Changing energy profiles and consumption patterns following electrification in five rural villages, South Africa

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Abstract

Following the democratic transition in South Africa in the early 1990s the government has implemented a widespread electrification programme, as well as introduced a free basic electricity allowance as a means of poverty alleviation. Yet there are limited longitudinal studies on the impacts of the introduction of electricity on the patterns of household energy use, and even more so in the neglected rural sector. This study reports on the patterns of household energy use in five rural settlements in 1991 and again in 2002. Results indicate a changing pattern of energy use for lighting and powering entertainment appliances, more specifically from dry-cell batteries and paraffin to electricity. Yet for thermal needs, most notably cooking, fuelwood has remained the most widespread fuel, and the amount used per month has not changed, despite increasing scarcity of wood in the local environment. There has been an increase in the proportion of households purchasing fuelwood as opposed to collecting their own. Overall, the mean total number of fuel types used per household has increased, indicating that electricity is simply viewed as an additional energy, rather than an alternative. Yet, electricity accounted for approximately 60% of expenditure on energy sources in 2002, despite the government's policy of a free basic allowance of 5–6 kWh per month. This has implications for energy supply costing, as well as the poverty alleviation dimensions of the whole programme.

Keywords: Domestic energy; Fuelwood; Electricity

1. Introduction

The energy sector in South Africa has both first world and third world elements. On the one hand South Africa produces and consumes over 60% of the electricity on the African continent and is the 12th highest carbon emitter in the world. Energy consumption levels are higher than in many other developing countries. Electricity is largely produced from coal-fired power stations, with some contribution from hydro- and nuclear-power (DME, 2000). The country produces the cheapest coal in the world and has succeeded in developing electricity generation plants that are water efficient and use low-grade coal.

Renewable energy resources comprise mainly biomass and account for 5% of the total energy supply (DME, 2000; Howells et al., 2005).

On the other hand, at the domestic level, over three-quarters of South Africa's rural households use fuelwood energy to a greater or lesser degree, ranging from a few times per month to daily (Davis, 1998). In addition to fuelwood, rural households use paraffin, candles, batteries and reticulated electricity for other applications but frequently find these expensive (Griffin et al., 1992; Davis, 1998; Howells et al., 2005). Many urban households also use fuelwood, although frequently in limited amounts. Even with the substantial household electrification programmes in the last 10 years and one of the lowest electricity prices in the world to consumers, most newly electrified households continue to use fuelwood because they cannot afford the appliances and/or the monthly costs (Davis, 1998; Howells et al., 2005). The latter have been reduced by the national Government's policy of a Free Basic Allowance (FBA) of 5–6 kWh per household per month. Actual application of this varies between municipalities, but is generally insufficient for all household thermal needs. Consequently, even electrified households make use of alternative fuels, including fuelwood. It is expected that a considerable number of households will continue to use fuelwood to some extent for decades to come.

The use of and reliance on fuelwood is not uniform across geographical areas or within individual communities. Typically the poorest and most vulnerable communities and households make most use of fuelwood with only limited use of other energy forms. Remote rural communities still rely extensively on fuelwood, with increasing concerns around deforestation, adverse health effects and escalating opportunity costs as local fuelwood scarcity increases. Over 60% of rural households are unelectrified. With increasing modernity and household income, it is argued that there will be a gradual shift towards more modern fuels such as paraffin, gas and electricity, in a typical energy transition dynamic (Alam et al., 1998; Vermeulen et al., 2000; Kituyi et al., 2001) following either an energy ladder pattern or a leapfrogging one.

According to the energy ladder hypothesis, changes in energy-use patterns usually take the form of a gradual decline of biomass fuels, from exclusive use for all purposes by a large number of households, towards reduced use by a smaller number of households for fewer purposes, with the reverse trend for technologically sophisticated fuels (Hosier and Dowd, 1981; Campbell et al., 2003). In other words, it is a shift from low-quality fuels, such as biomass, to more convenient, versatile and cleaner modern fuels such as paraffin, gas and electricity (Leach, 1987a). In contrast, the leapfrogging concept is used to denote a transition from traditional forms of energy (e.g. fuelwood and charcoal) to modern sources (e.g. electricity) (Murphy, 2001) without passing through the conventional path of energy development.

According to Leach (1987b), fuel choices and substitution are strongly driven by desires for greater convenience and cleanliness. Other researchers have argued that changes in fuel choices occur as availability of commercial fuels improves and household incomes increase (Sarmah et al., 2002). As the availability of modern fuels improves consumers have the opportunity of moving up the energy ladder and acquiring modern appliances such cooling fans, radios, television and fridges (Leach, 1987b). The ability to pay for the new fuel type and ownership of appliances that go with their use is strongly correlated to income (Davis, 1998). Wealthier households are less likely to be constrained by the usually high cost of non-biomass fuels and are therefore more inclined to make the transition to more sophisticated alternatives (Campbell et al., 2003). At the other extreme, the cost of the new fuels is likely to inhibit the proportion of users among low-income households because of their low purchasing power (White et al., 1997; Kabede et al., 2002).

Government policies have also been shown to affect household energy choices, typically in the form of subsidies for fossil fuels and electricity (Alam et al., 1998). In recent years, several governments of developing countries have adopted Structural Adjustment Programmes (SAP) of the World Bank (Reed, 1996), which generally require countries to devalue their currencies, lift import and export restrictions, balance budgets, and remove price controls and state subsidies (Kessler and Dorp, 1998). As a result of the removal of subsidies, SAPs often result in deep cuts in programmes designed to control prices of basics such as food and energy needs. Campbell et al. (2003) noted that the cuts have had negative impacts on low-income households and over time, “we might expect not simple energy transition but a growing dichotomy between wealthier households who are able to adopt modern fuels and poorer households who are increasingly forced to choose biomass alternatives”. Other government policies that enhance energy transitions include those that promote mass levels of electrification (Habtetsion and Tsighe, 2002). Mass electrification benefits poor households in terms of lighting and refrigeration and saves them money.

