant negative impacts might be as a result of transport. While the impact on flora and fauna is likely to be small, the extra carbon dioxide and air pollution associated with distributing bagasse nationally by road could be significant.

Frankly, although it helps with perspective, we do not really need our complex definition of environment or the stewardship ethic to inform our verdict on the case of using of wastes as fuels in brickmaking. It is substantially a win–win scenario. Not only does the use of wastes largely serve to preserve nature, it also enhances the environmental goods and services provided to humanity: forests and associated ecosystems are conserved while there appears to be a positive impact on the greenhouse effect, for instance. A drawback with burning industrial wastes as substitutes for biomass may be a negative impact on air quality. Given the scale and seriousness of the greenhouse problem and considering the other advantages of burning waste, however, the strategic verdict must be positive. The caveat to this verdict concerns the extent and nature of the transport required to provide brickmakers with waste-as-fuel. A second dimension of the win–win scenario is that fuel substitution benefits not only future generations, whose resources are largely conserved, it could also have a positive impact on the livelihoods of contemporary brickmakers. The moral imperative to act to further sustainable development is confirmed. As I have continually cautioned, though, each case of potential waste-for-fuel substitution should be assessed specifically as well as generally.

Economic viability: so what's stopping us?

Before proceeding, I should note that, so far, we have considered two types of brickmaking enterprises as if they comprised one and the same inseparable sector. Some small-scale artisanal brickmakers may fit the enterprise model in that their business can develop technologically, managerially and financially. Others are what may be referred to as subsistence operations, however. Such operations are not phenomena unique to the majority world. In my homeland, Wales, for example, Dylan Jones Evans laments the lack of ambition of 'lifestyle' businesses (Jones Evans, 2001). Subsistence or lifestyle business may have either no capacity to grow or no desire to do so. While the capacity for growth may be developed in some cases, I suggest that other businesses have largely reached the size that is compatible with the context in which they operate. This does not mean that they are unable to innovate to survive. As, for example, fuelwood becomes scarce and expensive and a small-scale brickmaking operation is threatened, borrowing, investing and growing the business is only one strategy. Brickmakers should also be able innovate to increase efficiency or find alternative fuels while retaining their characteristic scale.

Artisanal brickmaking clusters vary in scale. In some African countries, for instance, a cluster may be the workplace of tens of people. In India this number might be hundreds, and in China thousands. Overall, however, the numbers of people employed in brickmaking worldwide are small relative to other sectors of the global economy. It could therefore be argued that there would be little impact on national economies if most or even all small-scale brickmakers were forced to close down due to economic pressures. This macro view ignores the

situations. There are many issues that must be considered and these slip under marco-economic dragnets such as GDP per capita. Paying attention to such issues is fundamental to 'economics as if people mattered' (Schumacher, 1973).

There are alternatives to fired clay bricks for housing, communal and commercial buildings. These include concrete blocks, stabilized soil blocks, timber and stone. Those consumers of building materials who have the luxury of choice are, then, less likely to be affected by the knock-on effect of any crisis in fuel supply than are small-scale brickmakers themselves. In many countries, unemployment, underemployment and employment insecurity are rife. In such locations, if small-scale brickmakers did lose their livelihoods, they would not simply walk into jobs in other sectors. Many brickmakers have been producing bricks all of their working lives. They do not have the skills to obtain work or exploit business opportunities in other fields where the demands are rapidly changing. In the globalized world economy, labour is not a valued commodity. Though it may not noticeably affect GDP, the everyday impact of increased numbers of unemployed people on societies is severe. If brickmakers from rural or peri-urban areas are forced to migrate into towns and cities in search of work, they will most likely swell the ranks of not only the unemployed but also the homeless or ill-housed, perhaps even the mendicant or criminal.

If a fuel crisis did put small-scale brickmakers out of business, formal sector medium- and large-scale brickmakers will inevitably fill part of the gap in supply. These larger-scale brickmakers would generally produce bricks to a higher specification and sell them at a higher price, though, and such bricks would not suit everyone. Apart from being unaffordable, many people do not require bricks of the quality or in the quantity that larger firms supply. Artisanal brickmaking operations are flexible enough to meet local needs. People who have no choice and who rely on low-cost bricks to construct their homes and buildings, typically some of the poorest in the community, would be the ones to suffer if small-scale brickmakers were squeezed out. In short, without small-scale brickmakers the shelter crisis and poverty would be bound to worsen even if that change did not register on the scale of GDP per capita.

