Surrey Energy Economics Centre

ENERGY EFFICIENCY IN THE THIRD WORLD

Edited by: P J G Pearson

With papers by:
K Bennett, T W Berrie, S Boyle, J Burgess,
P Deshingkar, S Moyo, B Munslow and D Weiner

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PREFACE

The economic efficiency with which traditional and modern fuels have been used in Third World countries (TWCs) has always been a serious matter. For modern fuels the issue has become especially pressing for heavily-indebted petroleum-importing countries, since the inefficient use of imported fuels absorbs more scarce foreign exchange than would otherwise be the case. For traditional fuels, particularly in those locations where biomass fuel scarcity has led to rising costs - whether explicit (commercial fuels) or implicit (non-commercial fuels) - inefficiency implies lower economic welfare for rural and poorer urban energy users, especially women. Furthermore, increasing attention is now being paid to the contribution that energy efficiency might make to the control of energy-related environmental stresses. These include air, land and water pollution associated with fossil fuels. For biomass fuels, as well as the severe air pollution that can occur in dwellings, there is the deforestation, soil erosion and siltification of watercourses that often arises in complex conjunctions with non-fuel demands for wood. Moreover, as well as the effects of these environmental externalities on locally and nationally sustainable development, there are also impacts at the transnational and global scales (for example, acid deposition and greenhouse gases and global warming).

It is, therefore, not surprising that there has been a sharpening domestic and international focus on energy efficiency in TWCs. Nevertheless, it is clear that there are major difficulties in achieving greater efficiency, not least because if energy inefficiency contributes to poverty, it is also often a consequence of it. For example, the pursuit of energy (and pollution) efficient technology requires substantial funding. There have been suggestions that by taking advantage of the latest technologies of energy production and consumption, developing TWCs might be able to avoid following the energy-intensive histories of the industrialised countries and so move rapidly to much more energy-efficient strategies. However, it is unlikely that TWCs could afford to finance such a strategy themselves; nor until recently has there been much motivation for the industrialised countries to help them to do so.

The papers reproduced here consider energy efficiency from a variety of standpoints and for a range of fuels and countries. Stewart Boyle discusses the situation in Sub-Saharan Africa and its potential. He notes the existence of major inefficiencies throughout energy systems, considers the reasons for them and the possibilities for domestic and international policies to improve the situation in the future. Tom Berrie questions whether TWCs can afford improvements in the efficiency of their energy sectors. He sees the problem in terms of a conflict between the need for heavily indebted countries to devote scarce resources to projects with substantial longer-term payoffs and the pressures (both political and financial) that lead policy-makers to concentrate on the exigencies of the short-term, reflected in high discount rates. In his view, there is a need

for a new methodology to help policy-makers to deal more effectively with the short term, i.e. at less expense to the long-term.

Keith Bennett examines the objectives of donor-funded biomass energy programmes in relation to the perspectives of the various interested parties (donors, host government planners, producers and consumers). With the help of a matrix framework and illustrative examples, he argues that unless those involved in planning donor-funded biomass programmes give careful consideration to the motives of the end-user, such programmes are likely to fail - not least because end-users tend to be concerned with economic efficiency rather than narrowly-specified energy efficiency. Priya Deshingkar is also concerned with the efficiency with which biomass fuels are used. Based on her detailed observations in a village in India, she questions assumptions about the inefficiency of traditional energy systems and the superiority of modern systems; in some ways the traditional system seems efficient - there is little wastage of crop residues and there are smoothly functioning markets - although inequitable, while the supply of modern fuels is highly problematic. She concludes that simple calculations about the efficiency of end-use devices and the energy content of fuels should not be the only consideration when estimating the merits of different systems.

Barry Munslow, Daniel Weiner and Sam Moyo present a detailed review of patterns of energy use in Zimbabwean agriculture as a way to raise the wider issues of sustainable development options for that country. They argue that, '... in energy efficiency terms, a vitally important indicator of sustainable development practices, small farmers score highly.' Moreover, it will not be possible to match elsewhere the high levels of import-dependent energy inputs existing in the large-scale farming sector - instead, more self-reliant solutions need, if possible, to be found.

Joanne Burgess deals with global warming and carbon dioxide emissions from fossil fuels in TWCs. She argues that appropriate pricing of fossil fuels (i.e. prices set equal to marginal opportunity costs) could make a significant contribution to changes in patterns of energy consumption and the efficiency with which fossil fuels are used, thereby reducing carbon dioxide emissions. She presents detailed estimates of potential carbon dioxide reductions, based on assumed price changes and price elasticities of demand.

The papers reproduced here arose out of a workshop meeting of the Third World Energy Policy Study Group (TWEPS) held at the University of Surrey in April 1990. The organisation of the Group is based at Surrey Energy Economics Centre. The group has received financial support from grants made by the UK Economic and Social Research Council. The final word-processing of the text of this Discussion Paper was carried out by Isobel Hildyard.

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ENERGY EFFICIENCY IN THE THIRD WORLD

Energy Issues in Sub-Saharan Africa - A Personal View

Stewart T. Boyle,
Energy & Environment Campaign Director,
Association for the Conservation of Energy

The following is a personal view of some of the energy issues within Sub-Saharan Africa. It is based on a study trip in December/January 1990 to Ghana, Burkino Faso and the Ivory Coast, plus a subsequent series of meetings with aid and development experts from a range of organisations. I am particularly indebted to Gerald Leach (Stockholm Environment Institute) for his comments and advice, and my long-term colleague and fried Dr. Michael Flood, who initiated the study trip and provided many valuable insights. This short paper also reflects my concern over both the assumptions in the world view inherent in the World Energy Conference scenarios, plus the implications of trying to achieve Goldemberg et al's 'Energy for a Sustainable World' scenario (see Figure 1).

]Introduction

The word most commonly used to describe the situation in Sub-Saharan Africa (SSA) is 'crisis'. These are the poorest countries in the world, with per capita income actually falling from $600 in 1970 to $370 in 1988. Figure 2 indicates the changes in energy per capita and GDP per capita within African countries in the past 15 years. The coountries are heavily in debt, with little obvious prospect of paying such debt off. Even the Ivory Coast , the supposed jewel in the French colonial crown, has suffered a dramatic economic collapse in recent years. Its population are now in debt to the tune of more than $1,500 per head, greater than two years average income. Most are net food importers, with only two African countries being net cereal exporters.

Mortality rates, though varying throughout the region, are high. Twenty four of the 33 countries in the world with the highest levels of mortality in children under the age of 5 are in SSA. Despite this, the population is growing at 2 to 3% per annum, the highest in their history. This is putting immense strains on agriculture, (which would need to grow at 4% per annum simply to keep up), and the environment. Increased pressure for additional cropland leads directly to forestry losses (see Figure 3).

Desertification and famine, partially linked to what appears to be a long-term change in climate in the region, are a familiar part of many people's lives. Though figures on fuelwood are notoriously unreliable, with many smaller woodlots being ignored in official statistics, there is major forest loss every year. Not enough trees are being replanted to compensate for those destroyed by charcoal burners and woodfuel gatherers. Marland estimates that the afforestation/deforestation ratio is 1:29.

To add to the above list comes the spectre of AIDS. Official statistics grossly underestimate the extent of the problem. In the Ivory Coast, a World Health Organisation official showed me the results of two recent surveys in Abidjan. Over a three-month period, tests at the city mortuary showed that 46% of deceased were HIV positive. In one area of the city, 58% of men in the 18-35 year age range, and 65% of prostitutes, were HIV positive. Figures in the range of 15-35% for Burkino Faso and Ghana were quoted to me from USA and UK embassy staff. One can only imagine the impact in future on alreasdy inadequate health and social services, the productivity of the labour force, and balance of payments.

The causes of the above are many and varied, reflecting both external and internal factors. A recent Wilton Park Seminar (1) referred to many of these, including 1) the over-dependance on export revenues of a few commodity crops whose prices have fallen; 2) the impact of the two oil price shocks in the 1970s; 3) poorly managed and inappropriate aid programmes; 4) gross corruption at all levels of society; 5) bad management and inadequate governments; 6) conflicts, partially due to the artificial colonial borders; 7) excessive subsidies, tariffs and protectionism; 8) grossly over-valued exchange rates; 9) low food prices which reduced food production; 10) skill shortages, poor transport infrastructure and communications; 11) excessive armaments expenditure; 12) over-population and over-cultivation of soils; and 13) a rapid increase in urbanisation.

It is important before going on to discuss energy problems and possible solutions to appreciate the context of the discussion. The two are closely linked.

<u>Energy Issues</u>

Based on evidence from Ghana, Ivory Coast and Burkino Faso, some of the characteristics of energy supply and demand are as follows:

1. Per capita energy use is very low in comparision with OECD countries (see Figure 4)

2. Only a small percentage of the population are reliant on commercial fuels. In Ghana for example, only 25% of the population are linked to the electricity grid; in the Ivory Coast, less than 15% use bottled gas for cooking.
3. Woodfuels account for a large proportion of domestic energy consumption (92% in Ghana).
4. Due to low crop yields in Africa (only 50% of those in South America and 25% of those in Western Europe), there is continuing pressure on biomass resources for new cropland and fuelwood.
5. There is a strong, but currently latent, upward demand for commercial energy, if this can be provided at an affordable price. Demand is rising in most countries where supplies are available, particularly for electricity, diesel/petrol and charcoal.
6. Energy supplies are often based on a small number of potentially vulnerable sources. In Ghana for example, 90% of the country's electricity is derived form a single dam, the Akasombo. In the Ivory Coast, four power stations, plus the Akasombo, provide 85% of the country's electricity. Oil supplies for the transport system are generally imported. Though lower oil prices have reduced the percentage of exppport earnings paying for oil from a high of 40-70% in the early 1980s, it is still running at 10-20% in some countries.
7. There are gross inefficiencies throughout the energy systems. These range from power stations (where 20-25% efficiencies are common), refineries, transport and electricity infrastructures (where 15% transmission losses are not uncommon), and end-uses. Poorly maintained vehicles, which are often outdated models imported predominantly from Japan and France, give low fuel efficiencies, as do woodstoves, lights and heaters. The poor state of much of the energy infrastructure reflects a prolonged lack of investment and maintenance over the past two decades.
8. The capability and expertise within energy institutions is often low. This reflects low investment and wages, inadequate education and training, the lack of indigenous maintenance facilities and spares, and the economic malaise which has afflicted the countries over the past 20-25 years.

Energy Futures

There is clearly a strong demand for further electrification and oil in transport usage within SSA. The World Bank projects a 400% increase in overall energy consumption by the year 2020. At a time of serious financial restraints, and strong conditionalities in lending from the World Bank and other institutions, how can this demand be met? Among the options being considered are:

1. Gas-fired power stations, particularly in those countries with a coastline such as Ghana, Nigeria and the Ivory Coast.

2. Major improvements in the transmission and distribution systems in order to cut efficiency losses.
3. The refurbishment of inefficient power stations.
4. Improvements in energy end-use efficiencies.
5. New hydro-electric dams.
6. Village-scale electrification schemes using photovoltaic cells and/or methane digesters.
7. Agro-forestry and other biomass plantations.

Much of the emphasis of recent World Bank 'economic restructuring' loans in the energy sector has been in relation to 2 and 3 above. A recent $100 million World Bank to the Ivory Coast for example, focusses largely on improvements to the transmission grid, plus possibly a new gas-fired power station using Nigerian gas. Recent UK Overseas Development Agency loans to Ghana have been given to refurbish a power station at Tema, near Accra.

There is clearly a large potential for additional hydro-electric schemes, with perhaps only 25% of the commercial potential so far utilised. These are generally capital intensive however, can be vulnerable to prolonged drought, as occurred in 1983/84 with the Akasombo Dam, and bring their own set of environmental problems.

End-use efficiency has only recently entered the picture in Ghana and elsewhere, focussed heavily on the industrial sector, where even small gains due to modern processing and heat recovery can free up electricity for the poorer Northern regions of the country. Discussions on possible efficiency standards for appliances has recently started within the Ghanaian National Energy Board.

In the transport sector, the current low car/truck ownership is likely to grow, as long as the countries can afford to import the vehicles and the oil. Improved maintenance, a major problem throughout SSA, better driving techniques, and improved road systems, are crucial for first steps. The question of some efficient vehicles is a tricky one. The 'end-of-product life' dumping which is prevalent throughout the the developing world, is something that major vehicle manufacturers would be loathe to end. Aid is often conditional on buying such vehicles. To break this cycle, (assuming that the other factors make the entry of more fuel efficient, but arguably less tolerant, vehicles into the country feasible), technology transfer deals and some compensatory mechanisms will need to evolve. Inappropriate aid programmes will need to end.

Another speaker is covering the issue of woodstoves at this seminar. Let me make several observations however. Though less flexible than the traditional three-stone fire, the basic woodstoves common throughout SSA are at least more efficient. Made from scrap materials, they are up to 15% efficient. The cost of charcoal are now significant in many countries however, itself a reflection of reduced wood resources. More advanced stoves are now available, providing efficiencies of 25-40% efficiency. The problem is that the initial capital costs are perhaps five times as much as the current models. Even though the pay-back period, due to charcoal saved is less than one year, this cost is a major deterrent. (This is a remarkably similar problem to that in OECD countries, when contrasting compact fluorescent light bulbs with incandescents.) Tackling the front end capital cost problem is thus crucial if more efficient woodstoves are to be introduced, and much of the remaining forests are to be saved. A further problem is the ease of constructing the newer stove designs in local workshops. Based on the experience in Kenya, some compromises from optimum efficiencies may have to be made to overcome this problem.

Many environmentalists point to solar and other renewable sources of energy as the long-term solution to the energy problems of developing countries. This is not an easy panacea. To be sure, there is plenty of sunshine, and potentially a lot of biomass resources which could be harvested sustainably. The reality so far is littered with failures, inappropriate schemes, and expensive projects which collapsed once aid was removed. Photovoltaics are heavily used in many of the telecommunications systems in West Africa. Several solar villages based on PVs are being developed. At present, and until the price of PVs drop significantly, they will be totally aid-dependant. Sustainable forestry/biomass plantations have a major potential. My experience from talking to foresters is that large agro-foresty projects are not proving successful. Smaller village-based schemes, sensitive to social systems and ownership issues, are more likely to succeed in the longer-term. Figure 5 demonstrates the higher productivity of small-scale woodlots in Kenya.

A small number of biogas digesters are in use in SSA. Though quite successful, they are crucially dependent on appropriate training and maintenance facilities.

Commercial and particularly fossil fuel energy demand in SSA could grow very rapidly in future, in the absence of price, resource, technological, environmental and other restraints. In practice, it is likely to grow much more slowly due to such restraints. In addition, increases in demand could be considerably lower if energy system and end-use inefficiencies were to be substantially improved. There will be major financial restraints on a further growing dependency on imported oil, and much effort is being expended on indigenous oil and gas exploration. Reasonably priced gas supplies will also feature more strongly in the next few decades. For the majority of the population in SSA countries however, sources of cooking fuel will remain a key problem. Improved woodstoves and bottled gas in urban areas are the two potential solutions.

Ultimately, the performance of a country's economy, and the extent to which aid agencies and development banks continue to pay bills, will determine the future trend and development path of energy supply systems.

Institutions and Individuals - the key to a Sustainable Energy Future

An overriding impression gained from West Africans is the resilience and humour of the people, despite the appalling backdrop of mounting problems. There is a latent demand to acquire education and skills and to better their lives. It is difficult, examining the trajectories of the various trends referred to in my introduction, to view their future with a high level of optimism. They are currently being left further and further behind much of the rest of the world.

One of the many slogans on Ghanaian buses and 'mammy-wagons' is 'No Condition Permanent'. This is a double-edged statement of course. Things can change for the better, but they could also get a lot worse. People can improve their destinies and standard of living, but the forests and food supplies they take for granted may also disappear, unless they act. I would single out a number of key factors which, in my view, will be crucial in determining the future and the role of energy within that. These include the need to:

1. Change institutions, such that they become smaller, better-resourced, and more responsive to the public and organisations they are supposed to be supporting.
2. Focus aid on smaller-scale projects, particularly those administered by NGOs, and especially women, rather than government agencies.
3. Develop and encourage small-scale forestry.
4. Improve the productivity of agriculture by supporting multi-cropping systems rather than mono-culture.
5. Bias bank loans and other financial assistance towards small and medium-scale businesses.
6. Re-focus aid towards training and education which is relevant to the maintenance and infrastructure of energy systems.
7. Reduce conditional aid based on the export of inappropriate technologies.

8. Make efficiency a key criteria in all energy loans and developments.
9. Set targets for the widescale introduction of more advanced and efficient woodstoves, and heavily restrict the activities of charcoal producers.
10. Encourage self-reliance, indigenous industrial development, and a shift away from primary commodity crop exports, towards more value-added exports.
11. Cancel a substantial proportion of long-term debts for which there is little likelihood of repayment.
12. Set up technology-transfer schemes, administered largely through indigenous 'hands-on' technologists and advisors at a local and regional level, which would encourage the early uptake of more energy efficient machinery, appliances and processes.

It is people, and the institutions they belong to or work with, who will be crucial in the future development of SSA and other developing nations. Technology can help, but on its own is likely to fall by the wayside, like the rusted and stripped-down tractors of previous aid endeavours. I remain deeply skeptical that the various 'economic restructuring' programmes currently underway in West Africa will substantially improve the major problems facing these countries. Indeed, I have some sympathy with the view that inappropriate aid may have substantially worsened these problems in the past few decades. A sustainable energy system can only succeed within a sustainable economic development system. Neither are currently within easy reach.