In South Africa the post-apartheid government committed itself to address the historical inequalities, including a new energy policy that sought to address the energy requirements of the poor (Eberhard, 1995). Policies were designed to widen access to adequate and affordable energy services for urban and rural households. The policies were also aimed at providing cleaner and safer forms of energy for low-income households (Spalding-Fecher and Matibe, 2003). The Department of Mineral and Energy Affairs embarked on an accelerated electrification programme in most rural areas of South Africa (DME, 1998). Because much of the population of rural South Africa is located in areas far from the current and anticipated electrical grid connections, off grid renewable energy resources, particularly photovoltaic, also played a role in the electrification exercise. In the period 1994–1999, close on 2.8 million households were connected to the national electricity grid increasing the level from about 36% in 1994 to about 68% at the end of 1999 (Kotze, 2001). Studies have shown that as a result of the mass electrification programme and the provision of other renewable energy resources such as photovoltaics, patterns of energy use in South Africa have changed (Davis, 1998; Palmer, 1999). According to Davis (1998), “there is evidence for an energy transition largely driven by income. Unelectrified households tend to move from collected wood to purchased wood and kerosene, whereas, electrified households tend to switch to more extensive electricity use”. There is evidence that the transition is fairy rapid (Palmer, 1999) and according to Spalding-Fecher and Matibe (2003), the shift takes 5 years to complete.

Most of these studies are, however, based on observed differences between electrified and unelectrified households (e.g. Davis, 1998). Longitudinal studies with a clear baseline before electrification and that also included the full range of energy forms are scanty (e.g. Vermeulen et al., 2000). A few that are available are restricted to urban and peri-urban communities (White et al., 1997; Palmer, 1999). There is need, therefore, to establish a model of the post-electrification transition based on quantitative data representing overall rural energy-use patterns before and after electrification in a longitudinal survey of the same area or same households. By assessing variations in fuel choices over time, such an approach would cover a wide range of factors that determine a transition and provide a better understanding of the changes in fuel patterns in rural areas, without the results being confounded by differences in household wealth as experienced in latitudinal studies (Davis, 1998). The model would also inform policy makers in prioritizing intervention strategies in the rural energy sector. Thus, within the context of the above, the objective of this study was to investigate the changes in energy-use patterns that have taken place in rural Bushbuckridge district between 1991 and 2002. To achieve this, three key questions were posed, (i) how have the mix and quantities of different energy forms changed between 1991 and 2002? (ii) have energy preferences changed between 1991 and 2002 and if so how? and (iii) how have patterns of expenditure on energy changed between 1991 and 2002?.

2. Study area

The study was completed in five villages in the Bushbuckridge district in the southernmost section of the Limpopo province, South Africa. The settlements were the same as those for the 1991 study of Griffin et al. (1992), namely Athol (24°43′S 31°21′E), Okkerneutboom (24°44′S 31°13′E), Rolle (24°44′S 31°13′E), Welverdiend (24°35′S 31°20′E), and Xanthia (24°50′S 31°09′E). These settlements are spatially dispersed and represent a range from smaller, isolated settlements (Athol, Welverdiend) to larger, more closely settled settlements lying adjacent to major transport routes (Okkerneutboom, Rolle).

The region is characterized by shallowly undulating terrain with an altitude that is generally less than 600 m above sea level (Banks et al., 1996). Hot, humid summers and mild winters with moderate temperatures are characteristic of the area and the mean annual temperature is approximately 22° C and increases from southwest to northeast. The mean annual rainfall ranges between 500 and 700 mm, (Shackleton et al., 1994), and is concentrated in the summer season from October to April (Shackleton et al., 1994). The vegetation is broadly classified as semi-arid savanna and is characterized by a mixture of trees, shrubs and grasses. Dominant tree genera are *Acacia*, *Albizia*, *Combretum*, *Grewia*, *Sclerocarya* and *Terminalia*.

Human population densities range between 200 and 350 people km^{-2}. Mean household size is approximately 6–7 persons. These settlements are typical of the neglected and underdeveloped settlements in many other former ‘homelands’ established under the segregationist apartheid systems in South Africa (Pollard et al., 1998). Thus, there is inadequate infrastructure, high unemployment, household dependency on pensions and remittances from migrant workers. Consequently, households engage in a diverse array of informal activities to support their livelihoods, including arable agriculture, home-gardens, livestock husbandry, collection of natural resources (e.g. fuelwood, thatch grass, medicinal plants), casual work, migrant labour, and small-scale enterprises.

In the last major survey conducted in 1991, results showed that the majority of households in the region depended on biomass fuels as their primary source of energy, especially fuelwood (Griffin et al., 1992). Collected fuelwood accounted for a large proportion of the total fuelwood used in the region although some households bought it from local vendors. Other fuel types used included paraffin, candles, gas, coal, dry-cell batteries, dung, lead-acid batteries and some electricity (Griffin et al., 1992). Electricity was available in two of the study villages (Okkerneutboom and Rolle), but was not distributed within the villages, thereby making connection fees expensive and beyond the reach of most of the village inhabitants. Less than 1% of households in these two villages had electricity in 1991. With the democratic transition in the early 1990s, the new South African government embarked upon a major electrification drive. Consequently, over two-thirds of the households in the region now have electricity. Of the five study villages, only Athol currently has no access to the national electricity grid.

3. Methods

Since the current research was a follow up study, it used the same methods that were used in the 1991 study (Griffin et al., 1992). A structured interview schedule is ideal for longitudinal studies as it limits flexibility (Frey and Fontana, 1991). It ensures that the same style and approach is followed to gather data from surveys conducted at different times. Therefore, the current study used the same structured interview schedule that was used in the 1991 study (Griffin et al., 1992) to gather data on household fuel use, preferences and socio-economic status. It solicited opinions as well as quantitative estimates. The second author was a member of both the 1991 and 2002 research teams. All the interviews were conducted in the local language (XiTsonga). Wherever possible, the person who did most of the cooking and housework in the household was interviewed, as he or she would best know the types and quantities of fuels used. In the absence of such individuals, we interviewed the household head or another adult member. The interviewee frequently conferred with other family members in answering some questions, particularly those related to costs and quantities of the different fuel forms.