So, subsistence businesses can be regarded as the poorest supplying the needs of the poorest. As we saw when we reviewed the shelter crisis in Chapter 1, it does not look as if the numbers of the poorest are set to decline significantly in the foreseeable future. Some small-scale brickmakers will certainly migrate out of poverty via enterprise development. But life is more complex than the one-size-fits-all model of development as growth would have it. Another segment of the brickmaking sector will remain suppliers of lesser quality and cheaper building materials, if for no other reason than that a large market niche will continue to exist or even expand. (Here is a case of intrinsic value applying to humans as part of nature. All people are valuable to humanity but not all are valued by us when we apply crude financial measures.) Small-scale brickmakers can only remain suppliers to the poorest if they can obtain fuel, though there is the alternative of producing walling materials that do not require fuel enrgy, Thus, any meaningful attempt to address the shelter crisis must surely include assistance to small-scale building materials producers.

In livelihood terms, we have argued that both growth and subsistence brickmaking operations need to innovate on energy efficiency and fuel substitution. Growth is only an option for a limited number of enterprises, however. Others cannot follow the route of formalization and investment as a development strategy. This is where appropriate technology comes in. We must ask ourselves an important question. If we can technically substitute wastes for primary fuels, it is environmentally sustainable to do so, *and* there is a general livelihood imperative, what is preventing mass-scale adoption of the technology in small-scale brickmaking? In tune with our approach so far, I suggest some parts of the answer to this question may be general and others specific to a particular instance. In general, we seem to have technologies that *are* appropriate, 'building on small-scale, low-cost, environmentally friendly and non-violent local knowledge and skills via a dynamic and participative process', as we noted in Chapter 1. This is evidently not a sufficient condition to ensure mass-scale dissemination and adoption, however. Perhaps if we focus on specific cases, we will find clues as to why not. So, let us continue to focus on the wastes we considered in the previous section, being careful to draw on other examples from our case studies and reviews where they can be enlightening.

Despite our claim of general technical feasibility, the limit on incorporating rice husks or sawdust into bricks as fuels in Peru does appear to be largely technical. Only a certain percentage can be incorporated before the properties of green and fired bricks are critically affected. Brickmakers generally adopt the technology up to this technical limit and there is reportedly no problem with either the supply or price of rice husks or sawdust. Unlike some agricultural residues, these agro-industrial by-products are available in sufficient density at primary processing sites, i.e. rice mills and sawmills. With the technically successful technology of hand-moulded briquettes of coal-dust and clay, by contrast, the limit on adoption is economic. Where there is a ready supply of coal-dust and the cost of making briquettes is comparable to fuelwood, brickmakers use briquettes in combination with coal-dust in layers and an oil burner to ignite the kiln. It is the saving in time and labour that dictates the continuation of this combination-fuel technology. The limiting factor on adoption of the waste oil burner is not, as would be rational, the relatively high cost of the technology, a cost that includes the diesel for the motor that pumps the waste oil through the burner. Brickmakers accept the increased cost not only because of the time and labour saved but also, it seems, because the waste oil burner is perceived as modern. A limiting factor is apparently shortage of supply due to competing demands for the waste oil.

While our initial appraisal suggests the limit on the use of wastes in Peru could be as much technical as economic, the relatively cheap and ready supply of fuelwood in most regions may well be inhibiting technology development. Despite the acknowledged environmental problems and concomitant legislation, in the final analysis most brickmakers can get hold of fuelwood,

whether legally, quasi-legally or wholly illegally. Maybe an economist would judge that this fuelwood is not expensive enough to act as a spur to further innovation? Grinding rice husk for example, would allow more fuel to be incorporated into bricks. Moreover, low-pressure briquetting of wastes such as ground rice husks and sawdust in combination with a binder could increase fuel options. Grassroots economics means that innovation requires more than a spur. Whether or not fuelwood remains relatively cheap, small-scale brickmakers will not, in the majority of cases, be able to access the capital to buy machines such as grinding equipment or a block press. They would not, furthermore, be able to bear the costs of technology development: the inevitable failures involved as limits are pushed.