Source Materials

1. 'Desertification, Debt and Structural Adjustment in Sub-Saharan Africa', Nicholas Hopkinson, Wilton Park, 1989.
2. 'Aids and the Third World', Panos Institute, London, 1988.
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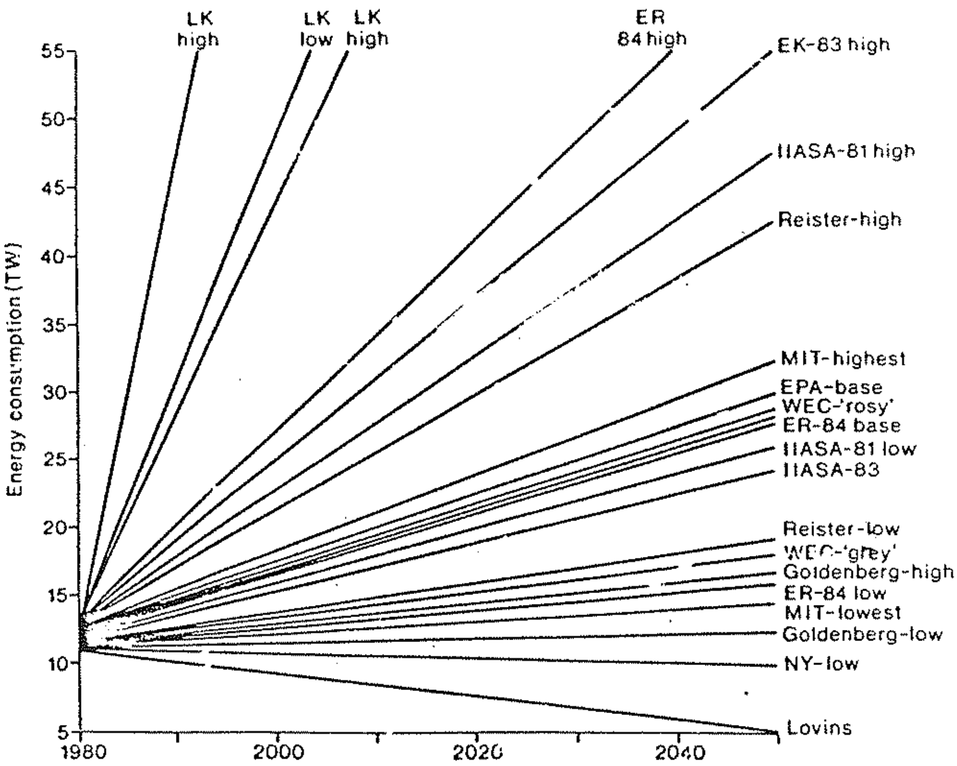
4. 'Grassroots Participation in Development', Issues Paper No. 7, IIED, June 1989.
5. 'Population in the Sahel'/'Rainfall in the Sahel', Issues Papers Nos 10 and 13, IIED, September and December 1989.
6. 'No Condition Permanent', Ian Smillie, ITDG, 1986.
7. 'Sustainable Industrial Development', Marilyn Carr, ITDG, 1988
8. 'Africa in Crisis', Lloyd Timbelake, Earthscan, 1988.
9. 'Aid for Just Development', Hellinger et al, Lynne Rienner, 1988.
10. 'A Fate Worse than Debt', Susan George, Pelican, 1989.
11. 'The Greening of Aid', Conroy and Litvinoff (Eds), Earthscan, 1988.
12. 'Energy for Development', Goldemberg et al, World Resources Institute, 1988.
13. 'Sub-Saharan Africa', World Bank, 1989

14. '1989 Work Programme', National Energy Board, Ghana, 1989
15. 'Britain and Ghana: Partners in Development', Overseas Development Administration, 1989
16. 'Africa: A little breathing space' (International Workshop in Budapest, April 1989), Gerald Leach.

Figure 1.



Source: Keepin 1985. Bill Keepin et al.: Future Energy and CO_2 projections. The Beijer Institute, Stockholm, Sweden.

Figure 2. Percentage change during 1980-86 of per capita modern energy consumption and per capita GDP: 38 African countries

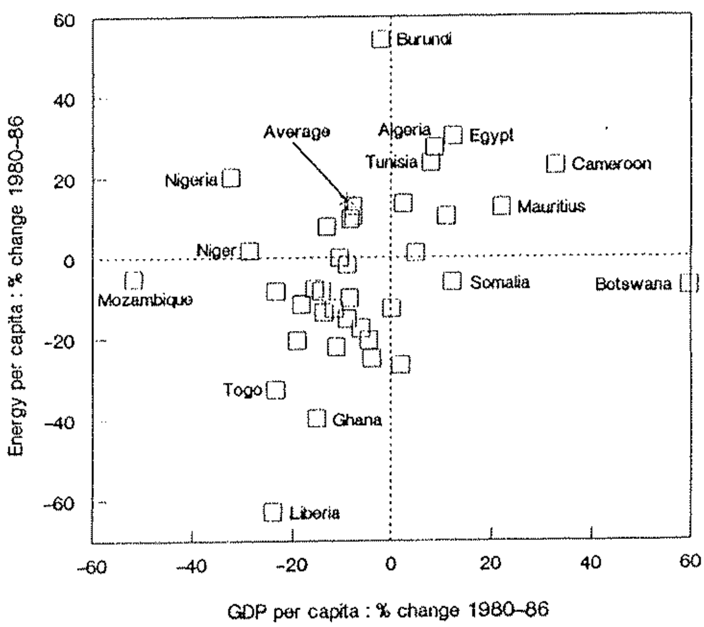
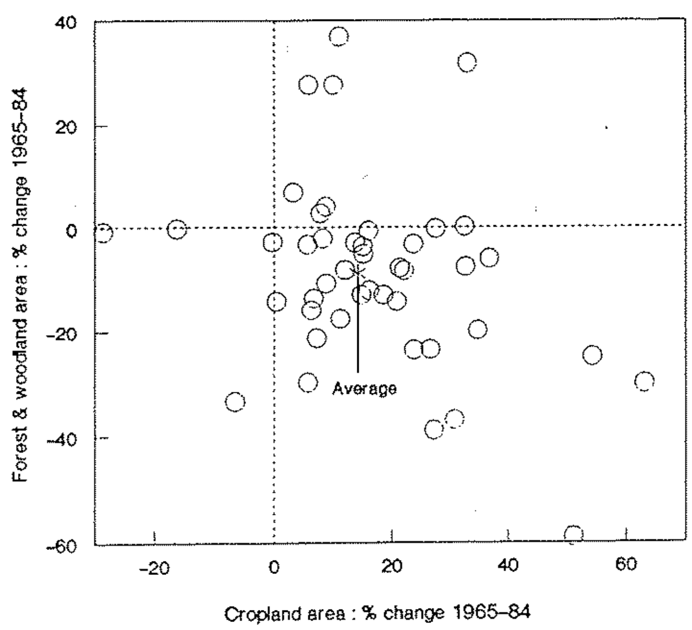
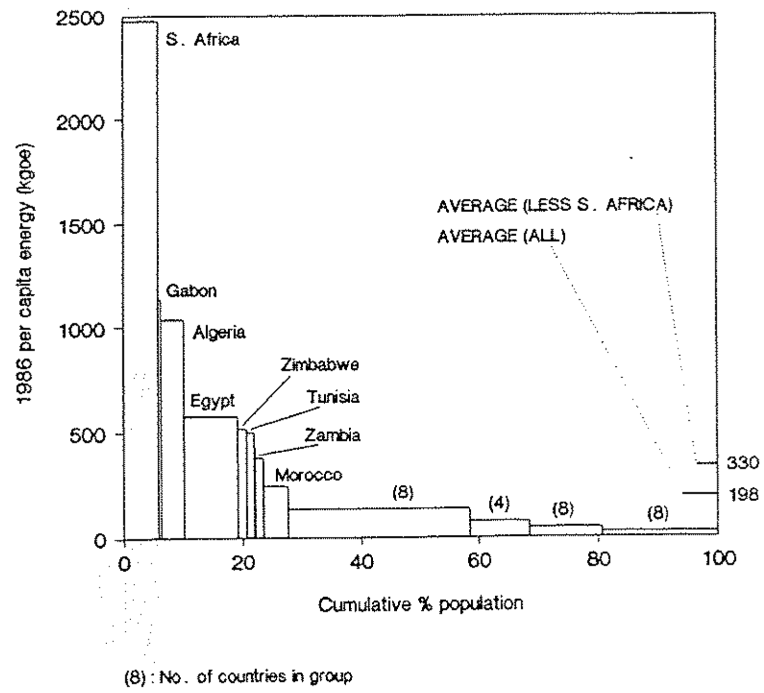


Figure 3. Percentage change during 1965-84 of areas of forest and woodland and of cropland: 44 African countries



Source: WRI/IIED [1988]
Excludes for lack of data: Cape Verde, Comoros, Djibouti and Equatorial Guinea (< 0.5% of 1986 African population)

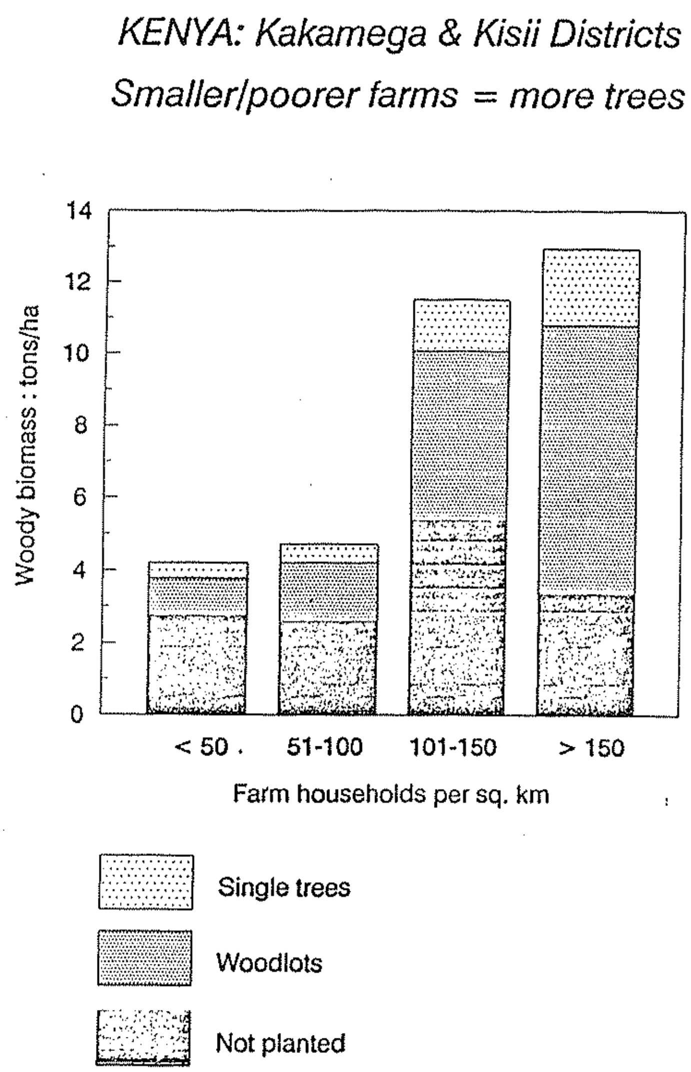
Figure 4. Per capita modern energy use against cumulative percentage population: 38 African countries, 1986



Source: World Bank [1988]

Excludes for lack of data: Angola, Cape Verde, Chad, Comoros, Djibouti, Equatorial Guinea, Gambia, Guinea Bissau, Lesotho, Libya and Swaziland (together comprising 3.5% of 1986 African population)

Figure 5.


KENYA: Kakamega & Kisii Districts
Smaller/poorer farms = more trees
Woody biomass : tons/ha
0
2
4
6
8
10
12
14
< 50
51-100
101-150
> 150
Farm households per sq. km
Single trees
Woodlots
Not planted

CAN DEVELOPING COUNTRIES AFFORD IMPROVEMENTS IN THE EFFICIENCY OF THEIR ENERGY SECTORS?

Tom Berrie, Imperial College, London

INTRODUCTION

The high level of debt which so many developing countries have incurred over the last ten to fifteen years is well known. However, what has not been properly thought through is the effect on this already too high debt service of trying to improve the efficiencies of energy sectors, engaging in energy conservation and carrying out better environmental maintenance. In order to take advantage of the latest technologies being used in developed countries to improve energy sector efficiency, etc. the less developed countries in most cases would need to borrow even more capital and use up even more scarce resources. Although spending this extra capital in the short term may prove advantageous in the medium and long term, through lower running costs, lower resource-use and a more friendly environment, the exigencies of the short term are very often paramount. In electricity supply, for example, this might well rule out LDCs substituting gas turbine and combined cycle plant for diesel generators, or hydro plant for thermal plant, and there are many more similar examples. Also, most modern technologies for burning coal/oil to produce heat/electricity will in most cases be ruled out for the same reason, and the same may well be true for many well proven long term economic cases for substituting renewable/traditional energy for conventional/commercial energy.

It is doubtful whether many developing countries today would cheerfully increase their debt-service burden or use up scarce resources more quickly in order to increase the efficiency of their energy sectors, engage in energy conservation measures, or in better environmental maintenance. However, they may well be obliged/persuaded to do so under the present conditions/atmosphere of lending prevailing in the multilateral aid agencies such as the World Bank, and the bilateral, government to government, aid agencies.

THE LONG TERM AND THE SHORT TERM: LOCAL RESOURCES

Most ways of increasing energy sector efficiency etc. need also a good deal of extra local capital and other resources as well as foreign borrowing eg. most of the technologies already mentioned which need an appreciable quantity of extra foreign capital in the first place, plus those particular, quite commonly occurring, projects which need injections of local capital and other resources throughout the life of the project to continuously provide and replace superstructure, and periodically engage in regular technological updates and conservation measures. It is not at all obvious, or easily demonstratable, that any particular developing country, for the sake of long term benefits should, voluntarily incur this extra expenditure of often scarce, not easily replenished, local capital and other resources in the short term; rather than, for example, spend that local capital etc. in other sectors, again even though it can be easily demonstrated that this should make possible large savings in the long term, ie the economic return on the extra capital etc. is expected to be high.

In the case of a large proportion of developing countries, to the top decision makers, the medium and especially the long term tends to weigh lightly compared to the heavy weight of short term/immediate demands and panics. Thus in any long term economic, fiscal or financial analysis (see later), when dealing with developing countries, the time value of money requires high discount rates, at least in line with those used by multilateral development agencies such as the World Bank, despite the high level of criticism concerning these high discount rates which there has always been, and still exists today in many quarters.

Thus it cannot be taken for granted that most developing countries would automatically, voluntarily, choose to put the medium and long term before the pressing problems of the short term, ie. spend the extra resources now that are necessary to improve their energy sector efficiencies, engage in more energy conservation, or carry out better environmental maintenance. Many people from developed and developing countries alike believe that LDCs just cannot afford to spend these extra resources now. Others, mostly from developed countries, believe that the developing world should for the global good in the long term, be 'required' or 'persuaded' to spend these. In any case, there is a requirement for some way of dealing with the short term better, ie not at the expense of the long term, plus some new methodology for helping developing countries to arrive at this overall meaningful decision. Such a methodology must be equally applicable to all developing countries, all energy sectors and sub-sectors (electricity, gas, coal, oil, renewables, etc) and possibly all projects in the energy sector. It must also deal properly with all the disciplines and aspects involved.

A NEW METHODOLOGY FOR ASSESSING THE SHORT AND LONG TERM

Any assessment of alternative ways of improving energy sector efficiency etc. must be made on four basic grounds: *viz* economic, fiscal, financial and marketing. The economic analysis must obey the normal rules of cost-benefit and analysis, using shadow pricing, discounting and present valuing. All costs and benefits must be rigorously included. Likely to be missed out are: costs and benefits connected with socio-economic factors, knock-on and multiplier effects and many aspects of energy conservation and environmental maintenance; and many projects in the energy sector introduced initially to improve energy efficiency have energy conservation and environmental aspects. Such an economic analysis applies mainly to the medium and the long term, say 10 to 25 years ahead, possibly more, although they can use the first year return and similar factors to bring in the short term at least to some measure.

Whether a developing country can afford to improve the efficiency of its energy sector, etc. as viewed from the fiscal aspects, must bear in mind, possibly project by project and certainly sub-sector by sub-sector (gas, electricity, oil, coal, hydro, renewables etc), such factors as: national balance in foreign exchange, local currency and other resources, national income solvency, financial-economic-fiscal subsidies, national debt service, fiscal-economic balance in capital, expertise, labour, land etc, between sub-sectors and possibly between projects. Exchange rate control, resource cost balance between sub-sectors and between projects, energy conservation measures and environmental maintenance might all be seriously damaged by attempting to improve the energy sector, sub-sector and project efficiency by attempting to use new technologies, however wisely these are transferred from developed to developing countries, eg. by turning to nuclear fuels, or fluidised coal burners, or magneto hydro dynamics for generating electricity instead of using diesels and gas turbines. A fiscal analysis, by its very nature, is aimed for the short to medium term, say 5 to possibly 10 years ahead, but it can bring in the long term to some extent by making projections.

Today most emphasis in the world tends to be given to the short term (next 2 to 4 year) financial analysis of any development being postulated, often to the detriment or even the complete neglect of the economic and fiscal aspects. Such an exclusive emphasis is discouraged by economists, but economists cannot deny that such short term financial analyses, both the utility and the sub-sector in which the utility is located, are vital to any decision making. Energy sector efficiency, etc. measures should not be made in developing countries by any means which unduly change for the worse, over the next 2, 3 possibly 4 years, such things a sub-sector or utility debt service ratios, self-financing ratios, annual return on net assets or turnover, debt-equity or debt-asset or debt-turnover ratios and similar financial performance indicator, whether the utility or the sub-sector is privately of publicly owned.

Apart from having a methodology which includes the three disciplines of economic, fiscal and financial, for judging whether to improve energy sector efficiency etc. or not, great emphasis is given today both in developed and developing countries on making such efficiency improvements by producing more efficient energy sub-sector markets ie. by changing these market in such manner as to make them more closely resemble and as close as it is reasonable, commodity markets. This is because many believe that such latter markets are very efficient. Energy sub-sector markets (electricity, gas coal, oil, etc) it is argued, can be made much more efficient by using such factors of commodity markets as spot pricing, buying forward, futures markets, agents, brokers, underwriters, insurers, etc. It is likely that such an approach could be carried out successfully up to a point. In fact some of it already has been carried out in most developed countries and the more advanced developing countries, leaving the less advanced developing countries to consider following on at first probably only with the large commercial and the industrial sectors of the economy.

Already well know measures will need to be used in order that any new methodology caters for a broad range of time horizons, short, medium and long; examples of such existing means of coping are: tilted annuities, variable and multiple discount rates, convex rather than concave shadow prices, and there are many more. In addition, probably needed are up to date or new means for tackling risk and uncertainty, involving such measures as catastrophe theory and methods of dealing with sudden changes either in the parameters and/or the background for assessment.

NEW MIX OF LENDING TO LDCs REQUIRED

The pressing need to improve the developing world's energy sector efficiency, including better energy conservation and environmental maintenance, is one of the major factors which points up the urgent need today for all aid agencies (public, official and private) to find a formula for making available an acceptable mix of loans/credits/grants to LDCs. For example, for projects or programmes with a large proportion of, or which are entirely for technology transfer, or for improving energy efficiency, or for better energy conservation, or for improved environmental maintenance, a mixture of soft loans and grants should be used, hopefully with the emphasis more towards grants. This change in the mix of aid packages for the above types of project is very defensible in that the donors should gain much more from their normal lending in the medium and long term from the particular borrowers which they are accommodating in this way in the short term.

FURTHER WORK NEEDED

Further research, both methodological and practical, is needed throughout the world in the above matters by study groups, development agencies, socio-economic research establishments, multilateral, bilateral and commercial aid agencies, etc. Such research should include:

(i) exploring social, financial, fiscal and economic criteria for adequately meeting medium and long term objectives, in a way which is not at the expense of the short term, or vice-versa;

(ii) investigating the best possible future role of both fungible and non-fungible, public, official and private, capital and other (expertise, skills, fuels etc) resource transfers from the developed to the developing world, including the use of such capital and other resources on projects for energy efficiency improvement and environmental maintenance, also getting to practical grips with the many issues and options involved;

(iii) examining further the role of spot pricing of energy, and of treating the latter as a commodity, including the role of market makers and agents, plus the mechanisms for always clearing the energy markets;

(iv) extending the presently well known, well developed theory of the firm towards its application to the industrial and energy sectors and sub-sectors of LDCs, in order to determine ways of improving the overall efficiency of these sub-sectors, hopefully without incurring the need for massive new infeeds of resources, whilst also improving both energy conservation and environmental maintenance.