Estimates of fuelwood consumption were made based on the respondent's estimates of their daily fuelwood use. The respondents were asked to estimate the amount of fuelwood used on a daily basis and this was weighed and recorded. During the 1991 survey, the accuracy of this method was checked by monitoring daily fuelwood use over 2 weeks at 10 households in Welverdiend village, which was then compared to their previous estimates of use. The household consumption data from the carefully monitored samples were not significantly different from the respondent's estimates of household fuelwood consumption in the same households.

Using 1:10 000 aerial photographs (1997) settlement boundaries were defined and household plots demarcated and numbered, which were then used to select an entirely random sample, as was the 1991 sample. The total number of households sampled was 399 in 2002, compared to 356 in 1991, which more than compensated for anticipated population growth during the intervening period. The numbers per settlement were 71 in Athol (299 households), 83 in Okkerneutboom (830 households), 80 in Rolle (640 households), 80 in Welverdiend (530 households) and 85 in Xanthia (643 households). Like the previous study, a number of conventions were followed if, for some reason, we were unable to interview a suitable respondent at a sample household. In the first instance we revisited that house within 7 days of the initial visit. If still no occupant, we removed that household from the sample list and moved on to another randomly selected household.

3.1. Data analysis

Data from the interview schedules were collated and analysed using Microsoft Excel (Excel 2000) and Statistica (Statistica 6.0). Discrete variables were summarized by determining the frequency of each code within the question. Frequency analysis was undertaken for each sample settlement separately. Summary statistics were calculated for all numeric variables. Normality for all the data was tested using the Shapiro and Wilks test. Other measures of distribution, for example skewness and kurtosis were also examined. After inspection of these data, it was decided that the arithmetic mean was the best measure of central tendency for the data. Since many of the numeric variables failed the assumption of normality and homogeneity of variances a Mann–Whitney *U* test was used to compare the means of the data from the two surveys (1991 and 2002) for the whole region. However, when comparing the means across the individual settlements, the data were transformed using the log transformation to stabilize the variances. Factorial ANOVA was then used to compare the means. The normal per capita consumption was used, for which each person in the sample, regardless of age or gender, represents one unit. The currency exchange rate was US$=R3.70 and R12.50 in 1991 and 2002, respectively, and is currently about R6.10. The mean diversity of fuels used per village was determined using Simpson's diversity index calculated as

$$S = 1/\sum (p_i)^2 \text{ where } p_i = \text{proportion of households using each fuel.} \quad (1)$$

4. Results

4.1. Prevalence of use

There was a large increase in the number of households with access to electricity at the time of the second survey. During the 1991 survey only three households across the five villages had access to electricity, while in 2002, almost all the households in Okkerneutboom, Rolle, Welverdiend and Xanthia had been connected to the national grid. Only Athol had no access to electricity. At the time of the 1991 survey, connection fees ranged from R900 to R1 091 at the 1991 value of the South African Rand (Griffin et al., 1992). However, with the new policies in place, households reported paying connection fees ranging from R62 to R123 in 1997/1998 onwards, and as a result almost 100% of households were electrified in four settlements.

In terms of the proportions of households using them, the dominant energy forms in 2002 were collected fuelwood, candles, electricity, and paraffin (Table 1). In comparison, in 1991 it was collected wood, paraffin, dry-cell batteries and candles. Notable decreases of more than 15% were observed for paraffin and dry-cell batteries, whereas more than 15% increase was noted for electricity and candles. Overall, the mean number of energy forms used per household did not change over the over the 11-year interval, although residents at Athol indicated a large increase. Similarly, across the whole sample there was no change in the diversity index, but the large drop at Okkerneutboom was noteworthy. The least change across nearly all the energy forms was observed in Athol, which still remains to be electrified. Thus, the large changes in most households in the other four settlements are probably, albeit not solely, a consequence of the introduction of electricity. Overall, use of fuelwood had not changed other than an increased propensity to use bought wood rather than collected wood, potentially a reflection of declining wood stocks.

Table 1
Changes in prevalence of use of different energy sources

	Year	Athol	O'boom	Rolle	Welvd	Xanthia	Mean
Paraffin	1991	94	92	96	97	89	94
	2002	70	55	58	60	52	59
Candles	1991	82	73	67	82	75	76
	2002	92	94	90	96	94	93
Gas	1991	11	13	23	13	10	14
	2002	13	0	3	4	4	5
Dry-cell batteries	1991	86	78	92	91	83	86
	2002	65	12	25	31	26	32
Lead-acid batteries	1991	6	7	16	9	6	9
	2002	34	0	1	3	0	8
Charcoal	1991	21	39	19	22	22	25
	2002	31	33	25	21	29	28
Coal	1991	3	18	12	9	0	8
	2002	0	0	0	0	0	0
Crop wastes	1991	21	39	19	22	22	25
	2002	31	33	25	21	29	28
Dung	1991	6	40	0	4	4	11
	2002	6	6	0	0	0	2
Electricity	1991	0	<1	<1	0	0	<1
	2002	4 PV panels	98	88	98	95	77
Bought wood	1991	1	68	34	19	15	27
	2002	8	63	48	20	16	31
Collected wood	1991	99	96	96	99	93	97
	2002	100	88	89	96	96	94
Mean number of energy sources per household	1991	3.9	3.8	4.3	4.4	4.0	4.1
	2002	5.1	4.1	4.1	4.7	4.1	4.4
Simpson's diversity index	1991	5.5	9.0	6.6	6.1	5.8	6.6
	2002	6.7	6.5	6.5	6.0	6.0	6.8

% of hhs using; $n = 356$ and 399 for 1991 data and 2002 data, respectively.

