H5 Ru
BN-HAR-910
ISN = 38387

A Rural Energy Study in Tanzania
The Case of Bundilya Village

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Based on observations and estimates, an energy flow model for the village of Bundilya in Tanzania has been set up. A serious imbalance is demonstrated, and possibilities for short-term and long-term planning efforts to overcome the imbalance are discussed. It is concluded that introduction of more efficient equipment for using energy, along with an integrated agro-forestry management programme, constitutes the only short-term solution of merit. Cultural aspects and the participating role of the villagers are discussed, and the relations between this study and other village energy studies for Tanzania and other countries are touched upon.

1. INTRODUCTION

Very few people in Tanzania realize the nature and seriousness of the rural energy problem, which may cause an even more serious impediment to economic development than the commercial energy crisis associated with increased fuel prices. Figure 1 summarizes estimates of population, energy use and forest loss. It can be seen that most energy use in Tanzania is in the form of fuelwood and that the per capita consumption of this energy source stays roughly constant at 680 W/cap in 1980 (corresponding to about 2.2 m^3/cap/y). This means that total fuel wood use increases in proportion to population. The annual increment in the standing crop of trees, shrubs, etc. is such that 50% of the 1980 fuelwood use may be said to be utilized in a renewable mode. The other 50% is associated with forest depletion. Based on estimates of forest area (savanna woodlands, intermediate woodlands and a few closed rain forests) made between the early 1940s and the present, the bottom part of Fig. 1 shows the trend in forest loss due to removal exceeding natural renewal. The shape of the curve indicates an accelerating process of depletion, starting in the 1950s and reaching catastrophic dimensions in the 1980s.*

*Energy use is in this article expressed in watts (W) or watts per capita. This is a unit of energy flow, that is energy converted per unit of time, one watt being one joule per second. This conveniently allows us to express all the activities implying an energy activity in similar units: solar energy assimilated by plants, fuels combusted, food energy intake, muscular work, biofuel production and end use rate of energy conversion. One watt equals 3.2×10^7 J/y, or 7.5×10^{-4} tons oil equivalent per year, or 3.0×10^4 Btu/y.

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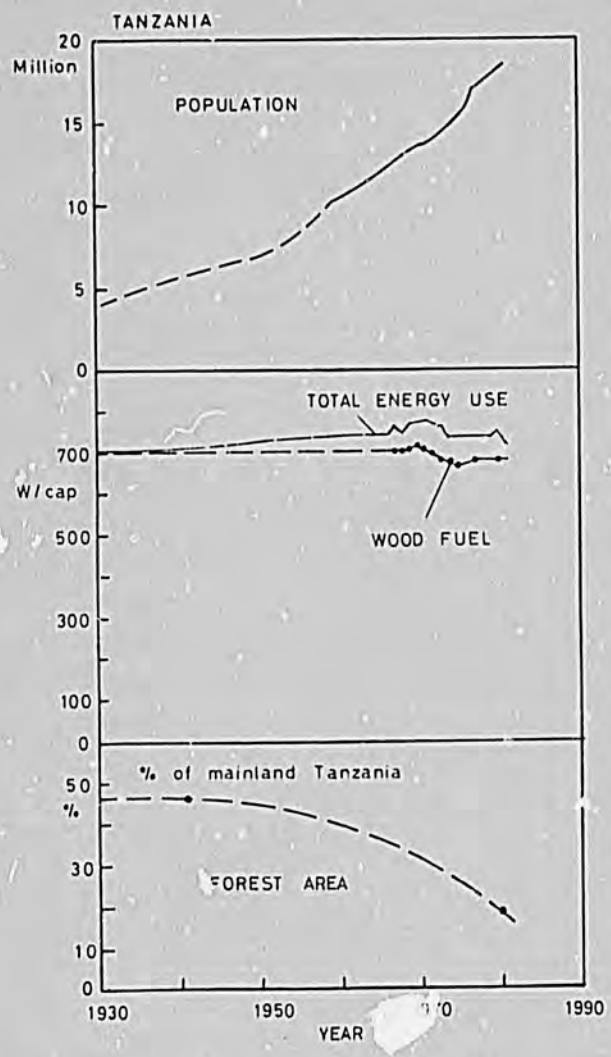

Fig. 1. Tanzanian population, energy use and forest area 1930–81 (dashed lines indicate estimates based on indirect data). Sources: UN (1980) and UN Statistical Yearbooks 1951–82, UNECA (1976), Nkonoki (1983) andKaale and Mwandosya (1983).