Let us now consider Zimbabwe. Boiler ash has been used as an auxiliary fuel, supplementing both fuelwood and coal in clamps or scove kilns. It has been successfully deployed between layers of bricks and the finer fraction has been incorporated into bricks as a fuel. Technology is not a limiting factor. Fuelwood is scarce and coal is relatively expensive in Zimbabwe, so the substitution of waste for a proportion of these primary fuels should be economically attractive. There could be a problem with competition as others apart from brickmakers recognize that the ash has a calorific and hence monetary value. Furthermore, the supply chain is difficult to establish, with power stations and tobacco farms obviously not treating boiler ash as their principal commercial product. Typically, they do not take orders, control stock or make deliveries, for example. In the current crisis, there is frequently no fuel for vehicles and hence no transport that brickmakers can hire to collect any sort of fuel. Such factors combine to make the availability of boiler ash a problem. It is not anyway certain that, in the long term, a sufficient quantity of ash will be available to support brickmaking across the nation. Moreover, now that the ash has a price and some sort of market for it has been established, small-scale brickmakers must find more money upfront, whereas fuelwood can still be (mis)appropriated or obtained on credit from their familiars operating in the same informal sector.

Zimbabwe's economy is currently in such a mess that it is difficult to say whether using boiler ash in brickmaking remains viable. Is there, in fact, an economic rationale that can be applied to countries like Zimbabwe? I have argued that a portion of most societies, though not most nations, will remain outside the prescriptions of globalization and development as economic growth. In other words, many countries will de facto have two economies, the one frantically modernizing, desperate for growth and increasingly defined by consumerism, the other characterized by at worst subsistence and at best sufficiency and frugality. I have also argued, however, that environmental sustainability and livelihoods demand that small-scale brickmakers, at least, share an imperative to innovate that runs through both economies. But this two-tier model of development with a common imperative cannot be applied to nations ravaged by continual strife. Sustainable development demands, in the first instance, peace and respect for human rights. In this, Zimbabwe is patently as for the majority of the population, economics is currently a matter of survival in the most immediate term.

The use of bagasse blocks as a substitute for fuelwood in Sudan is technically feasible, environmentally sustainable and desirable in terms of the livelihoods of brickmakers and the shelter needs of their customers. Furthermore, there are almost literally mountains of the stuff available and the supply appears secure. The problems with dissemination on the national scale are seemingly economic. The relatively high cost and scarcity of reportedly the most technically suitable binder for blocks, molasses, combined with the high cost of road transport and a lack of disseminated information, undermined attempts to introduce the technology on a mass scale. As we noted in Chapter 5, this is the most obvious example from all of our case studies of an economic system that works against ecological modernization.

To a degree, the economists are right: fuelwood is not expensive enough to spur innovation. To ensure intergenerational equity, the price of fuelwood should take into account the cost to future generations of deforestation and net carbon dioxide emissions. Alternatively, burning wastes that have less negative environmental impacts should be subsidized. Unfortunately, economics is not only a dismal science, as the historian Thomas Carlyle deemed, it is also a myopic one. In their analyses, economists find it impossible to adopt the very long-term perspective that sustainable development demands. To be fair, this is hardly surprising. For what will an adequately functioning greenhouse effect be worth to our great-grandchildren translated into cash terms today? How much should fuelwood cost in Sudan in order that the competition with wastes-as-fuels is truly fair?

Conclusion: what's to be done?

I should begin by stating that I do not want this conclusion to sound like either an abstract wish-list or a set of impracticable prescriptions for social change. These alternatives may actually amount to much the same thing in substance, differing only in tone between entreaty and demand. It is as hard not to plead on behalf of the increasing numbers of the global poor as it is not to insist that the system must change to eradicate poverty. So, should I entreat more development aid to continue work such as that done by the organization Practical Action? Or should I demand that the international community of governments regulate the development playing field in favour of sustainable development? While I suppose I have very slightly more chance of achieving the former, experience suggests that at best it could amount to only small changes for relatively few people. So, let me beard the lion in its den.

I believe we have shown that for the use of wastes as fuels by small-scale brickmakers to be viable, as well as feasible and sustainable, two aspects need particular attention. First, more technology development is needed. Second, we need the reflexive institutional reorganization of society that is fundamental to

modernization 'is the decoupling of economic growth and environmental degradation', thereby enabling so-called green growth (Revell and Rutherford, 2003). In other words, governments should enact and implement necessarily radical policies in favour of sustainable development. Such policies would include, for example, strictly enforcing regulation on deforestation and setting carbon emission limits far in excess of the modest targets of the Kyoto Protocol. This second aspect of change is by far the most critical and can be viewed as almost automatically enabling the first, i.e. promoting and supporting the development of sustainable technologies would be government policy and practice. While I am certain governments around the world would protest that they *are* considering sustainable development in policymaking, I contest that rather than radical institutional change they view ecological modernizsation as a political programme of, at best, modest socio-technical reform. Furthermore, I am convinced that reform, and certainly the current scale and speed of reform, is totally inadequate to the task.