TECHNICAL OBJECTIVES OF DONOR-FUNDED BIOMASS ENERGY PROGRAMMES

Keith Bennett, Independent Energy Consultant

1. SUMMARY

This paper briefly examines the various objectives of donor funded biomass energy programmes through the use of a simple matrix.

Through consideration of various programmes that the author has been involved with, the matrix is used as a framework to conclude that unless those involved in planning such programmes give careful consideration to the objectives of the end user, they are unlikely to succeed.

The following written paper is not a transcript of the paper given at the meeting, but rather a summary of the main points considered during the presentation, with some examples briefly considered.

The paper was illustrated with slides.

2. INTRODUCTION

In the donor funded programmes, objectives can only be properly determined in relation to the perspective of the various interested parties.

The activities and objectives of the groups can be expressed as follows:

Organisation	Donor	Host Govt. Planners	Producers	Consumers
Activity/ Objective				
Technical	XXXX	XXXX	XXXX	XXXX
Social	XXXX	XXXX	XXXX	XXXX
Economic	XXXX	XXXX	XXXX	XXXX
Environmental	XXXX	XXXX	XXXX	XXXX
Political	XXXX	XXXX	XXXX	XXXX

Although the paper is primarily concerned with the technical objectives and solutions proposed to meet these objectives, the various cells of the matrix are developed where appropriate as the issues are invariably interlinked.

The following examples are included to serve as illustrations of conflicts that can arise during the implementation of donor funded programmes.

2.1 Efficiency (Technical/Donor) vs. Utility (Social/Environmental/Consumer)

<u>GTZ Improved Stoves (Zimbabwe)</u>
In the Gutu district, the German Technical Agency has been promoting a massive sand and clay stove with a cast concrete top plate. Extensive testing has convinced the donor agency that the stove has the potential for saving significant quantities of wood in a communal land area largely deforested as a result of expanded agriculture.

Surveys indicate that in Ward 35 of the district, 147 from 153 households now have stoves. An impressive uptake, but residents have complaints about the programme. The elderly in particular, were not enthusiastic about the stove, as a condition of participation in the programme is that the traditional central kitchen fireplace, whereby they warmed themselves in the evening, has to be cemented over. Implementation is in conjunction with the VIDCOs (Village Development Committees), who gave the impression that having a stove built in the house followed by subsequent closing up of the central fireplace was required by all so-called progressive individuals. Many inhabitants feel they should participate in order to be seen to cooperate with the donor, who may subsequently come along with more important developments. Delegations of senior overseas visitors, high ranking government officials and even television crews have been to the area. The impact of the programme can be gauged by one woman, who, observed from a distance cooking lunch on an open fire and believing herself to be as yet unseen, grabbed her wood sticks from the fire and dashed into her hut to re-kindle the new stove before the visitors arrived in her compound.

NB Recent fuel consumption surveys in Zimbabwe indicate that it is not improved cookstoves that save wood, but the cook responding to a scarcity or to the increased price of firewood or charcoal. Users are likely to build walls around the open fire to protect it from draughts, extinguish the cooking fire as soon as it is not longer required, place the sticks carefully to get the most efficient performance and take other common sense measures thus saving considerably more fuel than the introduction of a so-called fuel efficient stove ever could. As in the industrial countries, women are likely to favour improved cooking stoves for reasons other than fuel efficiency and economy. Safety, appearance, convenience and speed may all take precedence over efficiency.

2.2 Economic (Planners) vs Technical (Donor) Economic (Planners) vs Economic (Consumer)

Cotton Stalk (Sudan)

Enormous investment has been made in irrigated, mechanised cotton farming in the Sudan. Regulations insist that the woody cotton stalk crop residue be burned in the field immediately post-harvest. This is a matter of farm hygiene. The Sudanese economy has been badly hit when Black Arm disease has destroyed the crop in past years, and the crop burning legislation was enacted in order to control the disease. Numerous crop sprays are also used. In recent years, a donor funded briquetting project has realised the potential of the cotton stalk as a domestic and industrial fuel and has made repeated submissions to officials in the relevant government departments in order to gain permission to test the imported compaction equipment. Limited trials were finally agreed, but when the machine was found to create large amounts of cotton dust which could infect the fields, the machine was banned within a mile of the field which rendered its operation impractical on a larger scale due to the cost of transporting a bulky residue to be processed.

Villagers in the areas do not have access to fuelwood as the forests have all been cleared for the cottony crop. Officially they are also denied the cotton stalk residue, as this has to be burned in the field. However, through necessity, the stalk is stockpiled by the villagers prior to being burned and it is reported that local officials turn a blind eye to this despite Ministry of Agriculture insistence that the regulation must be strictly enforced in order to protect the crop.

2.3 Economic/Technical (Producers) vs. Environmental (Consumers)

Triangle (Zimbabwe)

The internationally financed Triangle Company produce sugar and ethanol, grow cotton and have large cattle ranches in their huge complex, employing 6,000 people with a further 45,000 in the company town. Central areas and staff houses are supplied with electricity and all other sections are supplied with firewood supplied by the company from the surrounding forest. The fuel requirements of the population can be easily provided on a sustainable basis from the vast areas of surrounding woodland. However, the company wants to withdraw wood supply on the grounds that this is environmentally damaging. It may not be of secondary importance that the company also stand to make substantial savings in operating costs associated with the use of tractors and labour for wood cutting from an alternative fuel. To this end, the company are seeking donor support for a joint venture with the Hollow Core Company to supply waste burning stoves to the householders which will utilize the available crop residues available on site namely cottony waste and bagasse from sugar cane processing (which presently incur disposal costs).

Unfortunately the new stove has met with an overwhelmingly negative response from users. The stove proved to be difficult to light, especially when the fuel was wet and it is impossible to store in the small houses provided on the site. Many users felt that the smoke, especially from the cottony waste, led directly to ill health (greater incidence of 'flu and chest pains). The smoke is thick and oily, and the crop is sprayed with a number of chemical treatments which could react on combustion to produce dangerous emissions. Another serious drawback was damage to pots and clothes caused by intense heat and flying live ash. Most respondents were of the view that it would be cheaper to pay for wood than to pay for new pots and clothes. Complaints of poor food quality were also registered. Women claimed that it was necessary to remove children from the immediate vicinity for fear of burns from airborne sadza (staple food). Many families were using the stoves only through necessity, supplementing with illicit wood collections even though they face fines when caught.

2.4 Technical (Donor) vs. Economic (Producer) Environmental (Planners) vs. Environmental/Economic (Consumer)

Groundnut Shell Briquettes (The Gambia)

Groundnut shell briquettes, produced using imported Danish presses supplied as part of a fuel conservation project, have been the subject of marketing trials from 1983-1989 and have met with little success despite comprehensive advertising and public demonstrations.

The equipment is under the control of the GPMB (Gambia Produce Marketing Board) who produce and dispose of the groundnut shell residue at their Kaur factory, some 200km up the river Gambia from the capital and central market, Banjul. The donor, having recognised the availability of substantial amounts of potential fuel, agreed with the Government that the processing equipment would be sited with the parastatal GPMB, who would be responsible for production and transportation of the briquettes to the capital, where the donor agency project would market them through local outlets. Financial analysis indicates that the parastatal (a profit oriented organisation) cannot produce and transport the briquettes at a price that would make them competitive with wood. For this reason they have been understandably reluctant to fill valuable warehouses with a product that sells extremely slowly. The donor representatives interpret the economic data in a rather different light and argue that the medium to long term prospects are good, given the trend of increasing woodfuel prices. The GPMB regard the operation as marginal to their main activity and cannot be cajoled into anything more than supplying very limited quantities of the fuel. A private trader who installed briquette presses at the same site has also been unsuccessful in marketing against wood.

The urban population burned charcoal until 1981 when the President banned this fuel as a forest saving measure on the grounds that the conversion process is inefficient. The briquettes were introduced as a charcoal substitute which disappointed those families who took up the initial offer of a free trial. The briquette proved to be slow and smokey compared to charcoal. The fact that the briquettes were similar to wood in calorific value, but rather inferior in terms of convenience and unsuitable for storage during the rainy season, also proved to be a major drawback.

2.5 Technical/economic (Donor) vs. Technical/economic (Planner)

Groundnut Shell Briquettes (The Sudan)

The objective of the project is to save forests through the use of briquettes produced from agricultural residues. The briquettes were intended for the domestic market which has not proven viable. However, marketing trials with brick kilns, bakeries and oil producers, all large woodfuel consumers, have been very encouraging. Briquettes are a premium fuel for these consumers as, compared to wood, they have consistent moisture content and load weight. Thermal performance of the briquettes matches that of wood in a commercial furnace (which is not the case for a domestic oven or stove). So far so good; the objectives of arresting deforestation and providing affordable fuel, whether it be to industry or the domestic sector, clearly coincide. It is in the approach to achieving these goals that the problem exists.

The equipment, like most briquetting presses in Africa, is of European origin. It is evident that the foreign exchange component will absorb the greatest part of the cost of production. In fact, the ratio of the foreign exchange component of production cost to that provided from domestic currency is about 10:1. Sudanese currency has not been readily convertible at the official rate of exchange and servicing investments at the shadow rate would certainly make the operation uneconomic. Given that the project aims to examine the feasibility of producing briquettes on a national basis, this issue clearly needs to be addressed. Either equipment will have to be manufactured locally or from India or another low cost manufacturing country. The economic objective of the donor, unstated, clearly includes that of providing a stimulus to domestic industry in the hope that it will encourage the export of briquetting presses (and additionally in this case the opportunity to do some research and development in the field using Sudanese government staff). The economic objective of the government is to provide the cheapest, most efficient energy supply, with minimum foreign exchange and in this respect could equally consider the hard currency for importing oil rather than converting crop residues using imported equipment.

2.6 Environmental (Planners) vs. Social (Consumers)

Improved Cookstoves (Burkina Faso and The Sahel)

During the mid 1980s, Burkina Faso undertook many important rural development initiatives, including primary health care and provision of safe drinking water supply. Many of these programmes were implemented using a pyramidal system of training, where groups of trainers would be assembled and trained in order that they could then go and train others and continue the process in remote rural areas. In this way extension workers built, and trained women to build, hundreds of thousands of so-called improved stoves. These were constructed of sand and clay built around three stones - essentially a completely sheltered fire with the flames directed onto the base of the pot. The programme was based on laboratory tests which showed significant wood savings. However, although no comprehensive survey work has been undertaken, reports indicate that the stoves will not be rebuilt when they crumble, and they often last less than one year. There are many difficulties: women like to cook at different places at different times of day and need many stoves, different sized pots may not fit the stove, there may be no perception of fuel saving (indeed there may actually be no fuel saving), but most importantly the stoves are laborious and time consuming to construct and the advantages are insufficient to justify such time and effort.

3. CONCLUSIONS

3.1 Donor technical objectives may aim to increase the availability and efficient use of biomass fuel in the recipient country through the promotion of technology development and transfer. If the host country has adequate manufacturing capability and can manufacture briquetting machinery or cooking stoves for example, then this objective may coincide with that of the host country government.

3.2 Social and political objectives such as raising income levels and promoting self-reliance may coincide with those of the host country government.

3.3 However, the donor's often unclearly stated objective of stimulating domestic industry may be at odds with the recipient country's objective of achieving the least cost, most efficient supply of energy with minimum foreign exchange commitment.

3.4 A common objective of both donor and host country government is often to arrest deforestation. Donors' primary interest in appliance efficiency tended to lead to rather extravagant claims of improved efficiency for new designs of cooking stoves, charcoal furnaces, etc.

More recent studies indicate that appliance efficiency is strongly related to the user's desire to conserve fuel in the face of scarcity.

3.5 This notwithstanding, there have been some notable instances of improved wood or charcoal stoves designed for an urban market that have proved to be significantly more efficient than the traditional stove, and have sold in large numbers.

3.6 In line with donors and planners, the consumer may be interested in maximizing the efficiency of appliances, but this may not be of paramount importance. The consumer objectives of obtaining the cheapest fuel with highest supply reliability, and social objectives of modernising and improving status and considerations such as improving safety and the home environment may be of greater importance.

3.7 Both consumers and producers may be in conflict with donors and planners when legal requirements are not observed, enforced or do not exist.

DOES TRADITIONAL NECESSARILY MEAN INEFFICIENT? THE CROP RESIDUE TRADE IN SOUTH GUJARAT, INDIA

Priya Deshingkar, SPRU University of Sussex#

This is a mainly descriptive account of the biomass system in a village in Western India. The main purpose of the paper is to raise questions about the assumptions which are commonly made regarding the efficiency, or rather the lack of it, in traditional energy systems and the superiority of modern sources of energy. The focus is on crop residues as sources of fuel and fodder.

The paper starts with a general description of the types of biomass generated within the village and the end-uses for each type. It then goes on to trace, in some detail, the flows of the most important crop residues in the village economy which are paddy straw, sugarcane tops and sugarcane stalks. The objective is to illustrate the complexity and efficiency of the biomass system. In contrast to this, the working of problem-prone, supply and demand networks of commercial energy (kerosene, LPG and electricity) in the region is described.

Although the traditional energy system in the study village is highly efficient, it is by no means equitable. A brief analysis of the factors which determine access to biomass resources is presented at the end of the paper. The fact to emerge is that landless, poor and lower caste people are unable to obtain adequate supplies of fuel and fodder even in a highly productive region.

By traditional one means non-modern. In most Third World situations, this includes biomass resources[1]; namely wood, crop residues and dung, which are used primarily for cooking. Crop residues were chosen as the topic of the present study because they have assumed great significance in the village economy since reserves of fuel and fodder such as woodlots and grasslands were eroded and more land was brought under the plough.

Crop residues can be defined as biomass left over from the main crop after it has been either harvested or processed. Thus, millet stalks, cotton sticks and rice and wheat straw left in the fields after the main produce has been removed are crop residues, as are rice husks and bagasse, which are by-products of post-harvest operations. Various other

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The author wishes to thank Gordon McKerron of SPRU, University of Sussex for commenting on previous drafts of this paper.

[1]The Food and Agricultural Organisation of the United Nations defines biomass as any substance originating from living organisams with the exception of fossil fuels. This paper is concerned only with plant biomass.

terms such as "crop wastes" and "crop by-products" have been used interchangeably in the literature, but for reasons which will become obvious in the following pages, the term crop residues will be used throughout.

The paper is based on fieldwork carried out in the village over a period of one year. A combination of quantitative (measurements of crop residue yields and consumption according to different landholding and income categories) and qualitative (group discussions, informal interviews and case studies) methods was used in order to obtain a deep understanding of the production and use patterns of biomass resources.

WHAT IS EFFICIENCY?

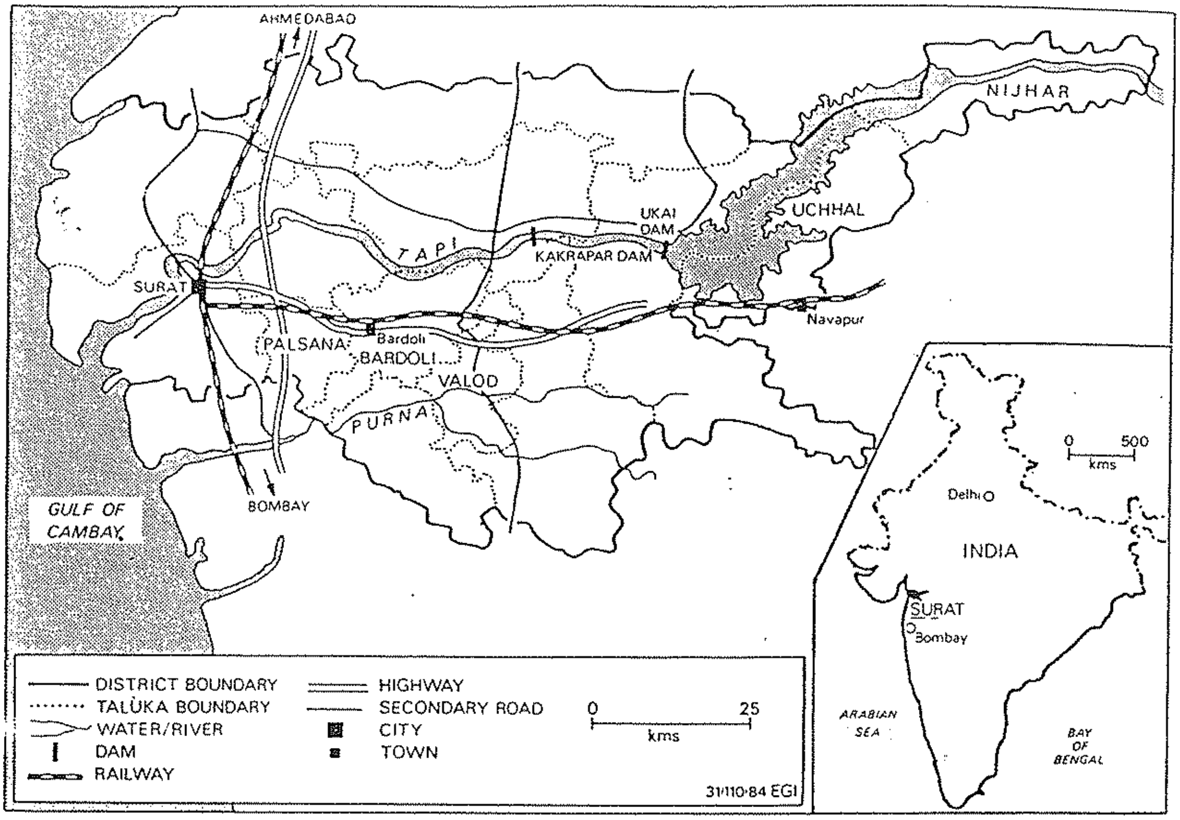
Let us begin by looking at the orthodox concept of energy efficiency, which is the ratio of the energy output to the energy input. In other words, the more output that is obtained in relation to inputs of energy, the more energy efficient the device is. On the basis of this simple rule, some will argue that household energy systems in developing countries (or biomass systems or indeed, traditional energy systems) are inefficient.

This argument can be supported only if one looks at the question of energy efficiency in a very narrow sense because it is true that the quantity of useful energy obtained from biomass energy resources per unit of input is typically very low. This is due to the fact that the resources themselves are "low-grade" in relation to petroleum based fuels and electricity. For example one kg of wood or crop residues contains 3,450-3,800 Kcals and dungcakes have an energy content of 2,400 Kcals/kg. Compared to this, LPG has an energy content of 10,700 Kcals/kg. Secondly, traditional conversion devices are also inefficient. Most traditional wood-burning stoves deliver an efficiency of only 10 per cent.