The loss of forest area is due to the use of fuelwood and timber, to the clearing of forest for expansion of agricultural activities to the burning of the forest as a crude way of eradicating tsetse flies, and to uncontrolled livestock grazing. In Tanzania more than 15 000 km² of forest are disappearing every year. The inability of the forest to sustain current fuelwood use, and the total inadequacy of present afforestation efforts, are shown on a regional basis in Table I where the total renewable supply from woodland and afforestation is compared with total demand. Only five of Tanzania's 20 regions are using fuelwood in a renewable mode.

The dominant use of fuelwood by the rural population is for cooking, usually using a three-stone arrangement. The efficiency of the type of fireplace in converting wood into useful heat is often about ten times lower than for this best modern cooking devices. In this fact we see the only possible short-term solution to the Tanzanian rural energy problem, a problem which in a more or less similar form is found in most of the least developed countries of the world. By improving the efficiency of current cooking devices, say by a factor of 2 or 3, the immediate problem of fuelwood depletion can be averted, and wood can be used in a renewable mode for a decade or two, while long-term solutions to the energy problem are being sought.

Improvement in the efficiency of the rural use of energy cannot be obtained without some social cost. The traditional ways of using firewood and charcoal are deeply rooted in the cultural traditions of the village populations. The challenge to the rural communities is to modify these traditions, which in any case cannot be sustained for much longer, in such a way that people retain their sense of cultural 'belonging' and self-respect. The following analysis and suggested solution is one attempt to provide quantitative input to a qualified discussion of this urgent matter.

2. SOURCES OF DATA

A number of studies have been performed, aiming at obtaining data on energy use in rural Tanzania. Major studies were conducted by the Tanzania National Scientific Research Council (UTAFITI 1978; Asman and Kayumbo, 1980) and at the University of Dar es Salaam (Nkonoki, 1981). The present study is based on data derived from these studies supplemented by additional field investigations in the Mwanza and Tabora regions.

For the present investigation data were collected from the following sources:

(a) Interviews in the villages, with heads of households in different income categories, with

TABLE I
Regional fuelwood supply and demand for the year 1983

Region	Supply from Savannah Woodland Area ($10^7 m^3$)	Potential Annual cut ($10^6 m^3$)	Supply from planted trees Area to be Clear felled ($10^7 m^3$)	Expected volume ($10^6 m^3$)	Total Supply ($10^6 m^3$)	Total Demand ($10^6 m^3$)	Demand Deficit ($10^6 m^3$)	Percentage Demand deficit	Afforestati Required t offset defic ($10^7 m^3$)
Mwanza	177	0.109	0.395	0.040	0.149	3.327	3.178	95	31.78
Mara	158	0.094	0.511	0.051	0.145	1.640	1.495	91	14.95
Kilimanjaro	110	0.100	0.382	0.038	0.138	2.101	1.963	93	19.63
Mtwara	542	0.260	0.090	0.009	0.269	1.703	1.434	84	14.34
Kagera	572	0.277	0.243	0.024	0.301	2.450	2.149	88	21.49
Tanga	1057	0.599	0.191	0.019	0.618	2.352	1.734	74	17.34
Shinyanga	1658	0.666	0.783	0.078	0.744	3.156	2.412	76	24.12
Pwani	1111	0.573	0.127	0.013	0.587	1.119	0.533	48	5.33
Arusha	1224	0.723	0.712	0.071	0.794	2.244	1.450	65	14.50
Dodoma	1460	0.840	0.602	0.061	0.901	2.233	1.332	60	13.32
Iringa	3092	1.413	0.693	0.069	1.492	2.101	0.619	30	6.19
Mbeya	3947	1.618	0.525	0.052	1.670	2.529	0.859	34	8.59
Kigoma	2269	0.859	0.220	0.022	0.881	1.496	0.615	41	6.15
Morogoro	3118	1.348	0.233	0.023	1.371	2.149	0.778	36	7.78
Tabora	5643	2.185	0.267	0.027	2.212	2.042			
Ruvuma	4143	1.581	0.474	0.047	1.628	1.320			
Rukwa	4718	1.809	0.520	0.052	1.861	1.121			
Singida	3555	1.727	0.272	0.027	1.754	1.407			
Lindi	4633	2.059	0.055	0.005	2.062	1.161			
Dar es Salaam	Nil	Nil	Nil	Nil	Nil	2.509	2.509	100	25.09
Total	43 187	18.838	7.295	0.728	19.566	40.160	20.594		205.94

Source: Forest Division, Ministry of Natural Resources and Tourism, Dar es Salaam, 1983.

village chairmen and ward secretaries and with district officials.

