IMPROVED STOVES IN SOUTHERN AFRICA: A SOLUTION FOR ALL SEASONS?

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ABSTRACT

Biomass fuels dominate the national energy balances of most sub-Saharan African countries, with wood contributing 80-90% of poorer countries like Ethiopia, Tanzania, the Democratic Republic of Congo and Mozambique. The predominant method of utilising wood for cooking is on an open fire, considered wasteful of wood. For this reason there have been many initiatives to improve the efficiency with which wood is used for cooking, or to introduce alternatives like solar cookers and ethanol gel stoves to avoid using wood altogether.

The requirements of a cooking fuel vary seasonally in any given household, and across different climatic zones. The ability of improved stoves to meet these requirements varies considerably across these different zones, and if efficiency is understood in the context of being able to meet the requirements with the minimum use of wood, then it can vary when the needs change from predominantly cooking, to include space and water heating.

This paper examines the different domestic heating loads in selected areas in Southern Africa in the summer and winter months to show that cooking energy is not always the main requirement. Where space heating becomes a critical requirement the efficiency of an open fire can be considered high since the 'lost' heat not going to the pot is fulfilling a critical need – space heating. Case studies are presented to illustrate how the reception of improved stoves has in some instances been influenced by climatic factors. Top down approaches to planning and dissemination of improved stoves often fail to appreciate such factors, typically resulting in limited impact of such initiatives.

The paper illustrates the shortcomings of a one-size fits all approach and concludes with recommendations for more careful assessment and matching modern energy interventions to local conditions to ensure more predictable outcomes.

1. INTRODUCTION

Biomass fuels dominate the national energy balances of most sub-Saharan African countries, with wood contributing 80-90% of countries like Ethiopia, Tanzania, the Democratic Republic of Congo and Mozambique [1] as illustrated in Table 1. The predominant method of utilising wood for cooking is on an open fire, considered wasteful of wood. For this reason there have been many initiatives to improve the efficiency with which wood is used for cooking, or to introduce alternatives like solar cookers and ethanol gel stoves to avoid using wood altogether.

Table 1. Combustible renewables and waste as a percentage of total energy use [1].

Country	2005	2006	2007
Cote d'Ivoire	74.5	77.5	76.4
Zambia	79.4	78.8	78.3
Nigeria	77.9	79.8	80.2
Mozambique	83.0	82.2	80.3
Togo	84.1	85.8	85.1
Nepal	86.8	86.8	86.7
Tanzania	88.8	88.3	88.6
Ethiopia	91.3	90.7	90.2
Congo, Dem. Rep.	92.9	92.9	92.9

Thermal requirements vary seasonally in any given household, and across different climatic zones. The ability of improved stoves to meet these requirements varies considerably across these different zones, and if efficiency is understood in the context of being able to meet the requirements with the minimum use of wood, then it can vary widely when the needs change from predominantly cooking, to space heating, water heating and cooking.

This paper examines the different domestic heating loads in selected areas in Southern Africa in the summer and winter months to show that cooking energy is not always the main requirement. Where space heating becomes a critical requirement the efficiency of an open fire can be considered high since the heat not going to the pot is fulfilling a critical need – space heating.

The opposite situation, where ambient temperatures are high presents challenges to stove usability since in such cases cooking may have to be done outside, a situation unsuited to a fixed mud or brick stove. In these situations portable stoves may be an option, however these will be more expensive than mud stoves built by the villagers for themselves.

Case studies are presented to illustrate how the reception of improved stoves has in some instances been influenced by climatic factors. Top down approaches to planning and dissemination of improved stoves often fail to appreciate such factors, typically resulting in limited impact of such initiatives.

The paper illustrates the shortcomings of a one-size fits all approach and concludes with recommendations for more careful assessment and matching modern energy interventions to local conditions to ensure more predictable outcomes.

2. VARIATIONS IN THERMAL DEMAND

Tables 2 to 4 below display selected average monthly climate indicators for three locations in Zimbabwe, namely Hwange, Gweru and Beitbridge, based on eight years of historical weather readings [2].