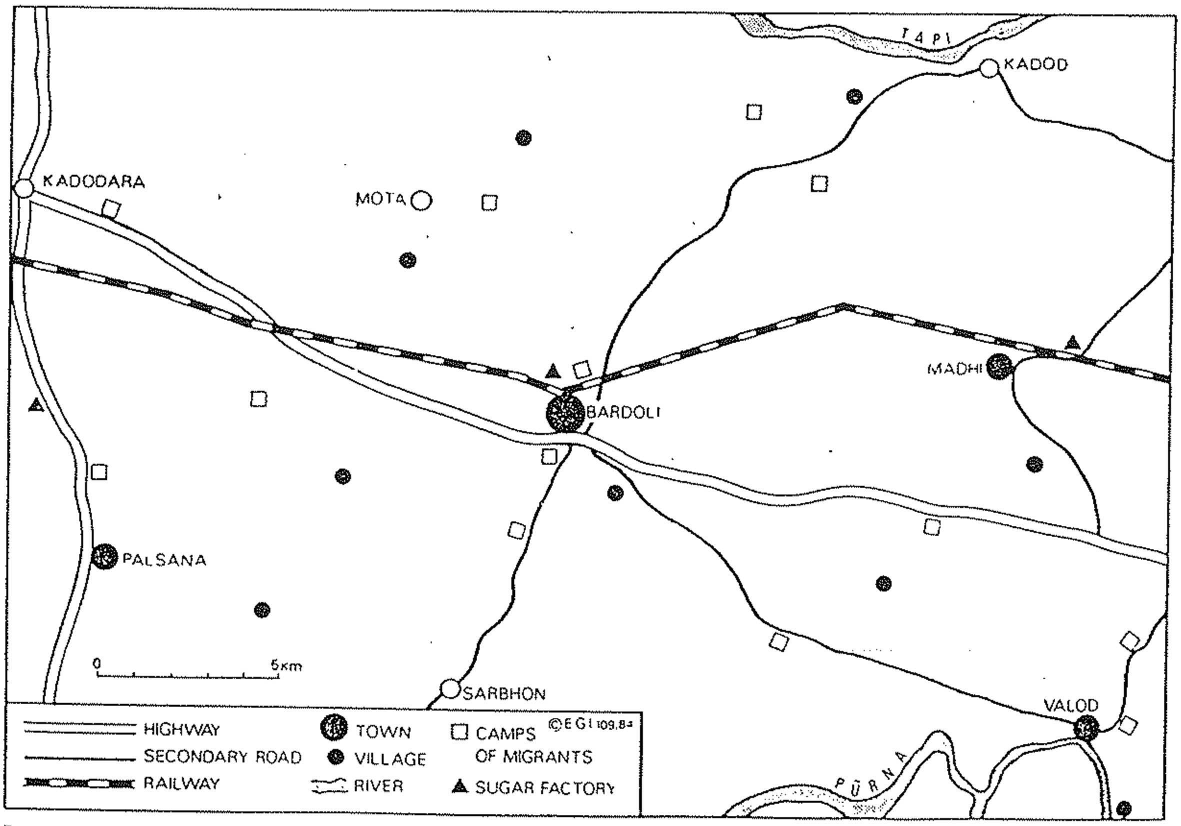
However, the total output of a traditional energy system (energy, agriculture and other end-uses) can be high; as we shall see in the coming pages. This paper is looking at efficiency from such a holistic perspective showing the complete lack of wastage and smooth functioning of markets in biomass energy systems.

THE VILLAGE

The study village, Afawa, has a population of around 1600 and lies about 5 km South-West of the town of Bardoli (see map). In many ways the village is very modern: the agriculture is intensive and mechanised, and the better-off households have the benefit of electricity, potable tap water, telephones and television.



Surat district in south Gujarat



Locations of researched villages and migrant camps

SOURCE: BREMAN 1985

LAND CROPPING PATTERN

Out of 1183.24 acres, 1165.23 acres or 98.5 per cent of the area is classified as arable land. Sugarcane and paddy are the main crops although some farmers grow wheat, beans, vegetables and mangoes for their own consumption. In the 1950s, the introduction of canal irrigation made sugarcane cultivation possible. According to records maintained by the village accountant, the crop allocation in the village was as follows:

Crop	Canal irrigated	Well Irrigated	Total area
Sugarcane	643.11	100.00	743.11
Paddy	226.30	-	226.30
Banana		14.20	14.20
Wheat	10.27		10.27
Okra	6.05		6.05
Groundnut	3.04		3.04
Brinjals		2.06	2.06
Vegetables		0.24	0.24
Total	889.39	117.11	1007.08

The area is given in acres.

Land distribution in the village is highly inequitable. Out of 334 households, only 82 or 32.5 per cent own land. Going by land holding one could say that there are just two dominant classes, the medium and large farmers (53 households) and the landless (252 households)[2].

[2]Given the number of combinations of biomass production that are possible on a piece of land such as trees-paddy-cane, paddy-vegetables-banana, cane-vegetables etc., etc. it is virtually impossible to ascertain how much land would be needed for a household to become self-sufficient in terms of biomass production or in terms of income generation for the purchase of biomass resources. The 'biomass budget' of a household also includes dung, so, additional variables to be considered would be the presence or absence of animals, their types and dung yields. Since the land in Afawa is nearly totally irrigated

In order to understand how the biomass system in Afawa operates, it must be given a human face. Below, is a brief description of the various social categories in and around the village which play an important role in the energy economy.

SOCIAL GROUPS WITHIN THE VILLAGE

The Patel

In terms of wealth, land holding and power, the patel are undoubtedly the dominant caste in the village. Their main occupation is agriculture although the new generation is venturing into business enterprises. Some patel households are obviously more wealthy than others. Apparently, they have become rich through their "foreign connection". A large number of patel have relatives in the US, UK, Panama, South Africa and other business havens. Remittances from abroad have given such households in the village an edge over the rest.

Evidence of the patel success story is visible everywhere: their caste name is seen on shops, paper mills, sugar factories, milk dairies and diamond workshops. They also occupy key positions in political bodies and educational institutions.

The Halpati

In sharp contrast to this picture of material comfort and power is the Halpatiwas or colony of labourers. It is some distance from the centre of the village where the higher castes live. There are over 200 halpati households and they easily outnumber the patels by 3 to 1. They live in appalling conditions. The huts are mostly made of mud and bamboo with no electricity, piped water or proper sanitation. The halpati look poor. They wear tattered clothes, are often ill and show symptoms of malnutrition. Only two halpati households out of 248 own tiny plots of land. The rest are landless and most of them work as agricultural labourers on the farms of the village landlords who are almost always patels.

Farm labourers are either "permanent" or "casual". Permanent employment seems to be a remnant of a system of bonded labour known as the halipratha (Breman 1985). These days, a permanent labourer or kayami majoor is not bound to be on call outside normal working hours and is to be paid the going rate of Rs 5 a day with one square meal

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and the soil (black cotton or loamy) is highly fertile, all households owning over 2 ha of land have been placed into a single category of medium and large farmers. In order to maintain some standard categories which are commonly used by agricultural departments, a land ownership of 2 ha has been taken as the cut-off point although, perhaps even 1.5 ha would have been an equally valid point of division. The categorisation will also facilitate a class analysis of biomass allocation in the village.

and tea. But, there is an unstated understanding amongst the labourers that if they do a few extra jobs around the house and work a bit longer in the fields, they can rely on their employers for a bit of extra food now and then and credit whenever they need it. Sometimes fringe benefits such as access to sugarcane residues, green grass and reeds from the employer's land also come with permanent employment.

The casual labourer or chhootak majoor on the other hand, is given Rs 7-12 a day, depending on the season, with no payment in kind. Women are almost always employed as casual workers in the house or in fields to do weeding and harvesting. Most labourers, whether permanent or casual, appear to be barely eking out a subsistence from their wages and seem to be caught in a deprivation trap[3].

The Outsiders

Since demands[4] from groups outside the village have also played an important part in determining the flows of crop residues in Afawa, two of the significant social categories are described below:

a. The Khandeshi

Each year, from mid-October to late May, a large number of workers are brought in by the sugar factory from neighbouring regions of Khandesh in the state of Maharashtra. These cane cutters, known as khandeshi, stay in the village for six months. They erect wig-wam type structures made from grass mats and bamboo along roadsides in the village. Some of them live in the animal sheds of wealthier farmers.

b. The Maldhari

The other outsiders are the Maldhari, who are a wealthy, nomadic sub-caste from the arid, western region of Gujarat. They specialise in rearing large herds of cows. The Maldhari live around the villages and towns and make a living by selling milk, calves (for rearing; not meat) and dung.

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[3]A condition resulting from the interlocking of various clusters of disadvantage, such as: poverty, physical weakness, vulnerability, powerlessness and isolation. When faced with sudden expenditures due to disaster, social conventions etc. such households become poorer still through loss of capital assets or rights. Often these effects are impossible to reverse (Chambers 1983).

[4]Here the word 'demand' is used in the literal sense and not as an economic term.

THE ENERGY ECONOMY

Nearly all of the biomass resources produced within Afawa, through cultivation or wild, are used. Since over 98 per cent of the land is under crops, their residues are the primary source of cooking energy, fodder and building material. Both sugarcane and paddy produce extremely useful residues. Some of them are generated within the village itself. For example, paddy straw is obtained after threshing the grain, either in the fields or the courtyards of farmers' houses. On the other hand, some residues such as rice bran and husk are produced outside the village or more specifically, at a stage in the processing of the crop which is not controlled by the farmer. Sugarcane also has a range of residues, some of which are produced in the village and the rest, such as molasses and bagasse are generated outside, during factory processing in Bardoli.

Chart No 1 lists the major residues of some of the crops grown in Afawa and their uses within and outside the village. It can be seen that those which are generated outside the village are also used outside Afawa.

For example, bagasse, which is the fibrous material left over after the juice has been extracted from sugarcane is used by the Bardoli sugar factory as boiler fuel or sold off to paper mills or cattle feed factories. Paddy husk is also no longer a component of the village biomass economy. It is used as a filler in brick making units around Bardoli and also used for parboiling paddy in the town. These days most of the rice bran finds its way from the rice mills of Bardoli to factories which extract rice-bran oil for use in edible hydrogenated oil mixtures and the soap industry.

Let us shift our attention to the biomass system in Afawa i.e. the flows from the source of production to various uses within the boundaries of the village. The two characteristics of the traditional energy system within Afawa which make it efficient are its frugality and the relatively smooth functioning of the biomass markets.

A frugal economy

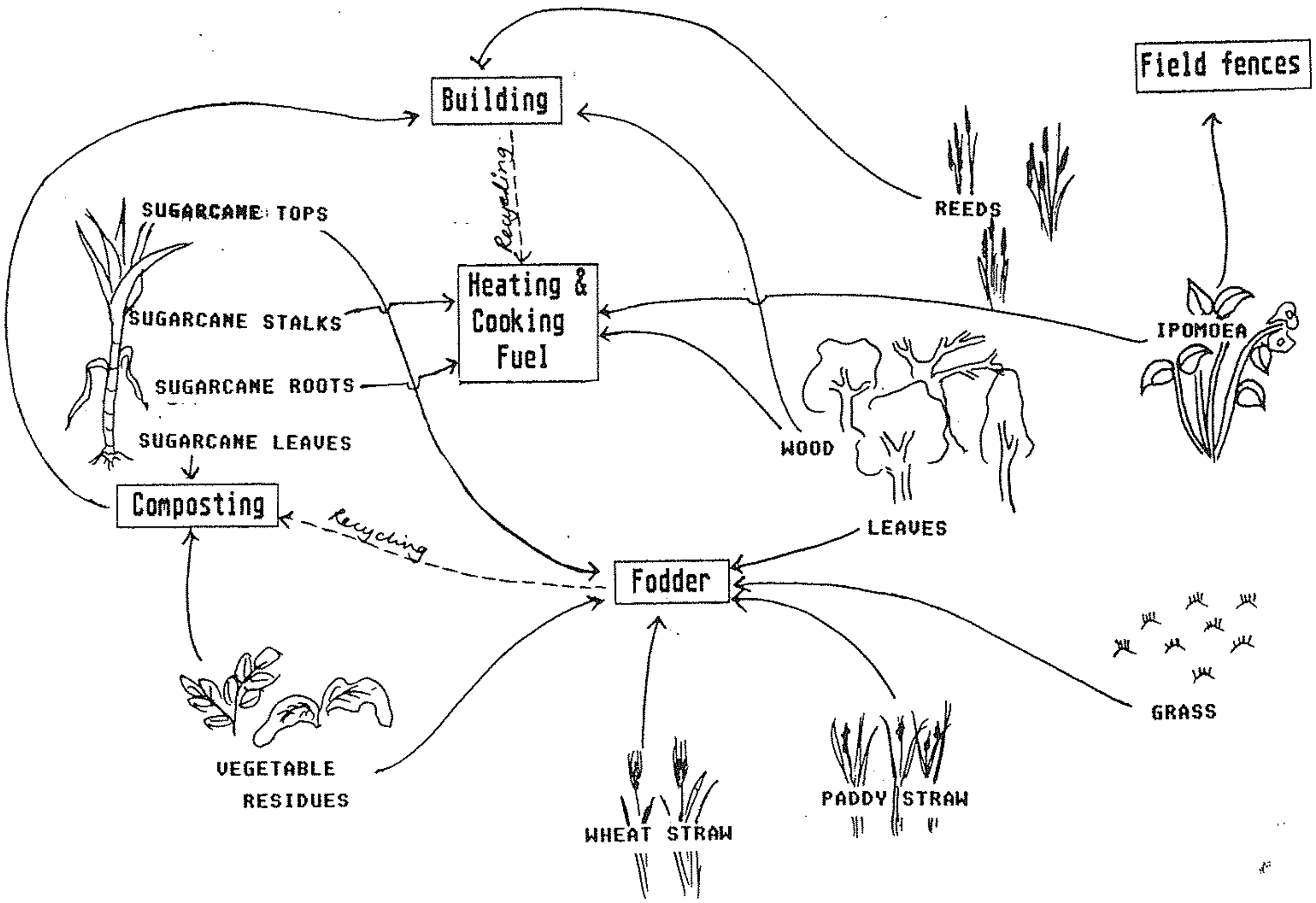
It can be seen from Chart 2 that all types of biomass produced within the village have at least one use. Some, such as paddy and wheat straw as well as cane leaves have more than one end-use. The efficiency of the system is further enhanced by the recycling of certain resources. For instance, sugarcane leaves which have been used as water-proofing for thatch roofs are composted when the thatch is replaced. Tur sticks used for supporting buildings are burnt as cooking fuel when they are replaced with new ones in the following year.

CHART 1

Crop	Residue	Use in Afawa	Use outside Afawa
Paddy	Husk		Filler in bricks, fuel in rice parboiling units
	Bran		Cattle-feed supplement, edible and soap-grade oil extraction
	Straw	Dry season fodder	Fodder, packaging, raw-material for paper
	Winnowings	For sprinkling on animal shed floors	
Sugarcane	Chimri/ tops	Fodder	Fodder
	Bagasse		Boiler fuel in sugar mills, raw-material for paper, fuel for jaggery making
	Bania/ stalks	Domestic fuel	Fuel for migrant sugarcane cutters*
	Muria/ roots	Domestic fuel	
	Raad/ "trash"	Water-proofing for thatch roofs	
Wheat	Straw	Dry season fodder	
Tur/Pigeon pea	Gotar/ husk	Animal feed	
	Karsathi/ sticks	Broom making	
Vaal/ Beans	Leaves	Fodder	
	Stems	Fodder	

* This has been considered as a use 'outside' the village since the migrant workers are not a part of the village population

CHART 2: BIOMASS USE PATTERNS IN VILLAGE AFAWA



The biomass market

In terms of competing demands and end-uses, paddy straw, sugarcane tops and sugarcane stalks are the most important crop residues produced in Afawa. All three are traded and follow complex paths from the producer to the ultimate consumer. Commercialisation is either obvious i.e. there is a monetary price attached to the commodity or disguised. In the latter case there is a rate of exchange but not necessarily in cash. For instance, bania or sugarcane stalks are part of the pay-packet of migrant khandeshi labourers. Virtually all commercialised biomass in Afawa, whether obviously or disguised, finds a market. If it is not traded within the village, then it is sold outside. Thus, the market is completely cleared. In the coming pages it will become evident that compared to the modern energy market, the biomass market in Afawa comes closer to the classical description of a properly functioning market.

In order to appreciate these market aspects of the crop residue trade in Afawa and their efficiency in relation to modern fuels, let us examine the patterns of production, trade and consumption according to the two major end-uses which are domestic fuel and animal fodder.

DOMESTIC FUEL

As mentioned previously, the effect of deteriorating common resources such as woodlots has caused a shift from wood as a major source of domestic fuel to crop residues (mainly sugarcane stalks) and dung.

Ideally, the residents of Afawa should no longer be dependent on crop residues, wood or dung but should have moved over to modern energy sources such as LPG and kerosene which are readily available in theory. Indeed, many government documents have expressed this hope (Government of India 1965, 1974, 1979). But in reality, rather than becoming more easily available as was expected by energy policy makers, these resources are becoming more difficult to obtain.

LPG

LPG was always a facility which only those with "contacts" in the right places got. Obtaining a gas cylinder for someone who does not know the right officials and suppliers in a personal capacity is a very time intensive, costly and difficult task. Although there are several companies in Bardoli who supply bottled gas such as Indane and Burshane, as well as thousands of potential customers both in the town and surrounding villages, there is always a shortage. The easing of the international oil situation does not seem to have had any significant impact on the availability of LPG in the area. Only fortunate individuals like L.N. Patel, a rich farmer, manage to buy enough LPG or even more. He always has three spare gas cylinders in his house; a fact which everyone in the village knows because it is something of a status symbol. Lower middle-class and poor people almost never have LPG in their homes. Even though the prices of LPG for domestic use have been kept artificially low, the initial costs of installing an LPG cooking system which can be well over Rs 1000 (£37), are a barrier to adoption. However, the major problem seems to be one of availability, and even if people are willing to pay, there is no LPG to be had. Therefore there is vast unsatisfied demand for LPG in the area and those who could have switched over to more superior fuels are stuck with biomass.

Kerosene

The supply networks of kerosene are equally fraught with problems. In fact, the difficulties involved in procuring kerosene such as the long queues outside ration shops and the misery they cause in hot weather were cited by people as the main reason for not using it. The cost itself is not a deterrent. Good kerosene stoves are still relatively cheap and sold cheaply by the government. The prices of kerosene in India are heavily controlled. In 1989 the price of one litre of kerosene was only Rs 3.50 (13p) in Bardoli. In fact, some estimates suggest that they have not increased significantly, in real terms, since 1970 (Leach 1986). The latest budget (March 1990) has yet again controlled price increases of kerosene.