Even the radical institutional reorganization and technological transformation of society that is ecological modernization would not be sufficient to ensure the livelihoods of *all* small-scale brickmakers. It would, I believe, help that segment of the sector with the capacity and scope for enterprise development. However, I have proposed that another segment of the small-scale brickmaking sector is intimately concerned with meeting the basic needs of the poorest in society and cannot grow away from that community. There is not a rigid boundary between subsistence and growth enterprises and individual operations will migrate both ways, On the sectoral scale, however, I am claiming that subsistence or sufficiency operations will remain part of society in the long term. For the foreseeable future, I am assuming that these producers will be needed because poverty is not going to disappear in the blink of an eye regardless of changes to institutional frameworks. In any event, I reject the idea that all socio-economic problems can or will be solved by growth. In at least the medium to long term, then, another approach must go hand in hand with ecological modernization, namely sufficiency.

> Swadeshi [meaning, essentially, local self-suffiency] avoids economic dependence on external market forces that could make the village community vulnerable. It also avoids unnecessary, unhealthy, wasteful, and therefore environmentally destructive transportation. The village must build a strong economic base to satisfy most of its needs, and all members of the village community should give priority to local goods and services. (Satish Kumar in Goldsmith and Mander, 2001)

Though theorists may view ecological modernization and self-sufficiency as antithetic (Murphy, 2001), in reality we always and inevitably live with contradictions in society. Practice does not change so easily and consistently as the enveloping logic of some grand theories tends to suggest. For the world's poor, particularly, everyday needs must be met regardless of 'the sound of introductory quote to Chapter 1, noble proponents of sufficiency, such as Mahatma Gandhi, Fritz Schumacher and Nelson Mandela, view it as an national-scale alternative to, say, export-oriented capitalism, I am suggesting that the two systems will exist side by side. In fact, they already do. Vandana Shiva identifies three economies, in fact:

> As the dominant economy myopically focuses on the working of the market, it ignores both nature's economy and the sustenance economy, on which it depends. In a focus on the financial bottom line, the market makes invisible nature's economy and people's sustenance economies... In the sustenance economy, people work to directly provide the conditions necessary to maintain their lives. (Shiva, 2005)

For the self-sufficient Gandhian village community expounded by Satish Kumar read local rural, peri-urban and urban communities not on the guest list for the neo-liberal globalization party. The imperative for politicians and policymakers is to recognize the simultaneous existence, and right to existence, of two economic systems, two communities. They should not prescribe a single, growth-oriented path out of poverty. As Rod Aspinwall said in the quote at the beginning of this chapter, sustainability is 'a place where there's an economy for all'. So, apart from favouring ecological modernization, regulation must also protect communities by nurturing sufficiency.

Though it is quite clear what is expected of politicians and policymakers, the current climate of global neo-liberalism makes acceptance of my suggestions not impracticable but ideologically unpalatable. My notion of the sustainability that would enable the mass-scale use of wastes as fuel in brickmaking is, no doubt, idealistic. As a vision, though, I concur with Rod Aspinwall, it is worth upholding. NGOs and individuals must continue to lobby for practical solutions to poverty, pragmatic solutions that circumvent ideological dogma, solutions that match the needs of particular communities, and solutions that are environmentally sustainable. We must be very clear about what we mean by sustainability and continue to develop mechanisms to operationalize the concept. On the ground, in the direct context of this book, we must continue to work with all small-scale brickmakers to develop technologies that help ensure both their livelihoods and also the supply of affordable building materials to the increasing number of people who have no other choice.

APPENDIX
Photocopiable forms

Environmental impact of national projects

Designation of environmental effects:
A=significant, B=should be examined, C=of minor significance, D=insignificant

Is the proposal believed to cause a change in or effect:	*A*	*B*	*C*	*D*

1. WATER
   1.1 Surface water
   - Discharges of organic substances, including toxic substances, into lakes & water courses?
   - Discharge into coastal areas or marine waters?
   - Quantity of surface water or water level?
   - Quality of salt water or freshwater?
   - Natural ecosystems & habitats in salt or fresh water?
   - Drinking water supply or reserves?
   - Consumption/withdrawal of water?