(b) Direct observations for a two week period in each village, making notes of movements connected to firewood collection, of chaircoal preparation, of fuel wood trade and use for domestic purposes or industrial purposes such as brickmaking, beer brewing, tobacco curing, fish smoking, and finally of trade in kerosene. Observations were also made of the use of cow dung, size of areas sown and harvested, time spent working in the fields, quantities grazed by livestock, etc.

(c) Sample measuremens of the volumes of the bundles of firewood collected, as well as of the tin containers or sacks used for charcoal.

(d) Samples of bark and leaves from trees used for firewood were taken to be identified by the Botany Department of the University of Dar es Salaam.

We shall present our findings first for one particular village, and discuss how a picture of the total energy use in that village might be sketched by adding estimates and derived quantities to the primary data. Then we shall compare the results to villages in other parts of Tanzania, and discuss the planning implications.

3. A VILLAGE IN THE MAGU DISTRICT

Magu is a district in the Mwanza province of Tanzania, situated on the east side of Lake Victoria north east of the city of Mwanza. Magu has about 100 villages, each with 1000–4000 inhabitants. Insolation is high, and the main rainy season lasts from November until May, allowing the growth of crops such as rice, maize and cotton, as well as sorghum, cassava and sweet potato. Nearly 96% of the population live in peasant families that practice mixed farming. Two out of seven families also keep livestock.

The village studied in Magu is Bundilya, a fairly small village (1341 persons and 226 households) in the Kahangara Ward, some 13 km west of the

TABLE II
Average agricultural yield and energy flows in Bundilya

	Quantity	*Energy flow*
Vegetable production		
Insolation on fields (260 ha)		600 MW
Harvest yields: Maize (160 ha)	108 tons/y	50 kW[a]
Cotton (60 ha)	36 tons/y	
Rice (28 ha)	20 tons/y	10 kW[a]
Sorghum (12 ha)	3 tons/y	2 kW[a]
Sweet potatoes	8 tons/y	1 kW[a]
Vegetables, beans, peas[a]	2 tons/y	~ 2 kW
Animal production		
Insolation on pastures (1000 ha).		2400 MW
Grazing yield		~ 1 MW[b]
Milk production (15% of cattle lactating)	40 tons/y	3 kW[c]
Egg production (15–20% of chickens laying)	1 ton/y	0.2 kW[c]
Meat production	9 tons/y	7 kW[c]
Fish (estimated consumption)	24 tons/y	20 kW
Draught animal power		ca. 0 kW

Insolation figures are based on Griffiths (1872), energy values on:
[a] Pimentel *et al.* (1975). [b] Long (1961) and [c] Ansbæk *et al.* (1973) [d] About 1.5 tons/y used as relish, mostly by poor households who cannot afford to buy fish.

Magu administrative headquarters at Nyalikungu. The total area used by Bundilya villagers covers approximately 2500 ha. Of this amount only 260 ha is at present cultivated although more could be. Some 1000 ha of marginal land is used for the grazing of livestock (1915 head of cattle, 360 sheep, 450 goats and around 1800 chickens—all numbers given for the village pertain to 1 January, 1982). The main crops are maize (which is cultivated on 160 ha), cotton (60 ha), rice (28 ha) and sorghum (12 ha). Average harvest yields are given in Table II, along with milk and meat yields from the animals. The average annual slaughtering rates were estimated to be: cattle, 3%; sheep, 11%, goats 33%, and chickens, 42%.

There are three types of farms in Tanzania. The traditional family farm, the *shamba*, has from 0.5 to 5 ha of land, usually in 2 or 3 different plots within the village borders (some 4 km from the village center). The size depends on family size, land fertility and demand and is distributed by the village government according to uniform rules. *Block farms* are large pieces of land, typically over 100 ha and are situated at some distance from the village compound. Again each family has a well-defined plot. This is not so in the *communal farms*, designed for shared agriculture to the benefit of the entire village. The communal farms were designed to be sources of income for the local administration, but only a few villages have established such farms. In Bundilya, the shambas dominate the picture. Soil tilling is by hand (hoe), there is no rotation among crops or between cultivated and pasture land, no irrigation and much less use of fertilizer and insecticides than that considered desirable for maintaining soil quality. Some animal manure is spread onto the fields, but most of it is used for construction or burned as fuel. Liquid waste is not collected.