4.2. Amounts used

There were significant decreases in the monthly consumption rates of paraffin, candles and dry-cell batteries (Table 2). There was no change in the consumption of gas, and purchased or collected fuelwood. These changes were against the backdrop of new access to electricity in 2002, which was not available in 1991, for four of the five settlements. Yet, despite not being electrified, the patterns of change in Athol were similar to those of the other settlements, except for a significant increase in the purchase of wood. In 1991 there was negligible buying of fuelwood in Athol (one household), compared to just over 350 kg per user household per month in 2002. In the other four villages the amount of wood purchased per household decreased, even though the proportion of households buying increased.

Table 2.

Monthly consumption rates of different energy forms

Energy	Unit	Signif.	Year	Athol	O'boom	Rolle	Welvd	Xanthia	Mean
Paraffin	l/hh/month	$Z = 9.26 p < 0.0001$	1991	10.3	17.3	14.4	14.6	14.8	14.2
			2002	5.7	7.9	5.3	5.2	2.9	5.4
	l/person/month		1991	1.3	2.0	1.7	1.7	1.8	1.7
			2002	0.6	1.7	0.5	0.4	0.2	0.5
Candles	No./hh/month	$Z = 9.22 p < 0.0001$	1991	26.2	13.3	37.5	28.0	20.7	25.0
			2002	8.5	7.0	8.2	9.2	8.5	8.1
	No./person/month		1991	2.9	1.3	3.1	3.0	1.8	2.4
			2002	1.1	1.1	1.1	1.1	1.2	1.1
Gas	kg/hh/month	$Z = 1.01 p > 0.05$	1991	14.0	10.4	16.0	11.3	15.8	13.5
			2002	17.1	0	17.4	13.7	8.4	11.3
	kg/person/month		1991	0.2	0.1	0.4	0.1	0.2	0.2
			2002	0.3	0	0.08	0.08	0.05	0.1
Dry-cell batteries	No./hh/month	$Z = 3.42 p < 0.001$	1991	3.8	3.6	2.6	5.1	3.3	3.7
			2002	2.0	2.0	2.3	2.2	1.9	2.1
	No./person/month		1991	0.4	0.4	0.3	0.6	0.4	0.4
			2002	0.2	0.04	0.09	0.1	0.8	0.2
Electricity	R/hh/month	n/a	1991	No electricity in the region in 1991					
			2002	n/a	73	71	62	42	62
	R/person/month		2002	n/a	12	11	9	7	10
Bought wood	kg/hh/month	$Z = 1.27 p > 0.05$	1991	< 1.0	373.8	762.3	858.1	602.5	519.0
			2002	351.1	344.0	496.0	564.0	398.0	430.6
	kg/person/month		1991	0	32.6	36.4	16.6	13.7	19.9
			2002	4.1	35.0	35.5	16.0	10.0	20.1
Collected wood	kg/hh/month	$Z = 0.92 p > 0.05$	1991	309.3	251.0	306.2	399.9	353.0	323.9
			2002	321.0	270.7	306.6	331.1	358.6	317.2
	kg/person/month		1991	42.1	31.3	37.5	46.7	45.0	40.5
			2002	46.5	38.4	40.7	45.4	53.8	44.9

Significance is for differences between consumption rates in 1991 and 2002 per household. Per capita consumption rates are derived measures from the mean and therefore not tested. (n=356 and 399 for 1991 data and 2002 data, respectively).

4.3. Energy choices for thermal applications

Fuelwood was the staple energy form for thermal applications (space heating, water heating, cooking) in both surveys (Table 3). Even households that had access to electricity by 2002 continued using fuelwood. Electricity did not displace the other fuels in as far as cooking and other thermal applications were concerned. The paraffin/wood combination was more popular in 1991 than in 2002. Only 1% of households used only electricity for thermal purposes in 2002.

Table 3.

Fuel choice for thermal applications

Fuel choice	1991						2002					
	A'ol	O'boom	R'le	W'nd	X'thia	Mean	A'ol	O'boom	R'le	W'nd	X'thia	Mean
Wood only	70	29	27	45	53	45	56	31	23	46	65	44
Paraffin only	0	0	0	0	2	0.4	0	3	1	0	0	0.8
Electricity only	0	0	0	0	0	0	0	2	1	3	1	1.4
Paraffin & wood	29	66	67	48	41	50	44	25	18	19	6	22
Electricity & wood	0	0	0	0	0	0	0	14	28	18	18	16
Electricity & paraffin	0	0	0	0	0	0	0	7	9	3	3	4
Electricity, wood & paraffin	0	0	0	0	0	0	0	18	20	11	7	11
Gas, wood & paraffin	1	5	7	7	4	4.8	0	0	0	0	0	0

Data show percentage of users; *n*=356 and 399 for 1991 data and 2002 data, respectively.

4.4. Energy choice for lighting

The candles/paraffin combination was popular for lighting in 1991 while in 2002 households mostly used a combination of candles with electricity (Table 4). Between the survey periods, new access to electricity enhanced the shift towards the use of electricity as a source of energy for lighting in the electrified settlements, largely at the expense of paraffin. Households only used candles for back-up purposes when there was an electricity failure or when they did not have enough money to purchase pre-paid electricity cards. However, in Athol, the candle/paraffin combination retained its importance.

Table 4.

Fuel choice for lighting

Fuel choice	1991						2002					
	A'ol	O'boom	R'le	W'nd	X'thia	Mean	A'ol	O'boom	R'le	W'nd	X'thia	Mean
Paraffin only	22	17	32	20	33	25	4	0	0	0	0	0.8
Electricity only	0	0	0	0	0	0	0	37	0	3	0	8
Candles only	14	38	25	23	8	21	0	2	0	5	6	3
Electricity & candles	0	0	0	0	0	0	0	92	80	79	78	66
Electricity & paraffin	0	0	0	0	0	0	0	3	2	8	8	4
Candles & paraffin	64	45	43	57	59	54	59	0	5	0	0	13
Candles, paraffin & electricity	0	0	0	0	0	0	0	3	13	5	8	6

Data show percentage of users; *n*=356 and 399 for 1991 data and 2002 data, respectively.