However, such populist measures appear to have little impact at the village level. Several poor people in Afawa reported that they could not buy more than 25 paise-worth of kerosene at a time. In the monsoons even that little ceased to be available. The general impression is that merchants sell the kerosene on the black market for high profits rather than through ration shops at controlled prices. There was also a rumour that autorickshaw drivers were buying up kerosene from control price shops for use in their vehicles because it is much cheaper than petrol. Any negative effects of this on the engines seemed to be of little concern to the drivers since they rarely own the vehicles themselves. The extent of this practice was difficult to substantiate because it is illegal.

Dung

The availability of dung to make cakes for burning in stoves has also gone down. Many of the farmers with four or more head of cattle have installed family sized biogas plants in their backyards. They try to minimise the wastage of dung; so much so that the cowherd who takes the animals out grazing is sent with a pail to pick up the dung which is dropped on the road. Thus those who do not own animals face slim chances of getting any dung for fuel.

Cane stalks

With wood, dung and modern sources of energy becoming scarce, crop residues are in greater demand. As has been mentioned, the dried bits of cane which are discarded in the fields because of their low juice content, locally known as bania, are collected by the landowners for giving to the khandeshi cane cutters. The welfare rules of the sugar factory at Bardoli state that the migrant labourers should be provided with shelter and fuel amongst other things. Though not monetised, the intrinsic value or disguised commercialisation of this crop residue is evident from the fact that most farmers plan its collection very carefully. The farmers usually cut a small plot of cane, collect the bania in a bullock cart, take them home and then cut the next plot. Otherwise they can not prevent people who are too poor to buy fuel, from stealing the stalks at night.

The phenomenon of disguised commercialisation is not limited to cane residues: it is now common practice for farm workers to offer a day's labour (threshing) in exchange for the sticks of tur which they need for sweeping the yards of huts. Such practices are prevalent elsewhere in the state. In the neighbouring district of Baroda tobacco residues are the only payment offered to labourers who separate the leaf blades from the mid-ribs.

FODDER

The animal economy

Afawa has a fairly large animal population. There are 228 adult buffaloes, 98 bulls, 70 adult cows and 168 goats. Almost all the medium and large farmers keep draught and milch animals. As a group, the halpati own very few head of cattle. A lack of cheap and easily available fodder has been a major constraint on dairying activities. Of the 252 landless families, only 27 or 10.7 per cent reported sale of milk whereas 71.7 per cent of the large and medium farmers are engaged in milk production for the market.

Paddy straw

Unlike earlier times, these days even wealthy farmers feed their animals on paddy straw because traditional animals feeds such as millet, jaggery and turmeric roots have become too costly. Although the farmers realise that buffaloes do not yield as much milk when fed on straw[5], there is little else they can do because the local dairy does not offer them

[5]In its natural state, cereal straw has a high proportion of indigestible matter. Several R & D projects have been taken up in scientific institutions in order to improve the nutritional value of straws through physical, chemical and biological treatments (ISCAR 1987).

a remunerative price for the milk (it is between Rs 5 and Rs 7 per litre depending on the fat content). This is because of the national policy to keep milk prices low for urban consumers supplied through the network known as "Operation Flood".

Most paddy cultivators take two crops in a year: one in Kharif and another irrigated crop in the spring. The large farmers cultivate enough paddy at a time to provide their cattle with straw for the whole year. The straw is stored in backyards or a loft. When the second crop of paddy is harvested, the surplus straw is sold off either to other farmers in Afawa or consumers outside the village.

Demands for straw from outside Afawa

a. From the Maldhari

During the 1987-88 drought, a large number of Maldhari migrated to the lusher parts of South Gujarat in search of fodder for their starving cattle. The local farmers with irrigated fields soon discovered that selling fodder was a lucrative business. Many took to cultivating crops and grasses purely for fodder with the aid of government subsidies on water and electricity. The price of paddy straw jumped up from less than Rs 200 (£7) a tonne to over Rs 1000 (£37) per tonne during the drought. Most of the straw found its way into government fodder depots and the Maldhari cattle camps on the outskirts of Bardoli. Now that the drought is over, the prices have fallen but not to pre-drought levels since the Maldhari continue to stay around the villages and constitute a significant outside demand.

The mechanisms of price setting of crop residues are not absolutely clear. To an extent, price rises are set by the degree of scarcity. This seems to have happened in the case of paddy straw. However, commercialisation itself seems to be due to a number of factors such as a general commoditisation of the society.

b. From the paper industry

In the early 1970s several large paper mills in the country began to face acute raw material shortages because they had run out of wood for pulping. In view of the shortage a decision was taken by the government to decentralise paper production and use "cheap, abundant and locally available" raw materials. Since the prevalent belief was that millions of tonnes of crop "wastes" were available in the country, these were singled out as the appropriate raw material. All kinds of incentives such as excise duty rebates were offered to entrepreneurs for setting up small paper manufacturing units based on crop "wastes"

(Sairam 1986)[6]. This led to excess capacity for paper making being established in the area.

In the mid 1970s, four such mills were set up in the Dastan Phatak area, on the Surat-Bardoli highway. But all of the mills, sooner or later, ran into raw material shortages. Only one, the Hari Om Paper Mills, continues to use paddy straw but the management complains about the rising costs of procuring it. The scarcity has become profitable for some. Nearby, there is a middle-man, Sohel Traders, who stocks straw when it is cheap and sells it at a higher price in the lean season.

Sugarcane tops

A sophisticated market has also developed for the trade of sugarcane tops locally known as chimri. According to the Bardoli sugar factory management, the migrant khandeshi cane cutters established a right to controlling the green residues of cane soon after the factory started. In the beginning, the Bardoli farmers did not realise that sugarcane tops made good fodder because of their high sugar content; so they did not object to this arrangement. It was felt that the cutters would work harder because of the incentive of earning a few rupees on the side from the sale of the tops. However, once the merits of the cane tops became better known and the cultivators realised that they no longer owned the tops from their own fields and actually had to buy them back, there was much resentment. By that time it was too late. So, now nothing is done by the farmers for fear of sparking off inter-class tensions. A couple or koyta of workers probably earn an extra 6-10 rupees each day through the sale of cane tops. The men usually do the cutting and the women tie the cane into bundles for loading and sell the tops in the village.

A typical scene in Afawa during the seven odd months of the cane cutting season is the sight of these women walking through the village with headloads of chimri. The richer farmers usually buy a couple of loads for each head of cattle a day. The asking price for a headload weighing anything between 10 kg and 20 kg is Rs 2 although it is frequently bargained down to Rs 1.50. Assuming that one adult buffalo can get through at least two headloads or bharas a day, the cost of feeding it works out at between Rs 1095 and Rs 1460 a year. For an agricultural labourer with an annual income of less than Rs 3000, this is prohibitive. Even the better off farmers complain that it is far too expensive.

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[6]An exemption from customs and central excise duty was granted, provided the paper (writing, printing and craft), contained not less than 75% by weight of pulp made from bagasse etc. If unconventional material (crop residues, waste paper etc.) was over 50% then a concession of up to Rs 1120 per metric tonne was granted.

The cane cutters have managed to keep the price of the chimri so high because they have a ready market outside the village. Every evening between 6.30 pm and 7.30 pm cartfulls of the green tops are brought to a main road crossing near the railway station in Bardoli. The tops are bought by fodder merchants who transport them by lorry to Surat at night; they sell them there the next day at a considerable profit. The customers are the milkmen of the flourishing informal dairy sector around Surat city.

The channels of trade and distribution of sugarcane tops, stalks and paddy straw have been summarised in Chart 3. It indicates a net outflow of the three most important residues from the village even though there exists the potential for absorbing them within the boundaries of Afawa. This is because economically and socially disadvantaged groups such as the landless poor have few legitimate claims on paddy straw, sugarcane tops and sugarcane stalks. They have neither the productive assets such as land and animals, to generate their own supplies of biomass, nor do they have the purchasing power to buy them. Therefore, both fuel and fodder are often obtained through theft. This is often done at night or in the middle of the afternoon when there are less chances of being caught.

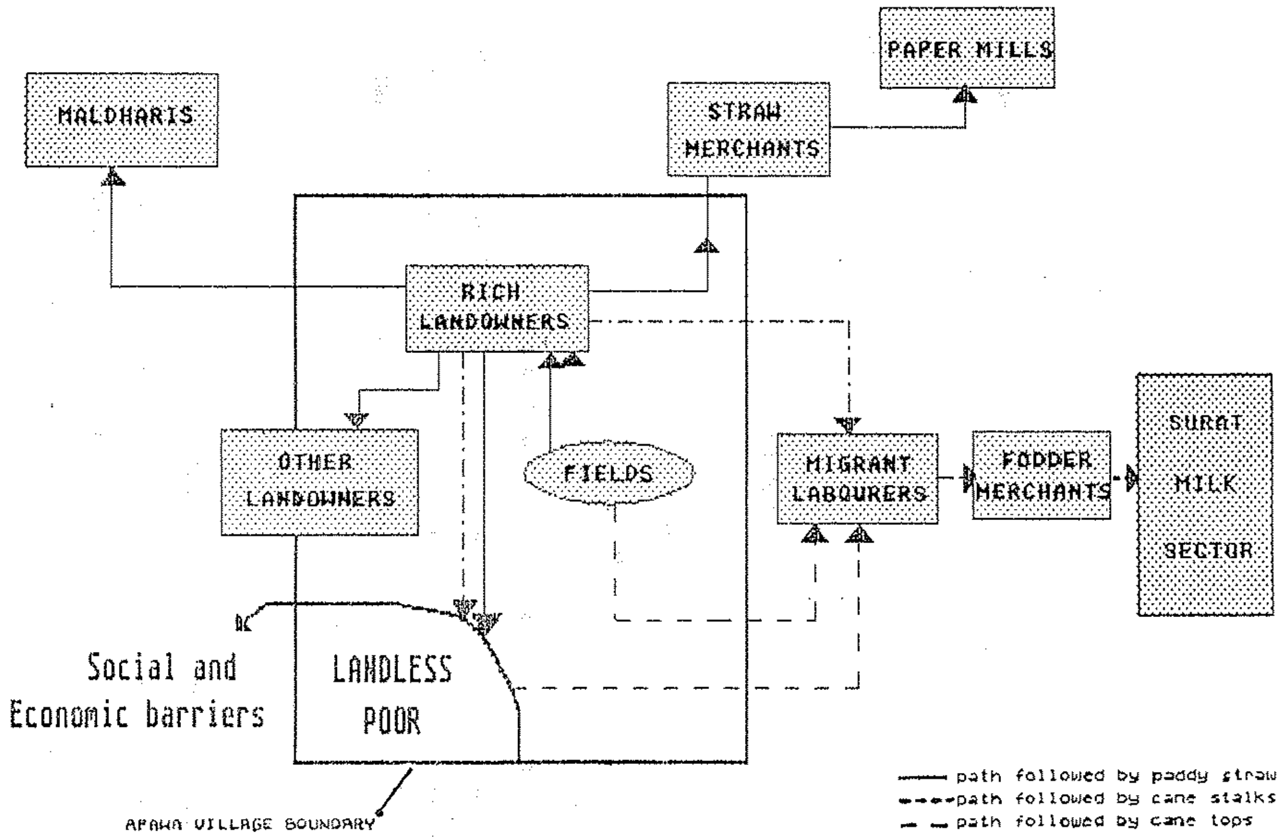
Firewood is collected from the few trees which belong to the government, along the Bardoli-Dhuliya highway, which is about 2 km away from Afawa. The trees are heavily patrolled by guards on motorcycles. If caught, a fine of around Rs 200 is imposed on the spot. The poor villagers are forced to turn to environmentally damaging practices. Very often, the poor people strip the bark off trees, rather than lopping off dead twigs. They stand a better chance of making a getaway if they are standing near a tree on the ground rather than being perched on one of the top branches. The trees which are damaged too severely because of bark stripping die. Such damage is fairly widespread.

Obtaining bania is a similarly risky business. As explained earlier, the cane stalks are collected by the landowners either to give as part payment to the migrant workers or to use as a fuel in their own households. If a farmer delays the collection of bania from his field, then the landless poor get an opportunity to take some back home. Again, this is done when the danger of being found out is at a minimum.

Who suffers most?

At first the casual labourers appear to be in a better position than the permanent workers because they are paid a bit more. In fact though, they are in a far worse condition than any other group in the village. A permanent worker is paid Rs 5 a day with some payments in kind and receives some perks. Payments in kind and perks are welcomed by the labourers because they help to preserve, to an extent, the real value of the wage. Bundles of food and fuel from the employer become crucial in times of scarcity. The four

CHART 3: FLOWS OF PADDY AND SUGARCANE RESIDUES IN AFAWA



months of the monsoon are particularly tough. Firstly, there is very little work to be done in the fields because the soil is so wet that it becomes impossible to enter the fields. Secondly, getting fuel becomes a major problem because everything is damp and the field paths are flooded.

The casual workers, on the other hand, suffer not only from a lack of any such protective mechanisms during bad periods but also because they are severely underpaid. A casual farm worker gets Rs 8-10 at the end of a day's weeding or fertilizer application which is much below the minimum wage prescribed for unskilled agricultural labour by the government. It was recommended to be Rs 10.50 per day in 1985. Given the high inflation rates of the last five years, the minimum wage should be much higher now.

Such underpayment continues because agricultural workers in South Gujarat enjoy very little bargaining power and can not demand higher wages. This is because of their large numbers which gives employers the upper hand when fixing the wage rates. The labour market in Afawa is further distorted by the influx of migrant labourers for at least six months out of every year. The patel prefer not to employ the halpati as they are considered lazy and dishonest. So, they are giving more and more work to the migrants who are thought of as hard working. The casual labourer households, thus, receive a double blow. They neither get paid enough and nor do they find enough employment.

It is not enough just to identify the casual labourer households as the main victims. Within the households of the poor it is often the women who bear the brunt of all of these negative forces. Drinking amongst men is a major problem in the poorer sections of the village. Many women complain that their husbands spend most of their money on drink and leave their wives to run the household.

Traditional vs. Modern

Thus we have here, on the one hand, a highly efficient system but also an extremely inequitable one. On the other hand, LPG and kerosene are thermodynamically superior but as we saw, the system of controls and bureaucracy has frustrated the process of energy transition with the result that consumers can not obtain them at any price. Biomass continues to be used in this highly modernised region and the markets have developed in almost a classical way. The resources themselves are used to their fullest capacity. Perhaps energy policy makers should also recognise these aspects of traditional systems and not write them off completely. The main lesson we can draw from these findings is that simple calculations about the efficiency of use devices and the energy content of fuels can not be the sole consideration when estimating the merits of particular systems.

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ENERGY FOR SUSTAINABLE AGRICULTURAL DEVELOPMENT: THE ZIMBABWE CASE

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1. INTRODUCTION

If the nitrogen and phosphorus lost annually by soil erosion in Zimbabwe had to be replaced by commercial energy inputs in the form of fertilizer, the cost is estimated to be US $ 2.5 billion at 1985 prices (Stocking, 1986). This is equivalent to half the country's Gross Domestic Product. Whilst this cost is not included in the national accounts of Zimbabwe, nor for that matter is this kind of cost included in the accounts of any other country, the economic loss is no less real as a result of this accounting oversight. Only now are efforts being made to recognise and redress this kind of problem by developing an economics of sustainable development (Pearce, 1989). Maintaining the productivity of the land is necessary for the long term economic prospects of any country. Energy inputs into agriculture are vital not only to increase productivity but to maintain the fertility of the land, so that future generations can continue to enjoy the fruits of the soil.

In this article we will analyse energy use in agriculture as a means to raise the wider issue of sustainable development options for Zimbabwe. We begin by looking into the relationship between farming systems and energetic efficiency presenting some of the findings to date. Sustainable development is all about using resources efficiently and energetics provides an important measure of resource productivity. Research undertaken on trends in energy usage in different production systems inside Zimbabwe will reveal the vast disparity in resource allocation between the peasant and the white-settler commercial sector. We will show how this developed historically and ask what it should mean for future policy.

2. ENERGY USE IN AGRICULTURE

The oil crisis of the 1970s stimulated hitherto neglected research in the field of energy use in agriculture. The preoccupation at that time concerned the potential constraints on energy intensive farming, given scares over declining fossil fuel resources. For the 1990s however, energy use in agriculture raises far wider issues of the environmental sustainability and wisdom of intensive non-renewable energy use. Addressing these issues requires investigating patterns of energy use in different production systems. By examining these historically, lessons can be drawn for the future.

Agricultural development has generally been closely associated with an increasing consumption of energy in the production process. Energy inputs in agriculture take two main forms. On the one hand there are yield enhancing/land saving biological inputs such as fertilizers, pesticides, herbicides and irrigation. On the other hand there are labour-saving mechanised inputs ranging from animal traction to liquid fuelled agricultural machinery. Development in agriculture has generally implied a transition from non commercial and renewable energy resources to commercial and non-renewable energy resources for both land-saving and labour-saving energy inputs. Energetic analysis based on the laws of thermodynamics has provided one mechanism for analysing this transformation in agricultural energy utilisation. Food production is both a producer and consumer of energy. Agriculture energetics is a mechanism for evaluating the ecology of agricultural systems; energy inputs are evaluated in the context of energy outputs by converting both into common energy units. If the ratio of the outputs to inputs is greater than 1, the agricultural system is viewed as a net provider of energy. The ratios of different production systems can then be compared which provides a measure of energetic efficiency.

In Table 1, energetic efficiencies for selected farming systems and crop types in various parts of the world are compared. The table provides a summary of some of the research findings. It demonstrates firstly the relationship between the industrialisation of agriculture and a reduced efficiency of energy conversion. For a sustainable development future, resource efficiency as well as strict economic criteria must be considered. The assembled evidence clearly indicates a decline in the efficiency of energy use in the move from renewable to non-renewable energy inputs in the agricultural production process. Far higher energetic efficiencies are found in semi-intensive rainfed hoe cultivation than in industrial farming. Hence the development process to date has been very resource demanding and as we are all now aware, very costly in terms of the social and environmental impact of non-renewable energy inputs. Yet judged in the narrow terms of traditional economic efficiency, productivity per unit of labour and land, and discounting environmental costs, industrial agriculture is enormously productive. In the mid 1970s it was estimated that a one dollar expenditure on fertiliser in US maize production yielded eleven dollars in the field (Green, 1978). Herein lies the dilemma.