The animals get no fodder to supplement the grazing input, but water is supplied or the animals led to sources of water.

There is no forest near the Bundilya village, but a 48 ha scrub area is available within the village boundaries. The average distance walked to fetch firewood is about 3 km (one way). The firewood is collected by women. The preferred species is *Acacia polyacanta* willd. ssp. (Mimosaceae), said to dry quickly in the sun and burn smoothly and without offensive odour (in contrast to *Euphorbia* species). The only problem with the Acacia is its vulnerability to insect borers, particularly termites

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which means that it has to be used within about a month after drying. For this reason other sources of fuelwood must be used in the rainy season. The preferred species being *Balanites aegyptica* Del. (Balanitaceae).

Typically, two bundles of firewood sticks are collected per week per family for cooking purposes. Each bundle consists of 10 to 15 sticks whose average length is just over one metre and whose diameters if from 3 to 10 cm per individual stick. The total volume is typically 0.05 m^3 for the whole bundle. Additional firewood is collected for industry, such as local beer brewing and for fish smoking (Bundilya is close to the major Lake Victoria fish market at Nyalikungu).

Other energy sources observed in use in the Bundilya village include charcoal (often made by inefficient kilns), cow dung, agricultural waste such as straw, and finally kerosene, the latter being used by practically every family for lighting purposes.

Food preparation takes place within the houses, and typically, two main meals are cooked each for about 2.5 hour on a three-stone fireplace. The village also maintains an evening bonfire for social purposes and overnight for protection against insects and wildebeasts.

4. ENERGY USE IN THE VILLAGE

Table III gives estimates of energy inputs into village activities associated with agriculture, household, industry and services. The primary data used to prepare the table include volume or weight of fuels, number of hours spent working in a given way, etc. From these measurements the energy content (for physical inputs such as fuels) and the energy expenditure (for example for

TABLE III
Estimated energy use for activities in Bundilya before proposed improvements

Activity	*Type of Energy*	*Gross energy flow*	*Practical net energy flow*[a]
Agriculture			
Soil preparation, manure spreading, harvesting, threshing, transport, water and firewood collection, livestock attendance[b]	Human labour[c]	30 W/cap	2 W/cap
Crop drying, fish smoking, milling	Firewood[d]	90 W/cap	9 W/cap
Industry (small scale, mainly beer brewing)	Firewood[d]	60 W/cap	10 W/cap
Domestic			
Cooking	Firewood[d]	310 W/cap	30 W/cap
	Charcoal[e]	40 W/cap	8 W/cap
Hot water for bathing, etc.	Firewood[d]	60 W/cap	6 W/cap
Lighting (see also below)	Kerosene	5 W/cap	1 W/cap
Services			
School, public bars	Charcoal[e]	10 W/cap	2 W/cap
Open-air fires (for lighting, insect control and for security)	Cowdung and agricultural waste	60 W/cap	3 W/cap
	Firewood[d]	30 W/cap	2 W/cap
Transportation[f]			
Total		695 W/cap	73 W/cap

[a]Defined as the energy needed to do the same task with the best available technolgoy.
[b]For details see Sørensen (1983).
[c]Estimates of muscle energy based on Long (1961).
[d]Assumed conversion factor $1 m^3/y = 310$ W.
[e]Given as wood input assuming 25% conversion efficiency from wood to charcoal.
[f]Was not assessed in this study.

muscular work) have been calculated for various village activities. Finally, the net energy required to achieve the desired activity was also estimated. It should be stressed that there are major uncertainties in the basic data, and certainly also in estimating energy flows from the non-energy type data. Most of the estimates we give should be taken as order of magnitude indications only, and the numbers quoted as 'practical net energy flows', which is the energy needed to do the same task with the best presently available technology, are only meant to show the most likely places where improvements in the efficiency of energy use might be achievable.

The energy use is seen to be concentrated in the domestic sector and more specifically on providing heat for cooking and other purposes. The use of open fires (such as the three stone arrangements for indoor cooking) implies that the efficiency of utilizing firewood is very low.