4.5. Energy choices for entertainment appliances

It was apparent that electrified households in 2002 had made a shift from dry-cell batteries to electricity to power entertainment appliances (Table 5). However, the dry-cell/electricity combination was also common in 2002. It appears there were certain end uses that could only be met by dry-cell batteries. These included powering torches, portable radios and watches. At the time of the second survey lead-acid batteries were only popular in Athol, where they had increased from 2% to 10% of households.

Table 5.

Fuel choice for powering entertainment appliances

Fuel choice	1991						2002					
	A'ol	O'boom	R'le	W'nd	X'thia	Mean	A'ol	O'boom	R'le	W'nd	X'thia	Mean
Dry-cell batteries only	82	74	82	86	80	81	44	12	25	31	26	28
Lead-acid batteries only	2	3	6	5	3	4	10	0	1	3	0	5
Electricity only	0	0	0	0	0	0	0	70	53	45	59	45
Dry-cell batteries & electricity	0	0	0	0	0	0	0	0	0	4	1	1
Lead-acid batteries & dry-cell batteries	4	4	10	4	3	5	21	0	0	0	0	4

Data are percentage of users; *n*=356 and 399 for 1991 data and 2002 data, respectively.

4.6. Changes in energy expenditure

Changes in the patterns of expenditure on each fuel were summarized as average figures for those households using the fuel and were also averaged over the entire sample (Table 6 and Table 7). The first set of figures gives an indication of the absolute amount of money that households spent on individual fuels while the second set of figures gives an indication of relative importance of each fuel on the energy budget.

Table 6.

Fuel expenditure by users (*R* per month)

Fuel	1991						2002					
	A'ol	O'boom	R'le	W'nd	X'thia	Mean	A'ol	O'boom	R'le	W'nd	X'thia	Mean
Paraffin	15	24	20	21	21	20	27	31	22	20	12	22.4
Candles	5	11	17	19	10	12.4	7	5	6	7	6	6.2
Coal	44	24	26	14	0	21.6						
Gas	42	28	54	41	46	42.2	106	0	100	6.5	53	53.1
Dry-cell batteries	29	22	22	30	25	21.6	40	14	28	22	16	24
Lead-acid batteries	6.5	7.7	8.5	15.4	13.2	10.3	11.3	0	8	10	0	5.9
Generators (diesel)		64	8.5	120	68	52.1	—	—	—	—	—	—
Electricity	—	—	—	—	—			73	71	62	42	49.6
Wood	—	48	61	60	156	65	88	86	109	118	171	96.8

n=356 and 399 for 1991 data and 2002 data, respectively.

Table 7.

Fuel expenditure by all households (R per month)

Fuel	1991						2002					
	A'ol	O'boom	R'le	W'nd	X'thia	Mean	A'ol	O'boom	R'le	W'nd	X'thia	Mean
Paraffin	14	22	19	20	19	18.8	19	17	13	12	6	13.4
Candles	4	9	11	14	8	9.2	6	5	5	7	5	5.6
Coal	1.3	4	3	1	0	1.9	—	—	—	—	—	—
Gas	5	4	12	5	5	6.2	1	0	3	3	2	1.8
Dry-cell batteries	25	17	20	27	21	22.0	26	2	7	7	4	9.2
Lead-acid batteries	0.4	0.5	1.3	1.4	0.8	0.9	2.4	0	0.1	0.1	0	0.5
Generators	0	3	25	5	3	7.2	—	—	—	—	—	—
Electricity	0	0	0	0	0	0	0	73	70	61	42	49.2
Wood	0	33	21	11	23	17.6	7	54	52	24	11	29.6
Total energy costs	49	93	112	84	80	83.8	61	151	150	114	70	109
Hh cash income	561	530	724	384	642	568	1112	958	1360	1038	1258	1145
Energy costs as % of total income	8.7	17.5	15.5	21.9	12.5	14.8	5.5	15.7	11.0	11.0	5.6	9.5

n=356 and 399 for 1991 data and 2002 data, respectively.

There was an increase in average monthly expenditure on energy in the region from R84 to R109 per month in 1991–2002 (Table 7) representing a 30% increase over the past 11 years, or an average annual increase of 2.6%, which is well below the inflation rate over the same period. In comparison, mean household cash income doubled (from R568 to R1 145 at 1991 and 2002 values of the South African Rand, respectively). Consequently, the proportion of monthly income spent on energy declined over the period, from 14.8% in 1991 to 9.5% in 2002 (Table 7). In 1991 the highest expenditure was on dry-cell batteries, paraffin and wood, which together accounted for just over two-thirds (69.7%) of total cash expenditure on energy needs. By 2002 electricity was firmly established as the highest cost associated with meeting energy needs, accounting for 45% of the monthly energy budget. This was followed by fuelwood and then paraffin. These three totalled 84.6% of the monthly energy budget. Monthly expenditure on all energy forms declined over the 11-year period except for electricity and fuelwood, where monthly costs increased.

Placing total expenditure in context, the unit costs of all energy forms increased between 1991 and 2002, with the greatest being for candles and paraffin (Table 8). Both of these increased well above the inflation rate. In contrast, the rise in the unit price of gas and fuelwood was below inflation. Thus, it makes economic sense at the household level to decrease the use of paraffin in favour of the electricity, a portion of which is received free, since the overall monthly expenditure of electricity reveals low consumption rates, such that the free allocation is a meaningful proportion of the total. The increased purchase of fuelwood is also prompted by the increasing amount of time required by household members to collect it locally (Fig. 1), from 239±15 min in 1991 to 268±21 min in 2002.

Table 8.