The existing laws of capital accumulation are not at one with the laws of thermodynamics. With development transitions to date, there has been a loss of efficiency in energy use, combined with an increased economic productivity of labour and land. The cost for future generations of this increased productivity remains at present unquantifiable in detail, but is sufficiently worrying in general to bring into question the entire foundation upon which the existing criteria of economic productivity of labour and land

Table 1

Energetic Efficiencies for Selected Farming Systems and Crop Types

Farming System	Energetic Efficiency Ratio	Crop	Location	Source
Hunting/Gathering	7.8:1	----	Southern Africa	Lee (1969)
Swidden	16.5:1	root crops	New Guinea	Rappaport (1971)
	8.6:1	cereals	Malawi	Haswell (1981)
	12.5:1	maize	Mexico	Pimental and Pimental (1979)
Semi-Intensive Rainfed Hoe Cultivation	18.5:1	cereals	Sub-Saharan Africa	M Norman (1978)
	29.5:1	root crops	Sub-Saharan Africa	M Norman (1978)
	10.7:1	maize	Mexico	Pimental and Pimental (1979)
with Inorganic Fertilizer	6.4:1	maize	Nigeria	Pimental and Pimental (1979)
Rainfed Bullock-Powered Cultivation	3.1:1	maize	Guatemala	Pimental and Pimental (1979)
	4.3:1	maize	Mexico	
with Inorganic Fertilizer	5.1:1	maize	Phillipines	Pimental and Pimental (1979)
Industrial Farming	2.1:1	maize	United States	Steinhart and Steinhart (1979)
	2.8:1	maize	United States	Pimental _et al._ (1973)
	4.1:1	maize	United States	Smil. _et al._ (1983)
	2.3:1	maize	United Kingdom	Leach (1976)

are based. High inputs of non-renewable labour and land saving energy resources were once considered efficient and unavoidable for development, a *sine qua non*. They are now considered potentially damaging *vis a vis* access, equity, dependence and environmental criteria and therefore unsustainable.

The need for development and growth is not at issue. Without it an increasing population would cause declining living standards, current levels of poverty are unacceptable and finally growth in other countries creates this imperative. With or without development therefore, environmental problems will grow. The challenge then, is how to develop in an environmentally sustainable way.

Achieving a better utilisation of renewable energy resources in agricultural production will provide one part of the answer. Given the mounting debt and continuing balance of trade distortions in African countries, non-renewable energy resources are obtainable only at a price. As commercial energy inputs in agriculture are essentially petroleum based, and as a majority of developing countries are not petroleum producers this creates major difficulties. In most developing countries there is a labour surplus and a foreign exchange shortage. Hence a sustainable development strategy could begin by concentrating more on increasing organic yield enhancing potential rather than focusing solely on labour displacing energy inputs. There is already strong evidence that productivity improvements can be obtained through better land use management using renewable energy resources (Munslow et al 1988).

Data on energetics gives a measure of efficiency in resource use. A failing of much energetic analysis however (Bunker, 1985; Pimental and Pimental, 1979), is that it fetishizes the role of energy rather than situating it within production systems. As Bayliss-Smith has commented "it would be unrealistic to expect that because one has analysed the workings of an agricultural system in terms of energy flows one has necessarily explained the reasons for its emergence and persistence as a system of food production". (1985, p5)

Essentially, looking at Table 1, production systems in the past associated with low population densities traded land availability against a labour shortage. This generally was environmentally sound but still left them vulnerable to the proclivities of climate and existing forms of socially organised production. Over the past century in central and southern Africa, colonisation restricted the land available to African farmers, with white settlers occupying much of the good land, creating migrant labour economies based on communal tenure African reserves. A shrinking land frontier and rising population densities gradually closed off the extensive land use option which was the foundation of sustainable production for African farmers in precolonial societies.

As we will demonstrate in the case of Zimbabwe, there have been enormous disparities in energy flows to the different production systems established inside the country creating great inequalities. On the one hand there developed the prosperous and successful Large Scale Commercial Farming Sector (LSCF) of the white settlers, and on the other the impoverished peasant farming sector on the African reserves. For the majority of the population of Zimbabwe who are peasant producers, sustainable development concerns the struggle to access resources. For many, their livelihoods are quite simply unsustainable without additional land and other resources. This raises in turn the whole policy question of land utilisation and its possible redistribution which we will go on to explore.

Energy utilisation in agriculture shapes and is shaped by the production systems in which it is employed. Climate, the environment, access to resources and land management skills play a pivotal role in determining outputs. The role of energy in the uneven development of agriculture in Zimbabwe has been but little explored to date and it is this issue that we will now address.

3. ENERGY AND UNEVEN AGRICULTURAL DEVELOPMENT IN ZIMBABWE

Agricultural energy use in Zimbabwe is strongly influenced by agro-ecological potential. Zimbabwe is customarily divided into five natural regions, based primarily on rainfall quantity and variability, with some consideration for soil quality. The natural regions provide a broad framework for the evaluation of potential land use. Natural region I confined to the Eastern Highlands enjoys annual precipitation of over 900 mm (with much higher amounts locally) and is, therefore, well suited to tea, coffee, fruit and forestry crops as well as intensive livestock production. Less than 2 per cent of Zimbabwe's land area falls into this category. Natural region II (divided between IIA and IIB) is the primary intensive farming area in the country and accounts for 15 per cent of total land area. Situated in the highveld region around Harare, average rainfall of 750-1,000 mm means that the area is well suited for dryland grain and industrial crop production (maize, wheat, cotton, tobacco and oil seeds). Natural region III is a transition zone where annual rainfall averages of 650-800 mm make dryland cultivation more risky. The region covers 18.7 per cent of Zimbabwe's total land area. In natural region IV, rainfall averages of 450-650 mm are inadequate to support dryland cultivation on a yearly basis. Natural region V consists principally of the hot and dry lowveld of the Zambezi and Sabi-Limpopo river valleys. These last two regions - which are best suited to extensive livestock production - together account for two-thirds of the country's total land area.

Through its control over access to land and agricultural institutions, the settler colonial state helped shape distinct farming systems and patterns of agricultural energy utilization.

On the eve of European settlement in 1890, Zimbabwe had an estimated total population of only 400,000 people, living on a land area of 39 million hectares. Arable farming was based on hoe technology employing slash and burn shifting cultivation techniques. Soil fertility was ensured in two ways. This chitemene cultivation system involved firstly, cutting the branches of trees, piling them on the ground and burning them, with the ash used as fertilizer. Secondly, there was a long fallow cycle to restore fertility. Floyd (1959, p100) calculated the mean population density as 10.7 per square mile, less than half the estimated carrying capacity (Mahlahla, 1980, p48). There is some evidence that the system was environmentally sustainable but vulnerable to protracted drought.

Traditional sustainable development production techniques were slowly disrupted with the advent of white settler rule. The Land Apportionment Act of 1930 established exclusive settler control over half of the country including 71 per cent of Natural Region I, 69 per cent of Natural Region II and 45 per cent of Natural Region III land (Munslow, 1985). Settler policy involved forcing African peasants off the most fertile land into reserves; a massively disproportionate level of financial support in favour of white farmers rather than African farmers; and closing off potential African competition in agricultural production. The land occupied by the indigenous population was transformed into migrant labour reserves. Although European and African farmers occupied roughly the same area of land, the African areas were of much poorer quality and immediately prior to independence carried 80 per cent of the total rural population compared with 20 per cent in the European areas. In effect the massive alienation of land from the peasant farmers undermined the sustainability of their production system.

Changes in the traditional chitemene system occurred prior to any state intervention in African agriculture. Such moves are testimony to the innovative potential of African peasant farming in general (Richards 1985) and of Zimbabwe in particular (Ranger 1985). Initially these changes involved using more mechanical rather than biological energy inputs. For example Palmer (1977), suggests that between 1906 and 1936 the number of ploughs used by Africans had already increased from 692 to 79,015. The adoption of the plough and animal traction, labour saving energy inputs, increased the area cropped precisely at the time when the state was trying to restrict African peasant farming to limited reserves and accommodate the expansion of the African population on marginal lands.

Recognising the potential production and environmental crisis associated with the closing of the land frontier and the breakdown of the chitemene system, chief agriculturalist Alvord initiated a governmental effort to transform African agriculture in the 1930's. In an attempt to increase the intensity of land use in an environmentally sound manner, arable and grazing lands were demarcated. Manuring, composting, contouring, rotational farming and grazing were introduced in a limited way (Jordan, 1965; Beinart, 1984). In order for the labour reserve economy to function, it was important that African agriculture did not collapse. As far as the settler state was concerned, this required a radical transformation in the structure of the traditional agricultural production system. Changes in land use were necessary, as was a transformation and intensification of energy use in agriculture. According to Alvord, African farmers needed to apply more of the available organic materials to maintain soil fertility (Jordan, 1965). Conservationist policies were almost inevitably authoritarian and repressive taking little or no account of indigenous and grass roots conservation efforts by the people themselves (Ranger, 1989). The way in which they were introduced and their association with authoritarian colonial rule guaranteed popular rejection and failure. This is an observation more widely applicable to the colonial and sometimes the post-colonial history of the southern African region as a whole (Beinhart, 1989).

The Alvord plan was also contradictory because a more intensive use of organic materials was proposed at a time when biomass resources were becoming depleted. During the period, the African reserves experienced increasing land degradation leading to an ever greater reliance on off-farm income. Because off-farm income was required for basic needs, productive investment was limited and there was little state encouragement for such a development. Farmers were unable to purchase non-renewable fossil fuel based biological energy inputs to increase soil fertility and enhance yields. A depleted physical resource base and state dismissal of the value of traditional farming knowledge and practices inhibited the intensification of local biomass utilization. As a result, the application of increased energy inputs into agricultural production was impeded. A crisis situation developed and Africans became increasingly dependent on the market to obtain their food as they could no longer produce it on the reserves. Jordan (1965), in a study of Zimutu reserve found that in 1963 only 15 per cent of the households surveyed applied adequate quantities of manure on their fields. Sixty per cent were short of animal draught power. Plowes (1976) estimated that less than ten per cent of the cropped area of the Manicaland reserves had manure applied at all. These studies indicate only a limited transition to the type of farming that Alvord envisaged a generation earlier.

Turning now to the evolution of the European LSCF sector, this began when the British South Africa company encouraged white settler farming in the realisation that there was no second Rand of South African mineral riches to be found in Southern Rhodesia. Occupying half of the land area of the country, and the best parts at that, white farmers were in an excellent position to increase energy inputs into agricultural production and reap the rewards of high productivity. The period after World War Two in particular, marked a rapid expansion in settler farming. In the decade to 1955 the number of white farms almost doubled to 6,255 (Muir, 1981). This expansion in numbers gave the spur to a rapid transition from animal traction to mechanical tillage. The number of tractors in use tripled to 3,448 between 1947 and 1949 alone (Conex, 1961).

The mechanisation of settler production preceded any significant diffusion of yield-enhancing biological fossil fuel energy inputs. Until the 1950s, green manuring and composting were recommended to furnish the nitrogen supply to maize. Yet these inputs soon followed and maize yields increased fourfold over a thirty year period following the War (Tattersfield, 1982). By 1960, settler farmers were utilizing over forty times the amount of fertilizer consumed in the African reserves.

This was a period of rapid change in the type and quantity of energy utilized on European farms. Mechanisation, irrigation, and the widespread use of fertilizers and agrochemicals soon became commonplace. The industrialisation of settler farming was the product of almost four decades of state involvement in agriculture. The state provided the land for the settlers and eliminated effective African competition. Infrastructure was developed and prices subsidized. With the state establishing a host of agricultural research initiatives, the conditions for the transformation of the settler agricultural production system were prime.

Settler agriculture became a critical component of the Rhodesian economy both as a provider of foreign exchange and a supplier of inputs into the manufacturing sector. The rate of capital accumulation was high. This allowed for the rapid diffusion of new forms and larger quantities of agricultural energy inputs. The transition to fossil fuel agriculture occurred and productivity increased accordingly. Because of an abundance of cheap labour, however, mechanization was only partial. The labour-displacing potential of machines were not fully utilized. Partial mechanisation set limits on the areal expansion of cropping. Hence, the Ministry of Agriculture developed a system of land use that was extensive. Cattle were allocated several hectares each. Long fallow periods were recommended as were extensive crop and livestock rotations. Numerous conservation methods were utilized and very little hilly terrain opened up for cropping. The transition to biological fossil fuel energy inputs was not needed to replace soil nutrients depleted through overuse. Rather, they were used to supplement existing resources and increase land productivity and profits.

The transition to high-input/high-output farming represented a significant change in human-environmental relations within the settler agricultural production system. Fossil fuel energy helped farmers create environmental conditions that did not naturally exist. A wheat crop was now grown during the long dry season, and the soil was given added nutrients. Larger tracts of land could now be opened for farming. The relation between people and the environment within the settler agricultural production system, therefore, was one of manipulation and transformation, but with what appears to have been, at least ecologically, limited negative effects.

The same could not be said for agriculture in the reserves. Effectively, a sustainable development strategy had been facilitated for the settlers by providing them with substantial landholding at the expense of the peasant producers, whose traditional sustainable development practices were undermined by the land alienation. The most detailed technical review yet undertaken on land degradation in Zimbabwe reveals the results of this policy. Erosion is severe or very severe in only 1.6 per cent of the commercial farmlands compared with a figure of 26.9 per cent in the communal lands (Whitlow, 1988, p22).

This disparity resulted directly from the monopoly of the country's best land resources by the settlers. It also followed from their monopoly of energy inputs in the agricultural sector as outlined in Table 2. The table shows that the Large Scale Commercial Farmers consumed 93 per cent of all of the petroleum used in the agricultural sector, essentially for tractors. Such a disparity is a reflection both of purchasing power and physical access. Only a quarter of Zimbabwe's fuel stations are in rural areas and a minute fraction of these serve peasant farming areas (Cheater, 1989). The white settlers monopolised a similar percentage of coal used for drying and curing and electricity for irrigation. The LSCF also utilize 85 per cent of commercial fuelwood (use of other fuelwood in the subsector is not known). Most draught animal power is used in the communal areas.

The essential challenge for a sustainable development future lies in the unequal resource access between the two production systems. Relative over population in the limited land area allocated to the reserves is exacerbated by the poor quality of the land. This restricted the availability of adequate supplies of draught animal power and manure. Population pressure on limited land restricted too, continuation of the traditional fallow system and land clearance reduced biomass supply for renewable energy inputs. Most households, particularly in the drier natural regions, could not accumulate sufficient capital to invest in productive resources, such as fertilizer, irrigation works and mechanical tillage. The peasantry - suffering from a depletion of renewable resources - were unable to make the transition to fossil fuel agricultural energy utilization. The reserves resource crisis combined with limited off-farm employment opportunities provided the political stimulus for the independence struggle with its rallying cry to return the 'lost lands'.

The scope for some land redistribution to increase the country's overall productive capacity exists within the LSCF sector. This is because although significant agricultural

TABLE 2: DIRECT AGRICULTURAL ENERGY CONSUMPTION

1981-82

Fuel Type	Primary End-Uses	Total Agr. Use (million GJ)	Per-cent of National Consumption	LSCF Use (GJ)	% of Total agr.
Petroleum Products	Tractors	2.78	10.3	2.59	93.2
COAL	Drying/ Curing	8.80	18.3	8.20	93.2
Electricity	Irrigation	1.94	7.3	1.78	91.8
Fuelwood	Drying/ Curing	7.31	6.5	6.21	85.0
Draught Animals	Land Preparation	3.60	N/A	-	-

Source: Weiner (1986)
N/A = Data not available

Note: National estimate for manure use are not available.
Indirect uses to produce fertiliser, pesticide and seed account for an additional 12-14 million GJ

intensification was undertaken by settler farmers, it was still limited given the abundance of cheap African labour, which left large tracts of high and medium potential land underutilised. High levels of productivity were limited to small portions of their large estates. The challenge now is how to devise a form of land redistribution that will not undermine the productive potential of the LSCF sector whilst enhancing the potential of the peasant farmers.

4. POST-INDEPENDENCE CHANGES OF ENERGY FLOWS IN AGRICULTURE

With independence the new government embarked upon a plan to redress previous imbalances by directing producer inputs in support of the peasantry. The key input was obviously land, but here the government was constrained by the 'willing buyer, willing seller' provisions of the Lancaster House independence agreement which limited the land available for resettlement until 1990, to what the white farmers were prepared to put on the market (Munslow, 1985). Little direct attention was given to the disparities in energy provision and overall resource efficiency between settler and peasant farming sectors and no concerted effort was made to alter historically derived production relations.

The agrarian debate in Zimbabwe has thus far rested on the issue of land availability for resettlement and the most appropriate production systems for the utilisation of the land. Whilst this must remain the central issue, we believe attention has also to be focused on the overall patterns of energy use, their disparities, and perhaps more tellingly the efficiency of resource use. First of all efforts need to be made to quantify these. This will then allow a discussion of policy issues concerning what has to be done to provide greater access to agricultural energy inputs and also what choices can best be made about the form those inputs should take if the government and aid agencies' commitment to sustainable development is a genuine one.

We begin by examining the existing energy flows to the three main agricultural production systems. These are the Large Scale Commercial Farms, Communal Areas and Model A resettlement schemes, which together account for 97 per cent of the total cropped area (Weiner et al, 1985). The Model A schemes were based on communal grazing with individual plots and intensive village settlement, and accounted for the vast majority of resettlement schemes for moving peasant farmers onto former white settler land. Model B schemes were based on co-operative farming and living, and Model C on a core estate generally incorporated with a Model A resettlement pattern.

Before policy decisions can be taken it is important to establish existing patterns of energy use in the three dominant production systems. Using energetic analysis it is possible to draw some conclusions based on data collected on the most important food crop, maize, which is grown extensively across the three systems. Table 3 sets out existing

'ABLE 3: Energy Inputs For Maize Production in Different Agricultural Production Systems

\GRICULTURAL 'RODUCTION ;YSTEM	Natural Region	ENERGY INPUTS USES (GJ/HA) Human	Bullock	Manure	Tractor	Fertilizer	Pesticides	Hybrid Seed	Irrigation	Drying	TOTAL INPUTS
.ARGE-SCALE :OMMERCIAL FARMS	IIA/ IIB	1.09	-	-	4.80	13.84	1.07	0.67	0.42	5.60	27.49
:OMMUNAL AREAS	IIA/IIB III	0.55	1.72	1.08	0.03	5.38	0.12	0.64	-	-	9.52
1ODEL A RESETTLEMENT ;CHEMES	IIB/III IV	0.70	1.15	0.31	0.17	3.22	0.17	0.49	-	-	6.21

)ATA SOURCES: Weiner (1986) and Weiner, Moyo and Chidiya (1988) flows of energy inputs for maize production in the three major production systems. As the table reveals, the Large Scale Commercial Farms employ three to four times the energy input per hectare of the two peasant sectors. This clearly illustrates the (historically derived) disparities, with settler farmers taking the lion's share of inputs. Furthermore, the data on the Large Scale Farming Sector comes from Commercial Farmers Union figures of the early 1980s and late 1970s, hence does not reflect the significant labour substitution of more recent years. In particular, in the decade to the mid-1980s the LSCF sector rapidly substituted machinery for labour using combine harvesters. The human energy component now is likely to be lower and tractor energy use higher, which will increase yet further the total figure of energy inputs for this sector and in all probability erode resource efficiency.