Table 2. Hwange National Park
18.63^o S, 27.0^o E, 1077 meters above sea level.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Avg. temp	23	22	22	21	17	15	15	17	22	25	25	23
Avg. max temp	28	28	29	29	26	24	23	27	31	32	31	30
Avg. min temp	18	17	16	13	8	5	5	7	12	16	18	17
Avg. rain days	8	8	5	1	0	0	0	0	0	2	6	5

Table 3. Gweru
19.45o S, 29.85o E, 1429 meters above sea level.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Avg. temp	20	20	20	18	16	13	12	16	20	21	22	21
Avg. max temp	25	25	26	25	22	21	20	23	27	28	27	26
Avg. min temp	15	15	14	11	7	5	5	6	10	12	15	15
Avg. rain days	10	7	6	3	1	1	2	1	1	3	7	7

Table 4. Beitbridge
22.21o S, 30.0o E, 457 meters above sea level.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Avg. temp	27	26	26	23	20	17	16	20	22	25	26	27
Avg. max temp	33	32	32	30	28	26	25	28	31	32	33	33
Avg. min temp	21	21	20	16	12	8	8	11	15	18	21	21
Avg. rain days	4	4	2	1	0	0	1	0	0	1	3	2

The coldest and hottest months in figures 2 to 4 have been shaded to highlight them

These locations were selected as examples of the hotter and colder areas, with altitudes ranging from below 500m to over 1400 metres above sea level. The mean monthly temperatures range between 5^{o}C in winter and 33^{o}C in summer. Minimum daily winter temperatures can drop below 0^{o}C and frost warnings by the meteorological office are common during winter.

The wide summer-winter temperature range for places such as Hwange mean that fixed stoves can be problematic in both winter and summer for thermal comfort reasons. These issues will be discussed further with specific cases for illustration.

3. HEATING AND COOLING IN BUILDINGS - DEGREE DAYS

The mean annual temperatures just presented do not indicate how much the temperatures varied within the period in question. *Degree days* are widely used in calculating building energy consumption [3]. *Heating degree days* indicate how much (in degrees) and for how long (in days) the ambient temperature was below a specific temperature, the base temperature. This measure is directly proportional to the amount of energy required to heat a building over the period in question. Here the base temperature is the ambient temperature below which a building would need to be heated. *Cooling degree days* are the opposite and refer to situations where cooling is required due to high ambient temperatures.

The degree-day figure for a given month or week is the accumulated total of daily results over the period in question. The daily result for heating degree days, Dh, is selected from the formulae in Table 5, [4] using the first one that matches:

Table 5. Formulae for calculating heating degree days

Condition	Formula used
Tmin>Tbase	Dh=0
(Tmax+Tmin)/2>Tbase	Dh=(Tbase-Tmin)/4
Tmax>=Tbase	Dh=(Tbase-Tmin)/2-(Tmax-Tbase)/4
Tmax<Tbase	Dh=Tbase-(Tmax+Tmin)/2
Tmax, Tmin, Tbase are maximum, minimum and base temperatures respectively.	

Table 6 gives the heating degree days for three quite different locations in Southern Africa, Dar es Salaam in Tanzania, Kasane in Botswana, and Bloemfontein in South Africa for base temperatures of 18**°C** and 20**°C**. These locations were chosen for availability of degree day data, and for their contrasting data.

Table 6. Heating loads for selected areas [3].

	Heating degree days for 18 °C and 20°C					
	Dar es Salaam		Kasane		Bloem-fontein	
Month	18°C	20 °C	18 °C	20 °C	18 °C	20 °C
Jan	-	-	0	1	19	37
Feb	-	-	0	0	22	36
Mar	-	-	0	2	42	62
Apr	0	0	7	15	104	147
May	0	0	36	54	198	249
Jun	0	0	91	132	318	374
Jul	0	0	64	102	273	328
Aug	0	0	64	91	255	305
Sep	0	0	19	31	125	166
Oct	0	0	2	6	92	127
Nov	0	0	0	2	47	70
Dec	0	0	0	5	39	60

Table 6 shows that Dar es Salaam does not require any heating for the chosen base temperatures, while the other two centres require heating, particularly during the winter months in mid-year. Bloemfontein, the coldest among the chosen centres would require over three time as much heating energy as Kasane for the same type of building in July, or over five times as much in September.

When one considers rural households faced with the different conditions outlined above, the question of how an ‘efficient improved’ stove would be received arises. Under Dar es Salaam conditions, the household would probably prefer cooling, in Bloemfontein there would be very pronounced need for effective winter space heating. This is not what an ‘impoved’ cookstove is designed to do, given that its efficiency is in directing heat to the cooking put as far as possible with minimal loss to the surroundings.