The total per capita gross energy use in Bundilya is slightly below the average for Tanzania, presumably due to the near-lack of industrial activity. The inputs of energy into agriculture are small, and the low agricultural outputs are witness to the impact of this fact. Estimates of crop yields per hectare (which may be obtained from Table II) are 6–10 times lower than those obtained for the same crops in mechanized (and subsidized) agriculture in other parts of the world (Pimentel *et al.*, 1975), and yields of milk, eggs and meat are also equally below what may be attained. However, this does not imply that rural Tanzanian agriculture is inefficient, if by efficiency we mean the output divided by the efforts being put into the agricultural enterprise. The total output per capita can be obtained from Table II (by dividing each number by the population of Bundilya). It is 71 W/cap of food in energy units, which according to Table III is 62% of the energy inputs. If fish smoking is left out, food outputs are 200% of the energy inputs. In mechanized and subsidized agriculture, the output/input ratio goes from about unity for farms with no livestock, down to 0.2 for some mainly animal-based farms. However, a more relevant question is whether or not the yields are sufficient to provide the necessary nutrients for the village population. With the age distribution of Bundilya, the average recommended food energy intake would be about 100 W/cap, so the figure of 71 W/cap is clearly low. It does not include all food consumed in the village, because some of the revenues from cotton production are used to purchase food from other parts of the country. Still, the food supply situation is not satisfactory, in particular considering population growth.

Bundilya is fortunate in that it has access to additional land that could be farmed, but to increase the area of land under cultivation, more effective techniques, such as plowing by bullocks, would be necessary.

5. COMPARISON WITH OTHER PARTS OF TANZANIA

Another village in Tanzania which was surveyed was Puge, on the main road between Tabora and Nzega. It covers 3200 ha of which an expanding fraction, presently covering over 600 ha, is used for food crops (sweet potato, maize, rice and ground nut being the major crops). The 1981 population was 2562 (843 households) plus livestock (2500 head of cattle, 2100 goats or sheep and 3600 chickens). There are 800 ha of forests and 200 ha of scrubland within the village boundaries. Puge's agricultural production amounts to 125 W/cap. This figure includes animal production and a cash crop, tobacco, grown on 600 ha. There is no food problem in Puge. There is however, a wood problem connected with the clearing of forest to establish tobacco plantations and the use of wood as fuel for the curing process. An additional factor is the rather large charcoal manufacturing industry which sells charcoal to the cities of Tabora and Nzega.

In Tanzania as a whole, the average per capita fuelwood consumption is 680 W/cap (UNECA, 1976; Nkonoki, 1983; a 15% lower value being quoted by UN, 1980). Food production amounts to about 90 W/cap (FAO 1978) and the livestock population is somewhat equal to the human population in numbers (Nkonoki 1983). Bundilya may therefore be described as near average in terms of energy consumption, below average in vegetable production but a good deal above average in livestock population and production. For Tanzania as a whole the present consumption of energy from other than biomass-based sources (mainly oil products and hydro-power) is about 50 W/cap. As this figure is largest in the cities, the

importance of fuelwood in rural Tanzania is evident.

6. RESOURCE MANAGEMENT PROBLEMS

For a number of years, the Tanzanian government has responded to the fuelwood problem with a number of afforestation schemes. However, not all have been successful. There are a number of reasons for this including grazing of the seedlings by livestock, destruction and burning of afforestated areas by villagers acting on traditional views of forests as carriers of diseases and hosts for dangerous animals. In some cases the failure of the afforestation programmes could be blamed on not giving appropriate information to the villagers, on planting tree species different from those locally preferred for fuelwood, and on selecting land not well suited to the project (for instance land traversed by paths traditionally used by herdsmen and cattle). In any case, the mixed results achieved from previous programmes makes it very delicate to propose a stepping up of the afforestation projects on the order of ten times the current level which is what is needed to put fuelwood use on a renewable basis, if improvements are not made in the efficiency in cooking stoves.

Other aspects of the government efforts have addressed the possibility of substituting other energy sources for fuelwood. Fossil fuels being out of reach for most rural inhabitants, the focus has been placed on renewable energy solutions. But these are emerging technologies, and economic only under the condition that construction as well as maintenance and repairs can be made locally. Unfortunately, the appropriate skills and technical knowledge which could make renewable energy projects viable are rarely found in a particular village or even a region.