The table also reveals that the Communal Areas are more highly capitalised than the resettlement schemes. Data from the two peasant sectors is taken from a 1984 survey. To date, this is the only national study of agricultural energy utilization which disaggregated Zimbabwe's agrarian structure. There is no analysis of trends possible from the data which is a limitation, but the snapshot picture is revealing nonetheless.

If we now turn to examine the energetic efficiency for maize production across the three production systems, see Table 4, we find that the two peasant sectors are twice as efficient in terms of their energy input/output ratios. In other words, the output differential is nowhere near as large as their input differential. Furthermore the average maize yield in highveld Communal areas is not far removed from that of the LSCF sector, in spite of having only a third of the energy inputs. Hence government policy of encouraging peasant producers to grow more is an efficient choice in terms of energy use. Lower yields in the resettlement schemes then in Communal Areas, is probably a reflection of their lower capitalization as revealed in Table 3 and poorer agro-ecological potential. If we compare the figures in Table 4 with those in Table 1, we find that the input/output ratio for the large scale commercial farms is similar to that of the industrial farming of maize in the United States or United Kingdom. Similarly, the energetic efficiency of the Zimbabwean peasant farming sector is comparable to that found in maize production in the Philippines using animal traction with inorganic fertilizer. Making these comparisons serves as a useful check on the reliability of the data.

Agricultural productivity in the peasant sector however, is extremely variable. The peasantry is not homogenous. Key determinants of energy flows into agriculture in the Communal Areas include: agro-ecological conditions which determine land potential, ownership and control of cattle and machinery, and access to wage labour remittances. In this migrant labour economy, households with access to wage income, particularly from formal employment, are an important segment of the emerging rural elite (Bonnevie, 1987;

TABLE 4:

ENERGETIC EFFICIENCY FOR MAIZE PRODUCTION BY AGRICULTURAL PRODUCTION SYSTEM

Agricultural Production System	Total Inputs (GJ/HA)	Average Maize Yield (Kg./HA)	Total Output (GJ/HA)	OUTPUT / INPUT
LARGE SCALE COMMERCIAL FARMS (LSCF) 1	27.49	4,929	73.24	2.66
COMMUNAL AREA	9.52	3,750	55.70	5.85
Model A Resettlement 2	6.21	2,250	33.40	5.37

DATA SOURCES: Weiner (1986) and Weiner, Moyo and Chidiya (1988)

Notes 1 The LSCF maize yield is an average for 1975-1982.

2 The resettlement schemes are generally on lower potential land which partially explains lower energy use and yields.

Coudere and Marijsse, 1986; Weiner and Harris, 1990). With the continued deterioration of local biomass resources, households with cash available are in a better position to purchase fossil fuel energy. This relationships, however, is interrelated with agro-ecological potential, which available evidence suggests is a primary determinant of agricultural energy utilization and diffusion. Our survey also examined the use of selected energy inputs for households with and without access to wage income in the various agro-ecological zones. The data is somewhat limited because quantities of agricultural energy used were not calculated. Nevertheless, given the paucity of data on the subject, the results are instructive.

The results are laid out in Table 5. Looking at the first column of the table, the highest percentage of manure use is found in Natural Regions III and IV where the cattle economy is most healthy. In Natural Regions IIA and IIB there is a clear move towards the use of chemical fertilizer. The low use of manure in Natural Regions V and some of IV reflects in part serious post-drought cattle loss at the time the survey results were collected and a generally deteriorating resource base for grazing. Those with a wage income have a higher percentage of manure use because they have more cash available to purchase cattle. The general trend however is a decline in the use of manure and its substitution with chemical fertilizer, a transition from renewable to non-renewable resource use.

In the second column on fertilizer use, over 90 per cent of households in Natural Regions IIA to III use some chemical fertiliser, a big increase over the situation in the post-War period. Use declines in regions IV and V, indicating a strong environmental relationship. In the marginal cropping areas the waged generally have a higher percentage of use; having the cash available to make the purchases places them in a better position to take risks. A similar pattern appears in the use of hybrid seed (see final columns of Table 5).

Energy inputs into peasant farming systems have clearly to be geared to local circumstances to be most effective. Following detailed trials in one Communal Area, Bratton and Truscott emphasise the importance of varying recommendations about fertiliser use for maize, based upon the following circumstances "ecological (rainfall zone and soil type), economic (household resource base), organisational (level of farmer management) and social (farmer preferences)" (1985, p6).

When looking at another major energy constraint, draught power availability, the results of the Rural Household Energy Survey indicate a shortage across all Natural Regions. Those with under 4 cattle accounted for over 50% of households in Natural Regions IIA, III and IV and 30% or more in regions IIB and V. One-quarter of the entire sample had no cattle at all. There is also evidence that wage remittances are used to purchase cattle (Weiner and Harris, 1990). Draught power constraint will inhibit both

TABLE 5: WAGE INCOME ENVIRONMENT AND ACCESS TO BIOLOGICAL ENERGY

INPUTS IN THE COMMUNAL AREAS

Communal Area	Natural Region	Percent Manure Use		Percent Fertilizer Use		Percent Hybrid Seed Use	
		With Wage Income	Without Wage Income	With Wage Income	Without Wage Income	With Wage Income	Without Wage Income
Guruve	IIA	17.7	39.1	94.1	87.0	100	95.7
Mangwende	IIA/IIB	31.8	26.3	100.0	100.0	100	100
Mhondoro	IIB/III	75.0	61.1	91.5	100.0	100	100
Mtoko	III/IV	83.3	66.7	100.0	90.5	100	90.5
Sabi-North	III	89.5	63.2	83.3	70.0	100	95.0
Nyajena	IV	100.0	81.8	80.0	45.5	100	91.0
Inyati/ Ntabazinduna	IV	65.6	8.3	40.6	8.3	84.4	41.7
Matshetshe	IV	71.4	36.4	14.3	0.0	85.7	36.7
Chibi	IV/V	47.4	27.8	5.3	11.1	89.5	66.7
Mtetengwe	V	0.0	0.0	0.0	0.0	0	0
	TOTAL	55.1	38.0	62.0	53.5	86.0	69.6

SOURCE: Rural Household Energy Survey NOTE: Total sample = 417 HH survey in 1984 mechanised and biological energy inputs into peasant agriculture. Only a small number of peasant farmers have access to tractors.

Access to human energy is another critical aspect of rural energy flows and an important component of agrarian differentiation in the communal areas. There is evidence of a growing labour market in the post-independence period and that households with access to wage remittances are more likely to hire labour. For example, Bonnevie (1987, p.133) argues that migrants holding permanent jobs "tend to combine this position with extended agricultural activities, and this expansion depends crucially on the use of hired labour. Although some households still use hired labourers to whom they are affiliated, or employ persons whom they know are most desperately in need of money, the trend is towards a market determined purchase and sale of labour power." Data from the rural household energy survey is consistent with this notion. While no relationship between access to hired labour and agro-ecology was discernible, households with access to wage income were more likely to hire labour in all natural regions (19-47%) as compared with households without wage income (4-36%).

5. SUSTAINABLE DEVELOPMENT OPTIONS

Having reviewed the existing patterns of energy use in Zimbabwean agriculture it is now time to suggest what this implies for environmental management aimed at a sustainable development future. We have presented some of the data necessary to inform policy directions, showing the relevance of energetic analysis to help frame the right policy questions. Zimbabwe is of particular relevance because it is hailed as a success story in a sea of failure in African agriculture. The percentage of total maize production produced by the peasantry rose from 8.2 per cent at independence in 1979-80, to 43 per cent in 1984-85, in response to government support. There is much to learn from the experience, therefore.

The success story is not a general one, however. Large variations in yield exist both between and within Communal Areas, depending on the environmental potential, the use of energy inputs such as draught power and fertilizer and on other factors including participation in farmers' organisations (Bratton, 1986). The massive expansion in peasant marketed production has occurred mostly in areas of high agricultural potential and these areas correlate also with a high level of energy inputs. Hence in Natural Regions II and III the percentage of households using inorganic fertiliser and hybrid seed ranged between 88 and 99 per cent. In Natural Region IV those households using inorganic fertiliser fell to 38 per cent and hybrid seeds to 75 per cent. In Natural Region V, households using inorganic fertiliser were negligible and those using hybrid seed were only 26 per cent.

There is also a widespread draught power crisis, linked to the uneven distribution of cattle and poor land resources.

The peasant success story in sum, is limited to those peasant farmers on the highveld, high potential land, benefiting from technical packages specifically developed for highveld use. Differential access to land, labour, off-farm income and credit is creating an uneven diffusion of increased energy inputs into the farming sector.

The process of agrarian differentiation is relevant to the debate of sustainability. Poor households in all natural regions still suffer from a severe shortage of local biomass resources and are unable to access new forms of energy for farming. Zimbabwe now has permanent food-for-work programmes in the communal areas to prevent starvation. Households with capital from farming and/or formal employment are experiencing an energy transition and this is reflected in yield increases. Emergent farmers also hire local labour to help with farming and domestic tasks. The growing labour market is mostly for low paid casual work performed by woman coming from households with inadequate land and livestock (Adams, 1988). Labour exporting households do not have the time or resources to practice sustainable farming. The wealthiest households are also part of the problem, however, because they control the bulk of livestock and arable land in the community.

Zimbabwe's historically derived production relations and land use patterns point to a fossil fuel transition for some peasant households and continued crisis for others. The use of local renewable resources is declining throughout the communal areas. In the long-term, both ends of the social ladder may prove to be unsustainable. This is the reality behind Zimbabwe's production success story. Ultimately, sustainable development options must be informed by a more thorough analysis of the relationship between agricultural energy flows and rural production relations than has been presented here. Future research that is geared to policy and project formulation must examine more carefully the social dynamics of energy use in agriculture. As Redclift has commented 'there are several combinations of mechanisation and chemical/biological technologies that are available and capable of being used in different societies. There is no one path to agricultural modernisation' (1987, p23). Redclift goes on to argue that it is essential to adopt energy conservation policies to control the consumption of non-renewable resources. He draws the conclusion that 'For the less developed countries one of the most potent arguments against using more oil-based energy is that, apart from its financial cost and its ecological effects, such energy feeds technological practices that make agriculture less-rather than more-energy efficient.' (1987, p29)

Our research findings demonstrate that peasant maize production is more energy efficient than large scale commercial farming in high potential areas. An argument used in the past to justify not redistributing land from the white settler sector to the peasant sector was the yield differential. Evidence accumulated since independence, when more state support was given to the peasant sector, ending the bias towards settler farming, has shown that yields have been improved and can be competitive given access to productive resources (Weiner, 1988 p68). Our earlier work on land use potential debunked the myth that the LSCF sector was using to best effect the available arable land. We demonstrated that only between one third and a half of the country's scarce arable land was actively being utilised for arable production in this sector (Weiner et al 1985). The current article demonstrates that in energy efficiency terms, a vitally important indictor of sustainable development practices, small farmers score highly. The argument about land redistribution is coming back on to the political agenda in Zimbabwe in the 1990s with the ending of the Lancaster House provisions. This article has furnished further evidence to consider the merits of some land redistribution to realise peasant farming productive potential.

The search for sustainable development options fundamentally concerns a struggle over the distribution of and access to resources. Within existing Communal Areas of course there is an urgent need for palliative measures to arrest degradation and rehabilitate land, but this is an additional measure to relieving population pressure in these areas. Finding the route to sustainable agricultural development means rectifying a situation in which natural resources are over-utilised in one production system and underutilised in another. Since the key resource, land, cannot be moved to the people, the people - or rather some of them - must move to the land. Significant land reform is unavoidable. Accordingly the government has drawn up a new draft policy for land which will permit a further six million hectares of land to be apportioned to communal and resettlement farmers in addition to displaced labourers on top of the 2.7 million hectares of commercial farmland already purchased (Financial Gazette, 25 Jan 1990).

It is not sufficient however for resettlement to occur without the necessary provisions being made for the resettled people to farm in a sustainable way. This was clearly acknowledged by the Minister of Lands, Agriculture and Rural Resettlement in a recent address (Chronicle, 19 Jan 1990). He stressed the need to provide the necessary infrastructure prior to resettlement and spoke of some resettlement areas in the past being reduced to semi-arid land as a result of farmers cutting and selling trees. Attention will have to be given, therefore, to the sustenance of renewable energy inputs for a sustainable agricultural production.

Of great concern will remain the current trajectory of energy transition in the communal areas. Peasant farmers in some areas are benefitting from technical packages developed for large-scale commercial farmers. The transition to fossil fuel inputs is substituting for depleted renewable resources. In the highveld region, there is little effort to incorporate local biomass resources into the production system. In natural regions III and IV especially, inappropriate use of resources had heightened drought vulnerability. Sensing this, some farmers are rejecting the advice of experts and attempting to farm in a more sustainable way. Undocumented research points to reduced use of chemical fertilizer and increased cultivation of drought resistant crops (sorghum and millet) in some households (Personal Communication, Andrew Mushita, ENDA-Zimbabwe). If peasants are spontaneously searching for sustainable solutions, that is very good news indeed. The challenge facing the Government of Zimbabwe is how best to support such initiatives.

Given the high levels of energy inputs existing in the LSCF sector, generalising these to the whole country will be impossible. Instead solutions have to be sought which are more self-reliant and where possible using renewable energy inputs as the cost of import dependent, non-renewable agricultural energy inputs may be too great to consider.

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EFFICIENT ENERGY PRICING AND CARBON DIOXIDE EMISSIONS

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ENERGY, EFFICIENT PRICING AND CARBON DIOXIDE EMISSIONS

The emission of carbon dioxide from energy utilization is a major factor contributing to the greenhouse effect. This alone accounts for 40-50% of total contributions to global warming, see Table 1 (Barbier, 1989). One option for reducing carbon emissions is to change patterns of energy consumption. The optimal way to do this would be to equate the price of each energy source (P_e) to its marginal opportunity cost (MOC) of energy production - that is, the value of the resources required to produce the last unit of energy output, including both internal and external production costs (P_e = MOC) (Pearce and Markandya, 1987). The price of fossil fuel would therefore reflect the costs of any environmental damage incurred. A carbon tax may be a suitable method for ensuring that the environmental costs of carbon emissions from fossil fuel combustion are accounted for in energy use (Pearce, Markandya and Barbier, 1989).

However, current energy prices often do not even reflect the private opportunity cost (POC) of energy production, that is, the value of the resources required to produce the last unit of energy output, in terms of internal production costs only. In the absence of distortions, the POC pricing rule could be achieved for non-traded energy, such as electricity, by equating price to its long-run marginal cost (LRMC), and for traded energy, such as petroleum, by equating price with the border equivalent (P_w), that is, the world price of energy.

Unlike the marginal opportunity cost (MOC) described earlier, the POC does not take into account the full value of social costs of production. If markets are efficient then current prices would reflect the marginal extraction costs and scarcity value - or the marginal user cost - of non-renewable energy resources, such as coal. However, these prices would not reflect marginal external costs, for example the damage associated with sulphur dioxide emissions from burning coal. In the case of a renewable energy resource, such as fuelwood on common property or on open access land, the POC would include the

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Table 1
Greenhouse Gases and Their Man-Made Sources

	CO_2	Methane	Nitrous Oxide	CFCs	Ozone
% contribution to GH effect 1950-1985	56	14	7	23	a
Estimate % contribution to GH effect 1980-2030*	50	16	6	20	8
concentration of GH gases - pre-industrial	275ppmv	700ppbv	280ppbv	0	15ppbv
concentration of GH gases - 1988	350ppmv	1700ppbv	310ppbv	0.7	335ppbv
annual growth of concentrations 1980's	0.5%	0.5%	0.25%	5-5.5%	1%
sources of GH gases	fossil fuel burning	rice paddy cultivation	fertilzers	solvents aerosals foam package	product of sun & pollutants
	deforestation land use change	rearing ruminants (eg cows)	fossil fuel & biomass burning		
		biomass burning	land conversion for agriculture		
		fossil fuel extraction & burning			

Source: M. Holdgate et al., Climate Change: Meeting the Challenge, Commonwealth Secretariat, London, 1989, Tables 2.1 and 2.3.

Notes: a/ contributions of ozone not estimated, perhaps around 8% of total.
ppmv = parts per million, ppbv = part per billion.

direct costs of harvesting the resource but will exclude the scarcity and environmental costs of harvesting the fuelwood, including the opportunity cost of the land.

Generally, due to government interventions through taxes and subsidies, the price of non-traded energy differs from its LRMC. In many developed economies P_e is greater than its LRMC, but in many other countries, especially developing countries, P_e is substantially below its LRMC or border equivalent. Kosmo compared retail prices to border prices for petroleum products for selected countries (see Table 2) (Kosmo, 1989). The data reflect the wide disparity between the actual price and P_e. The ratio is greater than one when there is net taxation of petroleum products, and below one when there is a net subsidy of petroleum products.

The electricity sector frequently sets prices below LRMC, and, in many cases, significantly so (see Table 3). Removing existing distortions and increasing the price of electricity to fully reflect LRMC leads to a reduction in electricity demand of 927,945 gigawatt hours (GWh) and savings in economic subsidies of US$163,155 million for the ten selected developing countries plus the USA shown in Table 4. The vast majority of these savings are made in India, China and USA, (over 95%), who are the major consumers. The decrease in electricity demand from LRMC pricing can also be translated into reductions in demand for primary fuels required for electricity generation. Lower levels of combustion of coal, oil and gas result in lower emissions of CO_2 of around 144 million tonnes of carbon (mtc) for the selected countries (see Tables 5 and 6). Again, the bulk of these savings are from China, India and USA.

However, it must be stressed that this is an approximate estimation. There are many technical difficulties in making such calculations. First, the mix of fuels required for electricity generation differs at different levels of energy demand. The input balance depends upon the 'merit' order, so at lower levels of demand there may be a different structure of fuel inputs. Second, there is a wide variety in the quality of individual fuels - some deposits may have a higher calorific value (energy content) than others, and thus lower inputs are required for the same electricity output. Third, the quality of the fuel may also differ in terms of its carbon content - for example, coal may be 'dirty' or 'clean' with a carbon content ranging from 50% - 80%. This will affect the quantity of CO_2 emitted from a given unit of coal. Fourth, the efficiency of electricity generation is likely to differ considerably across the countries, and across the various fuels. Although a standard efficiency measure of 38.5% has been used here, real figures may actually be as low as 20% or potentially as high as 60%.