Changes in mean unit price of selected energy forms

Energy	Unit	Year	Athol	O'boom	Rolle	Welvd	Xanth	Mean	% change
Paraffin	R/l	1991	1.45	1.38	1.39	1.41	1.40	1.40	200
		2002	4.70	3.98	4.15	3.81	4.29	4.20	
Candles	C/candle	1991	1.45	3.00	1.20	1.43	0.43	1.36	472
		2002	9.18	1.29	9.63	8.59	8.47	7.78	
Gas	R/kg	1991	3.00	2.77	3.35	3.61	2.92	3.13	84
		2002	6.20		5.75	4.75	6.29	5.75	
Bought wood	C/kg	1991		13	8	7	26	13.5	63
		2002	25	25	22	21	18	22	

n=356 and 399 for 1991 data and 2002 data, respectively.

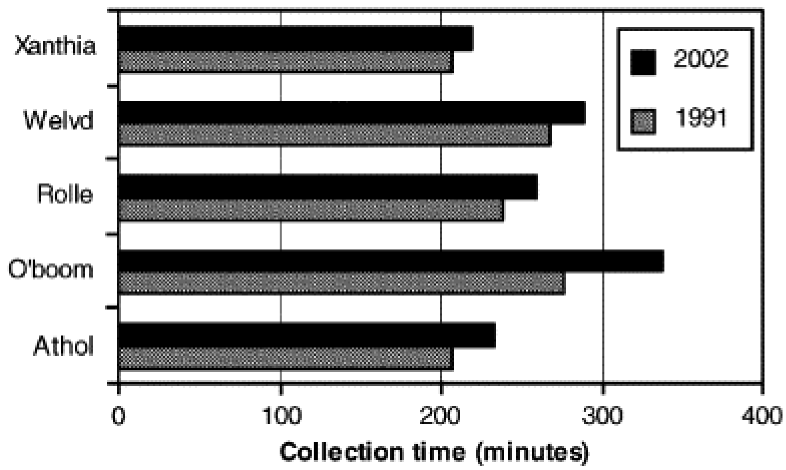

Fig. 1. Mean duration of a fuelwood collection trip per village in 1991and 2002.

5. Discussion

5.1. Prevalence of the different fuel types

In both surveys, fuelwood, whether purchased or collected, was the most widely used fuel in all the sample settlements. About 97% and 94% of households collected fuelwood in 1991 and 2002, respectively, while the percentage of households purchasing fuelwood rose from 27% in 1991 to 31% in 2002. The slight increase in the percentage of households purchasing fuelwood possibly indicates that there was an increase in fuelwood scarcity in the local environment around the settlements (Vermeulen et al., 2000), corroborated by the 12% increase (approx. 30 min) in mean duration of fuelwood collection trips (Fig. 1). Aerial photographic analysis of other settlements in the district has shown that there has been a decrease in fuelwood resources in the region (Pollard et al., 1998; Giannecchini, 2002), most markedly for large settlements such as Rolle and Okkerneutboom. A large portion of fuelwood users in those two settlements purchased most of their fuelwood or supplemented collected fuelwood with bought fuelwood. Purchased fuelwood in these two settlements was more expensive than in the other three settlements. Despite the increase in fuelwood scarcity, the majority of households continued using wood as their main source of energy for thermal applications, as was reported by Vermeulen et al. (2000) in Zimbabwe.

In both surveys the majority of households in all the settlements used paraffin, though the mean volume consumed by each household per month had decreased in 2002. Users of paraffin in 1991 mainly used it for lighting while in 2002 users mainly used it for cooking. More than half of the users were worried about poisoning and flame accidents due to malfunction of paraffin appliances. Such concerns have also been reported by SALDRU (1995) and White (1997) for low-income households in South Africa's metropolitan areas. The extent to which flame accidents occur from paraffin appliances is not known in South Africa, but is known to be high in some developing countries such as Bangladesh (Laloe, 2002). Considering its wide use efforts should be made to make paraffin appliances safer. The results of Vermeulen et al. (2000) show that patterns of paraffin use are perhaps the most sensitive of all the fuel types to changes in external factors, and hence uses patterns and consumption levels vary widely, temporally and spatially.

Households in both surveys also reported the wide use of candles. Almost half of the respondents in electrified households used candles mainly for back-up purposes and in times when they did not have enough money to purchase pre-paid metre cards. Some of the electrified households were not fully wired, and often had only one connection point and a single light in one room only. The rest of the rooms were lit with candles.

The use of dry-cell batteries decreased markedly between the two surveys. Only 32% of households used dry-cell batteries in 2002; almost a third of what was reported in 1991. It is also lower than the 73% that was reported by Eberhard (1986). The change seems to be a result of households switching to electricity to power entertainment appliances. However, in the unelectrified settlement of Athol households continued using dry-cell batteries on a large scale, even though the proportion had declined since 1991. Dry-cell batteries were still being used widely in all the settlements to power appliances that could not be powered by electricity, for example torches, clocks and small portable radios.

By 2002 dung, gas and coal were used by less than 10% of households in all settlements (other than gas in Athol), and thus contributed relatively little to the overall energy mix at village level, but still are important for certain individual households. There is a social stigma associated with use of dung, as it is interpreted as a sign of severe poverty (Griffin et al., 1992). With respect to gas, many respondents considered it to be an expensive fuel and dangerous in case of an explosion. White (1997) noted that the fears about the explosiveness of gas need to be addressed to encourage wider use. The relative cost of the fuel increased by 3.5% per year.