For Tanzania, integrated management of agriculture, livestock and wood resources is a new concept, which would have to be disseminated among villagers and their local governments, perhaps by some kind of extension service similar to the one presently working exclusively with farming practices. If it was made to include energy advice, it is possible that some of the present problems found in many villages in Tanzania could be avoided on the short time scale. The problems that need to be addressed include: the use of plant residues and cowdung for burning rather than returning this material to the fields; the keeping of large herds of livestock, where a reduction in number would make more food available per animal, reduce overgrazing and produce healthier animals with higher milk and meat yields; the use of draught animal energy to improve soil treatment; and most importantly, the introduction of improved methods of cooking, so that the fuelwood is stretched by higher efficiency of use.

There has been an effort to develop improved cooking devices, such as the double shell burners and Lorena stoves (see e.g. Nkonoki, 1980; VITA, 1980), but still the penetration of improved stoves into the rural areas has been virtually nil. This may have to do with the cost of the stoves, which although modest (compared to the price obtained from the selling of say, a sheep) would bring the fuelwood problem from the women's 'free commodity' domain into the money economy, which means into the men's domain.

This may be happening by itself, because fuelwood is becoming more and more scarce. Already over the last decade, there has been a growing proportion of fuelwood products sold for cash in the larger markets. Not only charcoal but also fuelwood is becoming a commercial commodity. If this trend continues, the village would have to assign specific communial rights to wood collecting sites, and the whole wood resource could become regulated within the village economy. This might rapidly make more efficient use of wood economically interesting and attractive to the villagers.

Government legislation or local by-laws is specifically needed in regard to the large-scale felling of trees for commercial purposes, such as tobacco curing and fish smoking, and for the establishment of new cash crop plantations.

7. SHORT-TERM PLANNING OPTIONS

Let us now try to sketch what an integrated energy/agricultural policy could look like for a village such as Bundilya. Table IV summarizes the measures suggested for food crops and livestock and Table V shows the expected effect of these measures on energy use. If the reduction in livestock population is achieved by slaughtering

TABLE IV
Proposed simple improvements for the Bundilya village
(Scenario for the near-term future, human population unchanged at 1350.)

	Energy yield
Vegetable production (food crops)	
Increase cultivated area from 200 to 260 ha, use bullock-driven plows and return manure and plant residues to fields, leading to about 40% higher productivity. Harvest yields increase from the present 48 W/cap to	87 W/cap
Animal production (livestock)	
Reduce cattle population from 1915 to 1000, which would raise lactation from 15% to 40–50%. Reduce population of sheep and goats from 810 to 400. In both cases double slaughtering rate. The average weight per animal should increase 20 to 30%, and the total grazing yield should go from 745 W/cap (human!) to	500 W/cap
Milk, egg and meat yield should go from 18 to	12 W/cap
To this comes fish, staying at	15 W/cap
Energy use	
Bullock power should be used in agriculture. Better kilns than the present eathen ones should be introduced for charcoal making, increasing the wood to charcoal conversion efficiency from 25 to 50%. Better stoves and burners should be introduced, increasing the end-use efficiency two-fold. More attention should be given to attendence of fires (including open air fires) for optimal combustion.	see Table V

TABLE V
Energy use in Bundilya after proposed simple improvements

Activity	*Type of energy*	*Gross energy flow*	*Practical net energy flow*
Agriculture			
Soil preparation, etc. (cf. Table III)	Bullock and human labour	50 W/cap	4 W/cap
Fish smoking, etc.	Charcoal	50 W/cap	9 W/cap
Industry (including new stove production)	Firewood/charcoal	75 W/cap	15 W/cap
Domestic			
Cooking	Firewood	160 W/cap	30 W/cap
	Charcoal	20 W/cap	8 W/cap
Hot water	Firewood	30 W/cap	6 W/cap
Lighting	Kerosene	5 W/cap	1 W/cap
Services			
Institutions, etc.	Charcoal	5 W/cap	2 W/cap
Open air fires	Firewood	50 W/cap	5 W/cap
Transportation			
Total		445 W/cap	80 W/cap

See also footnotes a–d and f to Table III.

and selling more animals annually, then there would be additional moeny both for improvements in cooking stove efficiency and for other new activities. Among the very important activities that would be needed to make this scheme acceptable is an education programme informing the villagers about the technc logy available and their options of choice. This could be an extension of the present

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adult education programme, considered to be quite successful. It is extremely important that the different interlocking components of the proposed scheme are carried out according to a common plan, and that the people in the village are involved in the planning process and are aware of the significance of each step in the programme.