   1.2 Groundwater
   - Percolation to groundwater?
   - Groundwater quality?
   - Quantity of groundwater?
   - Drinking water supply or reserves?
   - Consumption/withdrawal of water?
2. AIR
   - Emissions into air?
   - Air quality (e.g. acid gases, particulate or toxic substances)?
   - Obnoxious smells
   - Changes in precipitation quality?
3. CLIMATE

- Other factors, including deforestation, which may cause local or global changes in climate?

4. THE EARTH'S SURFACE & SOIL
   - Applicability or cultivation value of soil?
   - Percolation or accumulation of toxic or hazardous substances in the soil?
   - Water or wind erosion?
   - Soil in the case of changes in groundwater level?
   - The structure of the strata?
5. FLORA & FAUNA, INCLUDING HABITATS & BIODIVERSITY
   - The number of wild plants or animals of any species or the distribution pattern of species?
   - The number or distribution pattern of rare or endangered species?
   - Import or export of new species, including genetically modified organisms?
   - Quality or quantity of habitats for fish & wildlife?
   - Structure of function of natural ecosystems?
   - Vulnerable natural or uncultivated areas (e.g. bogs, heaths, uncultivated dry meadows, salt marches, swaps and coastal meadow, watercourses, lakes, humid permanent grasslands and coasts)?
   - The reproduction or natural patterns of movement or migration of fish & wildlife species?
   - Cultivation methods or land use in the agricultural or forestry sectors?
   - Fisheries, catches or the methods applied in deep-sea or freshwater fishing?
   - Open-air activities or traffic in the countryside which may affect the flora & fauna or cause wear & tear on the vegetation?
6. LANDSCAPES
   - The total area or the land use within areas used
   - Geological processes such as soil migration and water erosion?
   - Geological structures in the landscape, e.g. river valleys, ridges & coastal structures?
   - Permanent restrictions on land use which reduce the future possibilities of use of the open land?
   - The extent or appearance of archaeological or historical sites, or other material assets?
7. OTHER RESOURCES
   - Cultivation, cutting, catching or use of renewable resources, e.g. trees,

   - Exploitation or use of non-renewable resources such as fossil fuels, minerals, raw material (sand, clay)?
8. WASTE
   - Wastes, residues or quantities of waste disposed of, incinerated, destroyed or recycled?
   - Treatment of waste or its application on land?
9. HISTORICAL BUILDINGS
   - Buildings with architectural, cultural or historical value and with possibilities of preservation and restoration?
   - Buildings or historical monuments which require repair because of a change of the groundwater level or air pollution?
10. PUBLIC HEALTH & WELL-BEING
    - Acute &/or long-term health risk in connection with food, drinking water, soil, air, noise, or handling of hazardous or toxic substances?
    - Risk associated with exposure to noise?
    - Recreational experiences & facilities, including changes in the physical appearance of landscapes, natural or uncultivated areas?
    - The function & environment of towns, including green areas & recreational facilities?
    - Aesthetic values or visual experiences (e.g. scenery, urban environment or monuments)?
11. PRODUCTION, HANDLING OR TRANSPORT OF HAZARDOUS OR TOXIC SUBSTANCES
    - Risk of fire, explosions, breakdowns or accidents & emissions?
    - Risk of leaks of environmentally alien or genetically engineered organisms?
    - Risks associated with electromagnetic fields?
    - Risk of radioactive leaks?
    - Risk of breakdowns or accidents during transport of substances of materials?
    - Other effects related to the security and safety of the population (e.g. traffic accidents, leaks)?

Energy monitoring form

Energy consumption of brick firing process

Name of Producer	Location/Address	Dates of Firing
Type of Clamp/Kiln	Type(s) of Fuel	Mass of Fuel(s) Used (kg)
Calorific Value(s) (kJ/kg)	No. Of Green Bricks	Avg. Mass Of Bricks (kg) Wet = Dry-green = Fired =
Brick Moisture Content	Method Of Forming	Weather Conditions

Calculation Of Kiln Efficiency	Qualifying Information
Mass of green brick =	
Total moisture content =	(i) Vitrification temp =
Drying energy =	
Wood energy =	(ii) Max kiln temp =
Coal energy =	
Gross energy =	(iii) Firing time =
Firing energy =	
Mass of fired brick =	
Specific firing energy =	

COMMENTS

NAME, CONTACT DETAILS & DATE

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