5.2. Changes in the mix of the different energy forms

The majority of the households continued using mixtures of fuels and showed no tendency of narrowing down to, and dominance of, sophisticated fuels as the energy ladder model proposes. Households either used different fuels for different end uses or used two or more fuels for one application. The 1991 survey revealed that 62% of the households in the sample settlements used four or more fuels to meet their domestic energy needs and in 2002, 58% of the households in the four electrified settlements as well as the unelectrified settlement of Athol continued using four or more fuels to meet their energy needs. Thus, for the majority of households, the newly introduced fuels, i.e. electricity and solar panels, were additional fuels with limited displacement of the other fuels, as also reported by Davis (1998). This could be ascribed to a number of reasons, the primary one being economic limitations, particularly to the cost of appliances. Consequently, only 1% of electrified households had completely substituted all the other energy sources with electricity. These were mostly high-income households with relatively small family sizes. Davis (1998) also reported similar results in some former homelands of South Africa where a large portion of electrified households used three or more fuels, particularly low-income households. Another reason is the need for alternatives when supply of a single fuel is restricted, such as an interruption in electricity supply, or no paraffin at the local shop.

These results corroborate those of Vermeulen et al. (2000) in indicating that changes in energy-use patterns in rural areas cannot be generalized and are not a straight path as proposed by the energy ladder model. Fuel security for most households is still necessitated by a combination of a range of fuels that are accessed in spatially and temporally variable patterns as dictated by local and regional economic, social and environmental contexts. For this reason, newly introduced sophisticated fuels must not be regarded as the sole providers of all future energy needs in the region but rather as components of an energy mix (White et al., 1997).

5.3. Changes in the quantities of the different energy forms

Monthly consumption of fuels whose end uses were previously associated with lighting and powering entertainment appliances had declined at the time of the second survey in the four electrified settlements. The affected fuels included paraffin, candles, dry-cell batteries, lead-acid batteries, and gas. Generators were no longer in use. It was clear that the reported decline was offset by a corresponding rise in the use of electricity to meet the respective end uses.

In terms of cooking energy, fuelwood retained its traditional importance in all the sample settlements with over 90% of the households reporting use. There were no quantitative trends supporting the existence of a shift from fuelwood to other fuels. Monthly consumption of fuelwood remained the same. Only about 1% of the households used electricity alone for all thermal purposes. A few households that used paraffin and gas for cooking did so in combination with fuelwood. The continued use of wood could be attributed to the fact that it was obtained for free (other than opportunity costs of labour, which are low in regions of high unemployment and low skills base) and was believed by approximately 70% of users (in 2002) to cook faster than the other fuels. In cases where it was purchased, it was relatively cheaper than the other fuels. The mean annual increment in the price of fuelwood over the past 11 years was only 4.2%. This was less than the other commercial fuels, and less than the inflation rate. Additionally the use of fuelwood for cooking and heating does not require the use of expensive appliances. The observed trends corroborate those of White (1997) who observed that the majority of poor people who have access to electricity avoid using it for those needs that have a high-energy demand and for which the appliances are specialized and relatively expensive, such as cooking and space heating. Similar results were obtained in Zimbabwe and Kenya where rural inhabitants preferred using wood for thermal applications because it was a free commodity and in cases where it was purchased it was relatively cheaper than other fuels (Marufa et al., 1996; Vermeulen et al., 2000; Kituyi et al., 2001).

In light of these, an “energy web” could, perhaps, be used to denote the energy transition that has taken place in the four electrified settlements (Fig. 2). It is more elaborate than either the energy ladder or leapfrogging hypotheses. A discontinuous line in the figure stands for a transition path involving some households while a continuous line stands for a transition path for the majority of households. As can be seen from the figure, going up the energy web fuel types become more efficient and cleaner. Fuel switching in favour of electricity is only evident in as far as lighting, powering entertainment appliances and refrigeration are concerned. The majority of households in Bushbuckridge have achieved this transition. For thermal application, however, there is a dead-end on fuelwood. Only a few high-income households have moved to the use of electricity for cooking. The above model can also be used to explain the energy transitions reported by White (1997), White et al. (1997), Davis (1998) and Murphy (2001).

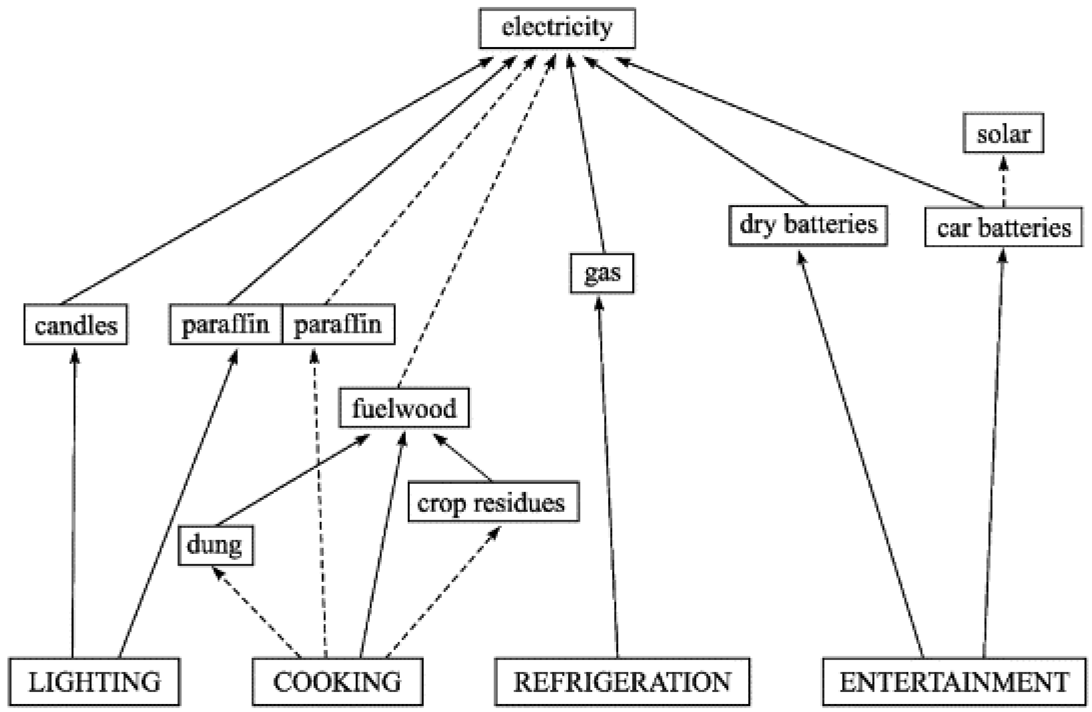

Fig. 2. An energy web denoting the kind of energy transition in the Bushbuckridge district.