4. SELECTED CASE SUMMARIES - END USER EXPERIENCES AND ACCEPTANCE

4.1 ZIMBABWE DEPARTMENT OF ENERGY REVIEW

There have been considerable effort to disseminate improved stoves and other modern energy technologies and services since independence in 1980. A major review of past efforts was undertaken by the country’s department of energy in 1996 [5]. Some of the pertinent issues are summarized here.

By far the most ubiquitous stove seen in virtually all households all over the country is the metal frame stove (Figure 1) which is simply a welded metal frame that supports the cooking utensils over an open fire. The traditional 3 - stone fire seems to have been widely abandoned in favour of the more convenient metal grate stoves. This stove is made locally in many areas by informal sector welders and often costs several US dollars, the exact price depending on the area and design. This is a relatively low cost, portable stove enabling multi-pot cooking without interfering with the space heating or lighting functions of the fire. It can take a wide range of sizes of wood pieces, up to sizeable logs and the power output can be varied widely by simply adding more wood and spreading the fire under the metal frame.

Figure 1. Typical metal frame stove

In the DoE review, no instances of exclusive use of the improved stove (wood or coal) were encountered anywhere. Fireplaces outside the home were common. It was evident through observation that many stoves had fallen into disuse or were used infrequently despite claims to the contrary by some owners. Numerous complaints were raised concerning different aspects of the stoves.

The reasons given by owners for disuse of their improved stoves included [5]:-

- It was too hot inside the kitchen during the hot season (which is when field visits were undertaken and stoves found unused). Cooking therefore was done outside.
- For large families using big pots, the stove was too slow, particularly because the stove pot holes were of unsuitable for large pots, causing the pot to sit too far above the firebox.
- Brewing seemed important to some families in certain areas, and this could only be accomplished on an open fire as very large utensils like drums were used.
- Heavy use of the stoves quickly necessitated considerable maintenance, particularly repairing cracked tops, and renewal of grates. This became a disincentive.
- Where dung was used, housewives did not like the strong smell and therefore cooked outside when using cowdung.
- For small, quick meals, like tea for school children in the mornings, the stove was not used. Instead a small open fire was lit, or alternatives such as biogas were used because instant heat could be obtained.
- Sometimes chimneys were too close to grass thatch, and were seen as a fire risk. In such cases owners were afraid to use their stoves.
- Except for small twigs, wood had to be split prior to use in a woodstove, and this took time.
- Stove takes long to warm up.
- Stove was seen as wasteful of dry wood.

Features of the improved stoves that users liked included:

- The stoves burn wood that is too moist to burn in an open fireplace. Some dry wood was still required to start the fire though.
- Can cook several pots simultaneously.
- Keeps pots clean.
- Removes smoke from house.
- Stove cooks quickly once warmed up.

In the colder parts of Zimbabwe the need for space heating is very pronounced and in some areas even electric heaters were said to be inadequate. In these cases the use of the open fire becomes inevitable. Although the brick stove was said to provide adequate space heating in the warmer areas, its high thermal inertia (high mass design) means it heats up slowly and cools slowly. This makes it unsuitable for quick meals and for space heating that is required quickly.

The opposite situation, where ambient temperatures are very high also applies. In very hot weather, people sometimes sleep outdoors because it is too hot indoors. Under such circumstances, the presence of a large hot stove inside the house makes a bad situation worse.

4.2 ProBEC STOVES

Dande, Zimbabwe

Reviews of ProBEC-funded stove programmes across Zimbabwe were undertaken in 2000 and 2004.

An area, Dande, along the low lying and hot Zambezi escarpment was visited in 2004 to look at mud stoves constructed under the regional ProBEC programme. Since the area was evidently still well-wooded, the question of why anyone would be interested in a wood saving stove was posed. Two explanations were given by the stove owners:

- the area was said to be windy and the stove resisted droughts well, and
- the wood saving was appreciated because not everyone had a cart to collect wood, which was not always within short reach.

High indoor temperatures

Because the area is hot, most households prefer to cook outside in hot weather. Most households reportedly built their first stoves outside, but these were destroyed when the seasonal rains started.

The high thermal capacity of the stove can exacerbate indoor thermal discomfort in hot areas. This problem can extend into the night if the kitchen is also used as a bedroom. In another area, Gwanda, to the South of the country, stoves have been built both indoors and outdoors. Outdoor stoves were successfully protected from rain; they were covered with plastic sheeting as soon as it started to rain.