The result of the improvements suggested in Table IV is that the village becomes self-sufficient in food, with an average food energy supply per person of 114 W/cap. A comparison between (present conditions) and Table V (after suggested improvements) shows, an approximately constant net energy flow, which means that roughly the same energy service level could be achieved with 36% less energy input. This would in the short term alleviate a large part of the deforestation problem and would give the village a chance to take a breath and formulate its long term policies. When more industry is developed in the village, and the expected population growth has taken place, then the simple measures suggested in Table IV will no longer be sufficient to keep energy supply in ecological balance. A long term approach will also be needed.

8. THE LONG-TERM FUTURE

It is not meaningful to plan in detail for the more distant future, and the direction Bundilya will be taking with respect to say industrialization is hard to predict. Still, there are some facts even about the distant future, which are known well enough to warrant some thoughts even today. If no substantial migration into or out of the village takes place, the population will double from 1350 to 2700 in 20 to 30 years, implying that food production must also be increased correspondingly, and that an environmentally 'safe' level of fuel wood consumption would be only half of what it is at present in terms of per capita consumption. Based on these assumptions, Table VI suggests a long-term plan calling for increased agricultural productivity, a permanent afforestation prog-

TABLE VI
Long-term energy plan for Bundilya village
(Scenario where human population has increased from 1350 to 2700)

	Energy yield
Vegetable production (food crops)	
Increase cultivated area from 260 to 500 ha, use both natural and (imported) chemical fertilizer, introduce irrigation (biofuel-driven pumps) in order to allow a second harvest, use tractors for plowing, etc. With double productivity, the harvest yields reach	167 W/cap
Fermentable (and collectable) residues, about	150 W/cap
Animal production (livestock)	
Increase part of pastures in rotation with crop land, add protein-rich cattle-feed (say based on 37 W/cap of the vegetable harvest yield). Number of cattle stays at 1000, with weight increasing 30–50%, the number of sheep and goats is reduced to 200. This makes the grazing yield about as in Table IV, but due to increased human population it becomes	250 W/cap
Milk, egg and meat yield	20 W/cap
Fermentable (and collectable) manure, about	60 W/cap
Biofuel production	
A permanent afforestation programme must ensure that wood is used only in a renewable mode. As fuelwood this represents	150 W/cap
If all were converted to charcoal it would be	75 W/cap
Still another alternative would be liquid biofuel conversion (methanol). The amount of biofuel (alchol or biogas) that may be produced from the fermentable resources quoted above is around	70 W/cap
Energy use	
Introduce electric power for lighting, communications, refrigeration, motors, etc. use second generation stoves with new efficiency doubline	see Table VII

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ramme and development of alternative biofuel technologies based on manure and plant residues, from which the energy is extracted before the nutrients are returned to the fields. Still, the greater intensity of agricultural production makes it necessary to add chemical fertilizer, and to meet the food demands, an additional growth cycle during the dry season would be needed, which would only be made possible by irrigation.

In terms of energy use, mechanized farming practices would need to be introduced, and the relevant techniques for utilization of biomass, such as building biogas digesters, would need to be developed locally as part of the village's industrialization. The energy picture evolving from this development is sketched in Table VII. The emphasis has been placed on industrial development, but on a scale suited to the village community. With the above industrialization in place the energy input on a per capita basis would be approximately half of what it is today, and illustrates what could be achieved by efficiency.

The types of energy used include electric power as an important component. However, it is not yet possible to make a decision on whether this would (and should) be part of a national electric grid system using large-scale hydro power plants, or a local electricity grid based on solar, wind or biomass-fuel generated electricity is preferable. One way to satisfy the energy needs of Table VII, assuming a national grid to give the village access to hydro power, would be to derive 150 W/cap from fuel wood, 70 W/cap from manure and residues in the form of biogas or alcohols, and 130 W/cap as electricity from hydro plants (with partical coverage by coal fired generating plants as an alternative). More details on the estimates of resource flows, on conversion efficiencies and system choice can be found in Sørensen (1979) and in Jensen and Sørensen (1984).