5.4. Effect of resource supply on energy-use patterns

The extent to which new energy sources (electricity and solar in the study) are integrated into households' daily patterns of energy use is guided by a number of social, cultural and economic factors. From this view, it is clear that energy projects may fall short of their objectives if planners do not consider the complimentarity between rural people's capabilities and the new energy resources. Murphy (2001) observed that many projects have failed because designers have oversimplified the social and cultural relationships existing in the implementation context of the new energy resources. Adoption and dissemination of the new resource has to be supported by social, cultural and economic institutions. These institutions may include people's daily behavioural patterns (Scott, 1995), NGOs, volunteer services, church groups and other multilateral organisations. The national Rural Development Strategy (1995) argues that there have been very few links between consumers and policy development, planning or implementation processes in the energy industry, so that the energy policies and strategies have seldom been developed in cooperation with the sectors in rural areas. Energy programmes have succeeded in Kenya drawing on knowledge and contributions from community-based organisations. For example, the GTZ (Deutsche Gesellschaft fur Technische Zusammenarbeit) Women and Energy Programme has been pivotal in energy dissemination projects since 1983. Similarly, if the newly introduced energy resources in Bushbuckridge district are to address the energy needs of the local communities more effectively, rural end users must be involved in the policy process through existing social institutions.

5.5. Changes in patterns of energy expenditure

Total fuel expenditure on paraffin, candles, dry-cell batteries, lead-acid batteries, gas and generators had generally decreased between the two survey periods, with the exception of Athol. This is an indicator of the falling demand for these fuels. The decline in demand is probably a result of the increase in the use of electricity to meet the end uses that where previously met by such fuels.

Households in the four settlements with electricity spent more money on energy than those in the unelectrified settlement (Athol). On average, they spent approximately 60% of their total fuel expenditure on electricity, despite the free basic allowance per household of 5–6 kWh per month. Similarly, in the city of Hyderabad in India, households spent half their energy expenditure on electricity (Alam et al., 1998). Studies in other developing countries have also shown that electricity is the main energy cost for most low-income households (Gupta and Ravindranath, 1997; Kituyi et al., 2001; Priyantha and Attalage, 2002; Kabede et al., 2002). Despite a doubling of households' incomes, per capita incomes remain well below the national poverty line in South Africa. Consequently, absorption of the new energy resources in the region (particularly electricity) can be expected to be slow since most households are not economically empowered to afford full use of the resources. This view is echoed by Murphy (2001) who noted that without increases in the per capita income levels, and/or economic incentives to encourage household investment in electrical appliances, the returns of rural electrification projects would continue to be poor in as far as cooking energy is concerned.

5.6. Policy dimensions

The longitudinal study highlights that households in the sample settlements have witnessed pronounced changes in their patterns of energy use in the past 11 years. The introduction of electricity has played a role in spurring the shifts. However, the pattern of change was not a straight path as suggested by the energy ladder or the leapfrogging hypotheses. In particular, the number and diversity of energies used by the rural households has not declined following the introduction of electricity. By examining the pattern of change in households' monthly consumption rates of the different fuels, it is evident that the changes are restricted to particular end uses, i.e. lighting, powering entertainment appliances and refrigeration. The transition does not gravitate towards end uses with a high-energy demand such as cooking and heating. Only 1% of families have completely displaced the other fuels with electricity. The high cost of electricity and the appliances that go with its use are the major constraints towards complete substitution of the other fuels with electricity, especially if fuelwood stocks are adequate or can be purchased at seemingly low prices relative to that of electricity. The role of the Free Basic Allowance of electricity needs to be examined further. Other reasons include the preference for traditional fuels and fear of electricity shocks as a result of malfunction of appliances. For cooking and other thermal applications, fuelwood retained its traditional importance as the staple energy source for almost 94% of the households in the region. A few households, however, do use fuelwood in combination with paraffin, gas and electricity but in such cases the other fuels largely play a supplementary role.

The local institutions and the socio-economic context of energy introductions need to be appreciated. The high unemployment in the region of this study means that cash income streams to households are low, as are also the opportunity costs of labour. Both of these limit the uptake of electricity for thermal purposes. This is in line with reports from urban areas. However, the relative availability of fuelwood needs to be considered in rural energy scenarios and interventions. Even in areas where fuelwood stocks are diminishing, residents opted to purchase fuelwood rather than substitution with electricity. Amongst using households, expenditure of fuelwood was consistently higher than expenditure on electricity. This has benefits in creating local-level employment and markets (Shackleton et al., submitted), provided it is not at the cost of environmental quality. In the Bushbuckridge region specifically this is a potentially sustainable option as there are extensive woodlands on private and State lands to the north, east and west. Much of the traded wood is sourced from these areas. The structure, dynamics and viability of fuelwood markets have been little studied in South Africa, and hence have been overlooked in energy policies.

The declining share of total household expenditure on energy, a result of low-cost increments in fuelwood and increased real incomes, means that rural poor will be less vulnerable to unanticipated changes in prices of individual energies. They will also have greater cash available for productive investment, rather than direct basic needs. Thus, it would be worthwhile for local institutions to support and facilitate fuelwood markets based on sustainable harvesting and clean combustion technologies (to limit adverse health impacts), to secure these advantages into the future, thereby by contributing towards sustainable rural livelihoods.

Acknowledgements

Thanks are due to the residents of the five villages for their enthusiasm and support of this work, so too the field assistants. The bulk of the funding for this work was received from the National Research Foundation (South Africa) for which we are grateful. Fiona Parkin commented on an earlier draft.

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