There were instances of different stoves in the same kitchen, as was the case illustrated in Fig. 2. In this case the metal frame stove is not fixed; a fire can be conveniently made outside or inside. The mud stove is built-in and cannot be moved. In such situations there is a risk of the mud stove falling into disuse as was likely in this case since the mud stove looked to be still in new condition while the housewife was found using the metal frame stove barely one metre away.

It was indicated that there was a strong seasonal switch between indoor and outdoor cooking because summers could be very hot. Almost all kitchens were built with half -height walls to enhance ventilation and keep temperatures down. Winter heating capacity was not seen as a problem because of relatively mild winters.

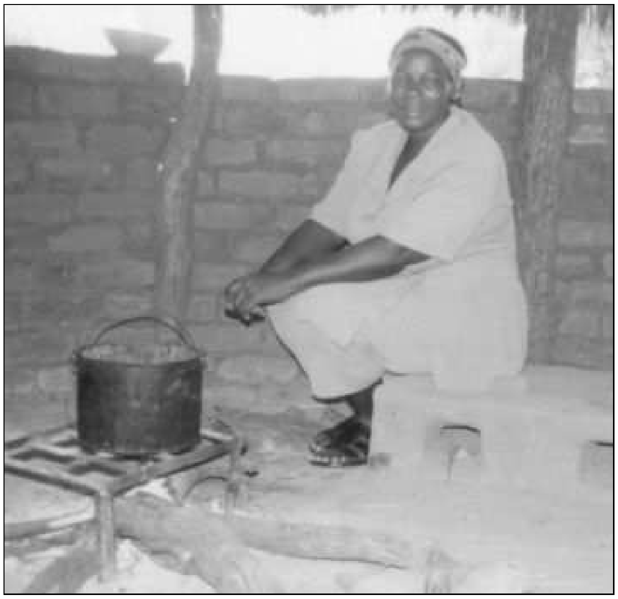

Figure 2.Two stoves in one kitchen. Mushumbi Pools area. Northern Zimbabwe

During a separate visit to **Tanzania**, in discussions with the Tanzania Traditional Energy Development Organisation (TaTEDO) which was promoting efficient stoves, it was learnt that in colder areas like the foolthills of Mt Kilimanjaro, stoves did not eliminate open fires due to the need for space heating. In Maasai areas stoves were not generally used also due to cold weather. In many households, the elderly needed a constant source of warmth, necessitating open fires [7].

5 CONCLUSIONS AND RECOMMENDATIONS

It seems that the best target areas for improved stoves are those with more moderate temperatures, and where people have a reason to want, and pay for, an improved stove, for example where firewood is relatively expensive.

In areas with extreme temperatures, seasonality in stove use may have to be accepted. Care need to be taken to ensure there are good reasons for the users to go back to the stove in the season they are expected to. There may be need to explore this behaviour further.

It is important to observe user modifications to stove designs and incorporate these as far as possible in order to improve adoption.

The performance of past stove programmes needs to be revisited regularly and systematically and lessons learnt and documented. This is important since new designs and approaches are being developed and disseminated all the time.

6 REFERENCES

1. The World Bank. Combustible renewables and waste (% of total energy) http://data.worldbank.org/indicator/EG.USE.CRNW.ZS?order=wbapi_data_value_2007+wbapi_data_value+wbapi_data_value-last&sort=asc. Accessed 29 January 2011.
2. Climate Zone.com. *http://www.climate-zone.com/climate/zimbabwe/celsius/beitbridge.htm* Accessed on 3 February 2011.
3. www.degreedays.net (using temperature data from www.wunderground.com). Accessed 5 February 2011
4. http://www.vesma.com/ddd/ddcalcs.htm Accessed 5 February 2011.
5. Department of Energy. 1996. Review of past programmes. DoE. Harare. Zimbabwe.
6. ProBEC 2004. Report for the Steering Committee. ProBEC. Zimbabwe.
7. CSIR. 2008. Report on a Bioenergy field trip to Rwanda, Tanzania and Malawi. CSIR Internal Report. Pretoria.

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PRESENTER: The paper is presented by Maxwell Mapako.

ACKNOWLEDGEMENT

The paper is based on work done as part of CSIR projects and the kind permission of the CSIR to present the paper and sponsorship of conference attendance is acknowledged.