9. VILLAGE ENERGY STUDIES IN OTHER COUNTRIES

A number of studies have been made with the purpose of setting up energy flow models (or parts of such) for rural villages in the Third World. A few will be mentioned here. Makhijani (1976) made a comparative study of the use of non-commercial energy in India, China, Tanzania, Nigeria and Mexico. This study was instrumental in bringing the non-commercial energy use to the attention of planners and collectors of statistical information. Material on the methods used in

TABLE VII
Energy use in Bundilya after implementation of Long-term Energy Plan

Activity	*Type of energy*	*Gross energy flow*	*Practical net energy flow*[a]
Agriculture			
Irrigation pumps, tractors and tools	Biofuels	45 W/cap	40 W/cap
Food preservation (refrigerators)	Electricity	30 W/cap	25 W/cap
Industry (producing stoves, biofuel plants and equipment, etc.)	Fuel and power	100 W/cap	80 W/cap
Households (cooking, hot water)	Fuel wood, power	100 W/cap	60 W/cap
Illumination (domestic and public)	Electricity	25 W/cap	10 W/cap
Services (education, health, communication etc.)	Fuel and power	10 W/cap	5 W/cap
Transportation	Biofuels	40 W/cap	25 W/cap
Total		350 W/cap	245 W/cap

[a]The definition of practical net energy pertains to the currently best available technology, and not to the (unknown) future technology at the time for which this scenario is valid. Anyway the estimates are extremely uncertain due to different views on what may be practical and not just imaginable technology.

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different regions for each task in agriculture and households were collected from existing sources by Palmedo *et al.* (1978). However, the need to do specific investigations and data collection in individual villages soon became apparent. One of the first such comprehensive studies was made for the village of Ulipur in Pakistan (Briscoe, 1979). An attempt to set up an energy flow model for a more extended area, the Zinder region in Niger, was made by Ferguson and Matlock (1979). A detailed study of the village of Pura in India has been ongoing at the Indian Institute of Science in Bangalore (Ravindranath *et al.*, 1980). At the same time, energy flow models have been worked out for cities (for example Lae in Papua New Guinea; Newcombe *et al.*, 1980) and for a number of communes and smaller regions in the industrialized countries.

A lesson that can be learned from these studies is that cultural patterns are extremely important in determining physical behaviour with respect to energy use. The villagers in India in some cases have developed solutions to the same problems entirely different from their counterparts in East Africa. On the other hand, energy use patterns in most villages across Tanzania are remarkably similar. In all cases, the pattern of energy use has been refined over a considerable period of time, and is well suited and on its own terms 'efficient', relative to the conditions that prevailed 50 or 100 years ago. The challenge today is to recognize the change in conditions, external as well as internal, and to respond to them in a dignified way: villagers consciously giving up traditional patterns of life where they are no longer in harmony with environmental constraints or with large populations settled on land of finite extension, while keeping those cultural patterns that are compatible with the present conditions or that cannot willfully be changed.

10. CONCLUSIONS

Many Third World governments are trying out several of the measures discussed in this paper: afforestation, reduction of the number of livestock, campaigns to conserve energy, to use better stoves, and finally to introduce renewable energy equipment such as windmills, biogas digesters and solar panels. We have tried in this paper to assess the quantitative size of the problem, and the relief that the various measures could bring. Our conclusion is that some efforts are at best long-term solutions, while others such as afforestation should be stepped up on the order of ten-fold to reverse a negative trend in the short to medium term.

In the short term, what is needed in Tanzania is improved management of forest, agricultural and livestock resources combined with a programme to introduce simple improvements of cooking stoves on a large enough scale so as to reach a majority of rural households. Based on quantitative estimates for the village of Bundilya, typical of the East-African situation, we call for a doubling of the average efficiency of preparing food, as a minimum effort towards halting deforestation. A joint village programme for ensuring preservation of the forest resource at least at its present magnitude is also needed, and both the stove improvements and afforestation efforts could be funded by better management of the livestock population. These combined efforts would give more healthy and high-yielding animals, and would increase the available cash funds for expanding food crop production and heighten the level of semi-industrialized activities in the village.

On the other hand, the introduction of new energy sources and highly mechanized equipment for farming is the next step in development, one that would however only be meaningful after the first steps proposed here have been implemented.

ACKNOWLEDGEMENTS

Simon Nkonoki would like to thank the Chr. Michelsen Institute, Bergen, the University of Dar es Salaam, The Rockefeller Foundation, New York, and Roskilde University Center for support at various stages during his work on rural energy in Tanzania. Bent Sørensen would like to thank the Nordic Africa Institute and the Beijer Institute for their support, and to thank Professor H. Kayumbo for communication of preliminary results from the UTAFITI village study in the Dodoma region.

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