The sensitivity of the analysis to the assumptions of responsiveness of demand to changes in price was tested. Assuming an elasticity of -0.8 leads to a reduction in gigawatt hours (GWh) of 750,000 and savings of 115.6 million tonnes of carbon (mtc), whilst an

Table 2

Ratio of Retail to Border Prices for Selected Petroleum Products (1981 and 1985)

Country	Date[b]	Regular Unleaded Petrol	Household Kerosene	Diesel Oil	Heavy Fuel Oil	Total[a]
Argentina	1981	1.23	0.90	0.60	0.43	0.78
	1985	1.91	0.97	0.81	0.74	1.18
Brazil	1981	2.77	1.21	1.62	0.76	1.70
	1985	1.60	1.09	1.24	0.78	1.25
Canada	1981	1.10	0.80	1.27	-	-
	1985	1.74	1.24	1.73	1.15	1.59
Chile	1981	1.83	1.22	1.70	1.33	1.62
	1985	1.63	1.51	1.51	1.26	1.49
Colombia	1981	0.78	0.81	0.86	-	-
	1985	0.71	0.63	0.79	0.58	0.71
Ecuador	1981	0.54	0.22	0.32	0.43	0.43
	1985	0.90	0.27	0.81	0.41	0.70
Egypt	1981	0.55	0.15	0.13	0.05	0.15
	1985	0.74	0.13	0.72	-	-
Ethiopia	1981	1.96	1.02	0.89	0.91	1.13
	1983	2.26	1.23	1.54	1.29	1.70
France	1981	2.72	-	2.17	1.05	2.03
	1985	2.85	-	2.55	1.23	-
Ghana	1981	3.47	1.58	2.73	1.37	2.70
	1983	3.80	1.69	2.99	1.57	3.05
India	1981	2.21	0.63	1.07	1.12	1.07
	1985	1.94	0.64	1.19	0.84	0.90
Indonesia	1981	0.84	0.20	0.30	0.50	0.50
	1985	1.67	0.72	1.03	1.25	1.12
Japan	1981	2.26	1.19	1.54	1.05	1.43
	1985	2.63	1.49	2.06	-	-
Kenya	1981	2.28	1.01	1.58	0.89	1.49
	1983	2.13	1.07	1.70	0.89	1.57
Korea	1981	3.48	1.27	1.28	1.34	1.40
	1985	3.43	1.56	1.59	1.27	1.61
Mexico	1981	0.43	0.24	0.18	0.11	0.26
	1985	0.75	0.29	0.49	0.16	0.48
Morocco	1981	2.51	1.39	1.47	0.90	1.33
	1983	3.05	1.53	1.60	1.19	1.59
Pakistan	1981	1.74	0.91	1.07	0.63	1.09
	1983	1.69	0.84	1.10	0.54	1.05
Peru	1981	0.88	0.16	0.62	0.62	0.61
	1985	0.94	0.79	0.74	0.72	0.79
Philipp-	1981	2.16	1.29	1.34	-	-
ines	1985	2.11	1.77	1.93	-	-
Sri Lanka	1981	-	0.66	1.03	0.88	-
	1983	-	0.73	1.17	0.95	-
Thailand	1981	1.86	0.95	1.21	0.96	1.23
	1985	1.80	1.10	1.30	0.91	1.29
Tunisia	1981	1.95	0.37	0.79	-	-
	1983	2.00	0.60	0.93	0.64	0.90
Uganda	1981	2.97	1.63	1.83	1.16	2.06
	1983	3.83	2.36	2.71	-	-
UK	1981	2.52	1.33	2.72	1.40	2.20
	1985	2.56	-	2.77	1.31	-
USA	1981	1.18	1.09	1.09	0.91	1.13
	1985	1.39	-	1.73	0.95	-
Venezuela	1981	0.13	0.09	0.10	0.12	0.12
	1985	0.77	0.41	0.30	0.25	0.55
West	1981	2.52	-	2.28	-	-
Germany	1985	1.12	-	2.28	0.98	-

Source: M. Kosmo, 'Commercial Energy Subsidies in Developing Countries: Opportunity for Reform', Energy Policy, June, 1989, pp. 244-253, Table 1, pp. 247.

Notes: a/ Based on weighted average of the four petroleum products.
b/ Figures are averages for the last quater of 1985 or 1983; annual averages where 1985 data were unavailable.

Table 3

Comparisons of Average Revenues (AR) and Long-Run Marginal Costs (LRMC) of Electricity in Selected Countries

Country	Year	AR (USc/kWh)	LRMC (USc/kWh)	Price/MC	LRMC-AR (USc)
Bangladesh	1984	5.94	9.09	0.65	3.15
Bolivia	1982	3.70	5.85	0.63	2.15
China	1984	3.29	5.65	0.58	2.36
Ethiopia	1983	6.01	18.78	0.32	12.77
India	1981	3.70	7.00	0.52	3.30
Morocco	1983	8.00	12.70	0.63	4.70
Paraguay	1982	4.00	5.00	0.80	1.00
Peru	1983	5.36	8.40	0.45	3.04
Senegal	1981	11.70	12.72	0.82	1.05
Tanzania	1983	7.79	8.20	0.95	0.42
USA	1984	6.52	8.93	0.73	2.41

Source: M. Kosmo, 'Commercial Energy Subsidies in Developing Countries: Opportunity for Reform', Energy Policy, June, 1989, pp. 244-253, Table 4, pp. 249.

Table 4

Decreases in Electricity Demand and Economic Subsidies if Prices are Increased to Reflect Long-Run Marginal Cost

Country	% decrease demand[a]	electricity consumption (GWh)[b]	GWh savings[c]	reduction in economic subsidies (million US$)[d]
Bangladesh	35	4414	1545	139
Bolivia	37	1000	370	22
China	42	413144	173520	97550
Ethiopia	68	791	538	101
India	48	165530	79454	5463
Morocco	37	6629	2453	312
Paraguay	20	1698	340	17
Peru	55	12025	6614	366
Senegal	18	640	115	7
Tanzania	5	756	38	3
USA	27	2455400	662958	59175

Source: Based on M. Kosmo, 'Commercial Energy Subsidies in Developing Countries: Opportunity for Reform', Energy Policy, June, 1989, pp. 244-253, Table 6, pp. 251. Updated electricity consumption figures from OECD/IEA, World Energy Statistics and Balances: 1971-87, IEA, HMSO, London, 1989.

Notes: a/ The % decrease in demand is derived from Table 3, assuming a long run price elasticty of demand of -1.
b/ From Annex 1.
c/ The savings in electricity consumption is estimated by: (percentage decrease in demand x electricity consumption)/100.
d/ The reduction in economic subsidies represent reductions if prices are increased to reflect marginal costs. They are equal to: (LRMC - Average Revenues) x Total Electricity Consumption. LRMC and AR are based on data from Table 3.

Table 5
Percentage and Actual Savings in Electricty
Generated from Primary Energy Inputs

COAL

	TOTAL SAVINGS (m)KWh	% saved from total %	elect. savings from coal (m)KWh	coal input saved (m)KWh	primary energy savings (t)joules	carbon emission savings as carbon (m)tonnes
Bangladesh	1545	0	0	0	0	0
Bolivia	370	0	0	0	0	0
China	173520	67.8	117646.6	305575.6	1100072.2	26.6
Ethiopia	538	0	0	0	0	0
India	79454	66.2	52598.5	136619.5	491830.2	11.9
Morocco	2453	23	564.2	1465.5	5275.8	0.1
Paraguay	340	0	0	0	0	0
Peru	6614	0	0	0	0	0
Senegal	115	0	0	0	0	0
Tanzania	36	0	0	0	0	0
USA	662958	56.9	377223.1	979800.2	3527280.9	85.4
TOTAL	927943		548032.4	1423460.	5124459.1	124

OIL

	TOTAL SAVINGS (m)KWh	% saved from total %	elect. savings from oil (m)KWh	oil input saved (m)KWh	primary energy savings (t)joules	carbon emission savings as carbon (m)tonnes
Bangladesh	1545	35	540.8	1404.7	5056.9	0.1
Bolivia	370	18.6	68.8	178.7	643.3	0
China	173520	12	20822.4	54084.2	194703.1	3.9
Ethiopia	538	19.8	106.5	276.6	995.8	0
India	79454	7.8	6197.4	16097.1	57949.6	1.1
Morocco	2453	66.7	1636.2	4249.9	15299.6	0.3
Paraguay	340	0	0	0	0	0
Peru	6614	19.2	1269.9	3298.4	11874.2	0.2
Senegal	115	100	115	298.7	1075.3	0
Tanzania	36	30.2	10.9	28.3	101.9	0
USA	662958	4.6	30496.1	79210.6	285158	5.6
TOTAL	927943		61263.9	159127.2	572857.7	11.2

Table 5 continued
Percentage and Actual Savings in Electricty Generated from Primary Energy Inputs

	TOTAL SAVINGS (m)KWh	% saved from total %	elect. savings from gas (m)KWh	gas input saved (m)KWh	primary energy savings (t)joules	carbon emission savings as carbon (m)tonnes
Bangladesh	1545	56	865.2	2247.3	8090.3	0.1
Bolivia	370	12.4	45.9	119.2	429.1	0
China	173520	0	0	0	0	0
Ethiopia	538	0	0	0	0	0
India	79454	1.1	874	2270.1	8172.4	0.1
Morocco	2453	0	0	0	0	0
Paraguay	340	0	0	0	0	0
Peru	6614	2	132.3	343.6	1237	0
Senegal	115	0	0	0	0	0
Tanzania	36	0	0	0	0	0
USA	662958	10.6	70273.5	182528.7	657103.3	9.1
TOTAL	927943		72190.9	187508.9	675032.1	9.3

Table 6
Total Carbon Emission Savings Under Privately Efficient Electricty Pricing

	COAL carbon emission savings as carbon (m)tonnes	OIL carbon emission savings as carbon (m)tonnes	GAS carbon emission savings as carbon (m)tonnes	TOTAL carbon emission savings as carbon (m)tonnes
Bangladesh	0	0.1	0.1	0.2
Bolivia	0	0	0	0
China	26.6	3.9	0	30.5
Ethiopia	0	0	0	0
India	11.9	1.1	0.1	13.1
Morocco	0.1	0.3	0	0.4
Paraguay	0	0	0	0
Peru	0	0.2	0	0.2
Senegal	0	0	0	0
Tanzania	0	0	0	0
USA	85.4	5.6	9.1	100.1
TOTAL	124	11.2	9.3	144.5

elasticity of -1.2 leads to savings of 1,113,000 GWh and 173.4 mtc. This does not differ significantly from the assumed elasticity used in this paper of -1, which leads to reductions of 927,000 GWh and 144.5 mtc. Further discussion of various economic constraints of analysis that were raised during the Surrey Workshop on 'Energy Efficiency in the Third World' are given below.

The estimate of total annual carbon emissions saved by POC electricity pricing for the selected countries of over 144.5 mtc is just less than the UK's total annual emissions of 166 mtc, and just under 3% of the global total of 5,600 mtc emitted each year from the burning of fossil fuels (Leach and Nowak, 1989). These savings are significant, especially for some of the major consumers, such as the USA, China and India. In India the annual saving in carbon emissions under privately efficient electricity pricing amounts to some 13.1 million tonnes, that is 12.5% of its total annual carbon emissions from fossil fuel combustion (see Table 7). 30.5 mtc are saved in China, that is 7.4% of its current total emissions of 413 million tonnes per annum and substantial reductions are estimated for the USA, at 8.8% of its total current emissions of 1,135 million tonnes each year, with annual carbon savings in the USA reaching 100 million tonnes.

The analysis only looks at carbon savings from efficient pricing in the electricity industry, and does not look at the savings from efficient pricing in all energy sectors. What is more, the estimates are only calculated for a small range of mainly developing countries, the majority of which are not major energy consumers, plus the United States. Other major energy consumers, such as Eastern Europe are not included but may be significant. If the analysis was extended to encompass these additional factors then it is likely that the savings in carbon emissions are likely to increase substantially.

Moreover, as mentioned earlier, privately efficient energy pricing only removes existing market distortions and reflects internal production costs and benefits. POC pricing does not reflect external costs or benefits of production, and would not reflect the benefit of decreases in carbon dioxide emissions, say, in terms of postponing any of the adverse climatic impacts of the greenhouse effect. Therefore, although POC pricing improves the level of production in terms of private efficient levels of production, it does not ensure the optimal social level of energy production that is necessary for averting the greenhouse effect. Further policy instruments and considerations need to be adhered to in order to attain this optimal level globally (Barbier and Pearce, 1990).

TABLE 7

Carbon Dioxide Emissions by Fuel Type
For USA, China and India, 1982
(10^6 ta^{-1} as carbon)

Country	Solid Fuels[a]	Liquid Fuels[a]	Natural Gas[a]	Total Emissions[a]	Total Savings[b]	% Savings[c]
USA	377.0	501.9	245.4	1135.3	100.1	8.8
China	340.6	66.3	6.2	413.1	30.5	7.4
India	78.4	25.5	1.2	105.1	13.1	12.5

Source: a/ R.M. Rotty, 'Estimates of Seasonal Variation in Fossil Fuel CO_2 Emissions', Tellus, 39B, pp. 184-202, 1987.
b/ From Table 6.
c/ Calculated by: (Total Savings/Total Emissions) x 100

DISCUSSION POINTS

The discussion following the presentation of the above paper at the Surrey Workshop on 'Energy Efficiency in the Third World', threw light on many of the issues and assumptions contained in this paper. I have briefly recorded here some of the major points of discussion.

1. The basic assumptions underlying the above analysis (i.e., that changing the price of energy would lead to shifts in energy demand in line with an elasticity of -1) were considered too simplistic and out of touch with reality. This was thought to be particularly the case when the change in price is substantial, for example over 50% for Ethiopia and Peru. What is more, the demand for energy in the majority of developing countries was described as 'supply driven' with the existence of considerable latent demand. It was therefore considered unlikely that energy demand would be highly responsive to price increases in such situations.

   It must be noted that over 95% of the estimated benefits of private efficient pricing are incurred by three semi-industrialized and industrialized major consumers - China, India and USA. In these countries it is more realistic that price increases will lead to declines in demand for energy, and consequential reductions in CO_2 emissions.

2. Changing patterns of energy consumption is not solely determined by price, for providing alternatives, but is dependent on a whole range of other factors, such as information, infrastructure for providing alternatives and so on. These additional factors are rarely established in developing countries and may undermine price incentive structures. However, this should not necessarily deter policies to price energy to reflect their full costs. The removal of excessive subsidies may in fact release funds that can be diverted towards these additional factors and thus enable a more efficient use of energy.

3. Reducing energy subsidies may have undesirable social consequences that undermine what is often one of the initial objectives of the energy pricing policy - that is, to provide minimum standards of living to the poorest sectors of the economy. However, it often arises that this sector of the population benefits relatively little from the subsidies, and that an

alternative more direct, targeted approach may be more effective in improving the standards of living of such people.

4. It was suggested that the current focus on CO_2 is merely a fad, and that there exist many other, already established, reasons for efficient pricing. This may be so, but the impacts of distortionary pricing policies on the levels of CO_2 emissions are real and need to be addressed, and the benefits derived from price changes in terms of reduced CO_2 emissions may add further support to the existing arguments and should not be ignored. Given their relevance to international concerns of global warming at present they may add considerable weight to the existing arguments for POC pricing.

5. It was stressed that the objective of the paper was to attempt to put some figures, albeit very generalised figures, on the impact of changing to energy efficient pricing on CO_2 emissions. This may be used as an additional reason for recommending efficient pricing. Further, more detailed and rigorous analysis is required if further progress is to be made in this area.

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ANNEX 1

Electricity Generation and Consumption

Bangladesh (1987)

	GWh	%
Coal	-	0.0
Oil	2065	35.0
Gas	3300	56.0
Hydro/other	530	9.0
Total Generation	5895	100.0
Total Consumption	4414	

Bolivia (1987)

	GWh	%
Coal	-	0.0
Oil	316	18.6
Gas	210	12.4
Hydro/other	1174	69.0
Total Gen	1700	100.0
Total Con	1000	

China (1987)

	GWh	%
Coal	337071	67.8
Oil	60023	12.0
Gas	-	0.0
Hydro/other	100227	20.2
Total Gen	497321	100.0
Total Con	413144	

Ethiopia (1987)

	GWh	%
Coal	-	0.0
Oil	160	19.8
Gas	-	0.0
Hydro/other	650	80.2
Total Gen	810	100.0
Total Con	791	

India (1987)

	GWh	%
Coal	143900	66.2
Oil	16948	7.8
Gas	2400	1.1
Hydro/other	48933	22.5
Nuclear	5319	2.4
Total Gen	217500	100.0
Total Con	165530	

Morocco (1987)

	GWh	%
Coal	1840	23.0
Oil	5336	66.7
Gas	-	0.0
Hydro/other	825	10.3
Total Gen	8001	100.0
Total Con	6629	

Peru (1987)

	GWh	%
Coal	-	0.0
Oil	2686	19.2
Gas	280	2.0
Hydro/other	11044	78.8
Total Gen	14010	100.0
Total Con	12025	

Senegal (1987)

	GWh	%
Coal	-	0.0
Oil	752	100.0
Gas	-	0.0
Hydro/other	-	0.0
Total Gen	752	100.0
Total Con	640	

<u>Tanzania</u> (1987)

	GWh	%
Coal	-	0.0
Oil	264	30.2
Gas	-	0.0
Hydro/other	610	69.8
Total Gen	874	100.0
Total Con	756	

<u>Paraguay</u> (1987)

	GWh	%
Coal	-	0.0
Oil	5	0.0
Gas	-	0.0
Hydro/other	1693	100.0
Total Gen	1698	100.0
Total Con	1698	

<u>USA</u> (1987)

	GWh	%
Coal	1464000	56.9
Oil	118000	4.6
Gas	273000	10.6
Hydro/other	262000	10.2
Nuclear	455000	17.7
Total Gen	2572100	100.0
Total Con	2455400	

Source: OECD and International Energy Agency (IEA), <u>World Energy Statistics and Balances: 1971 -87</u>, IEA, HMSO, London, 1989. * USA data from <u>Statistical Abstract of the United States, 1989</u>. US Department of Commerce, Bureau of the Census, Washington DC, (1989).

ANNEX 2

Carbon Emissions from Primary Energy Combustion
(Standard Figures)

Coal: 24.2 tonnes of carbon (88.7 tonnes of CO_2) per terajoule of coal burned.

Gas: 13.8 tonnes of carbon (50.6 tonnes of CO_2) per terajoule of gas burned.

Petroleum Products:

i. Petrol (cars) - 18.2 tonnes of carbon (66.7 tonnes of CO_2) per terajoule of petrol burned.

ii. Diesel (road) - 18.8 tonnes of carbon (68.9 tonnes of CO_2) per terajoule of diesel burned.

iii. Oil (ships) - 19.1 tonnes of carbon (70.0 tonnes of CO_2) per terajoule of oil burned.

iv. Oil (industry) - 19.7 tonnes of carbon (72.2 tonnes of CO_2) per terajoule of oil burned.

v. Oil (power stations) - 19.8 tonnes of carbon (72.6 tonnes of CO_2) per terajoule of oil burned.

1 tonne of carbon translates into 3.667 tonnes of CO_2,
i.e., 1 tonne of carbon x 44/12 = 3.667 tonnes of CO_2.

Source: pers. comm. John Marrow, Chief Scientist's Group, Energy Technology Support Unit (ETSU), December 1989.