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TRANSITIONS BETWEEN TRADITIONAL AND COMMERCIAL ENERGY IN THE THIRD WORLD

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CONTENTS

TRANSITIONS BETWEEN TRADITIONAL AND COMMERCIAL ENERGY - A SUMMARY

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The fifth workshop meeting of the Third World Energy Policy Study Group was held on October 6, 1986 at the University of Surrey (with financial assistance from the Economic and Social Research Council). The theme of the workshop was, "Transitions between traditional and commercial energy", an issue whose importance had been frequently commented on in discussions at the earlier workshops.

Five papers were presented and vigorously discussed. They were, in chronological order: "Traditional and commercial energy: some thoughts on terminology, boundaries and accounting treatments", by Niall Roberts (Energy Consultant); "Energy transitions in South Asia", by Gerald Leach (International Institute for Environment and Development); "Alternatives to fuelwood in African Towns", by Walter Elkan (Department of Economics, Brunel University); "Fuel Transitions within households", by John Soussan (Department of Geography, University of Reading); and "Investigating Medium and Long-Term Energy Transitions in Asia", by Peter Pearson (Surrey Energy Economics Centre, University of Surrey).

The investigation and understanding of energy transitions requires good information. Inadequate amounts of appropriately classified data on energy and energy-related variables act as a significant constraint on effective energy forecasting and policy formulation. The problem, however, cannot be overcome simply by calling for more data to put into energy information systems. Important decisions have to be faced about precisely what data to collect, how to organise, analyse and present them, and how many scarce resources it is worth devoting to this task.

The Workshop began with a paper that addresses these issues. As **Niall Roberts** clearly demonstrates, the methodological problems concerning terminology, boundaries and accounting treatments for energy data are complex. Moreover, as he points out, some generally-accepted solutions to a number of these problems in relation to fossil fuels and electricity may need to be re-examined when considering how, and to what extent, to incorporate information on fuelwood, charcoal, agricultural residues, muscle-power and 'low-tech.' solar, wind and water power into existing energy data systems. These issues require appropriate attention if energy data systems are to be able to deliver useful information at reasonable cost. And even when the major conceptual issues have been sorted out, the decision about how much to include should depend on an assessment of the balance between the cost of building up the data, on the one hand, and the cost of the economic and social welfare 'errors' that policy makers may make through not having the data, on the other.

Roberts discusses the problems that can result from attempting to use only dichotomous classifications of energy sources, such as: (a) 'commercial' and 'non-commercial' (eg, fossil fuels and electricity are usually classified under 'commercial', although auto-generated electricity is often not sold, while fuelwood and charcoal come under 'non-commercial', although much of it is sold); (b) ´traditional´ and ´non-traditional´ (what is traditional varies over time and space); and (c) ´conventional´ and ´non-conventional´ (again, this varies across time and space). Strictly logical categories confined to ´A´ and ´non-A´ do not, however, have to be used. An Annex to Roberts´ paper offers energy classifications which include ´commercial´, ´traditional´ and ´novel´ (with the sub-group ´biomass´ falling partly in traditional and partly in novel), while ´renewable´ and ´non-renewable´ appear on another ´dimension´ of the classification scheme.

It is important to recognise that there will be many fuzzy boundaries encountered when trying to define the scope of an energy information system. One such problem is encountered when trying to decide whether and how to include in the category ´traditional energy´, data on animate energy, in the form of animal and human muscle power. If, for example, you decide to include human muscle power, where are the boundaries to be drawn. As an illustration of the controversial nature of some of these issues, there was in the workshop itself considerable disagreement over human energy, with some participants arguing that it was both unnecessary and undesirable to measure and record human activity in this way.

Roberts does not attempt to make specific recommendations about whether an energy information system should include in ´traditional energy´ all or any of animal and human musclepower, or the many forms of low-tech solar, wind and water power sources that can be identified. He does however, make the point that for a wide range of practical policy issues, actual and expected changes in a country's energy situation may be adequately observed and assessed without complete and continuous information on levels. He also briefly reviews arguments for and against including information on traditional energy when considering commercial energy issues.

Roberts is of the view that fully 'integrated energy planning', requiring wide-ranging information on traditional energy sources and associated economic activities, could not be pursed effectively without at the same time widening the scope of a country's National Accounts and Balances. Thus the whole range of 'non-commercial' activities currently omitted from (or inadeqately treated by) a country's National Accounts would need to be looked at critically.

In the final part of his paper, Roberts examines accounting treatments, concentrating on the ways in which and the extent to which various traditional and novel energy sources might most appropriately be introduced into Energy Balances in particular.

Gerald Leach's paper is about energy transitions in the household sector and reports on a much larger study, 'Household Energy in South Asia', shortly to be published. With the aid of data from several large, nationally representative energy or household expenditure surveys for India, Pakistan and Sri Lanka, Leach has been able to investigate energy transitions in the household sector, both by a cross-section of income levels and also over time.

Leach's working assumption is that people attempt to move up the 'ladder of fuel preferences' for cooking and heating, aiming for greater convenience, cleanliness, time-saving, 'modernity' and thermal efficiency. In South Asia the usual progression is from low to high grade biofuels, kerosene, bottled gas (LPG), natural gas (in Pakistan) and electricity. Kerosene and cheap LPG stoves are not full substitutes for biofuels because they do not offer the same breadth of facilities. Only the more expensive modern gas or electric stoves with grill and oven provide the desired features, and thus enable a complete transition away from traditional fuels. Because of this imperfect substitutability and also uncertainty about fuel and power supplies, the use of multiple fuels/technologies is common.

The progressive substitution away from biofuels is a function of income, relative fuel prices, the capital cost of end-use equipment and the availability of competing fuels. Cross-section data show, according to Leach, that in rural areas the biofuel share in total household energy is in the region of 90 per cent for all income levels. Transitions seem to be particularly constrained by limited supplies of premium (or 'non-traditional') fuels. Leach argues that fuel price could not be a major constraint in India and Pakistan, where kerosene and LPG are much cheaper than firewood on a useful heat basis.

In urban areas, with better general availability of premium fuels, biofuel shares decline rapidly with income in India and Pakistan, but not in Sri Lanka where firewood is readily available and cheap relative to kerosene. There is evidence that even for the urban poor it is not the investment cost of obtaining a kerosene stove but rather fuel availability that inhibits the switch away from woodfuel. This is not so for the more expensive LPG stoves. In India and Pakistan, relative price movements seem to have reinforced urban energy transitions, while the opoosite has occurred in Sri Lanka.

Leach's analysis of two surveys in India suggests that a major transition from biofuels to premium fuels took place between 1979 and 1984. Moreover, in Pakistan an even greater urban transition seems likely to have occurred. A limited transition in Sri Lanka seems to have been reversed when the relative price of kerosene rose strikingly.

Leach concludes that in South Asia rapid transitions away from biofuels were taking place, in situations where premium fuels are available and where relative prices are favourable. To date, the transitions seem to be limited to urban areas. However, Leach believes the ineteresting question to be, when and in what circumstances rural populations will be willing and able to make their transitions.

Walter Elkan's paper addresses the key question of why, despite the gradual depletion of woodlands, woodfuel continues to be relatively cheap and therefore dominate the fuel consumption pattern in African towns. As a starting point, the paper (using World Bank data) shows the relative costs of different fuels. However, these costs were adjusted to take account of the cost of fuel using appliances, an exercise which significantly alters the actual fuel costs and tends to make wood (relatively) even cheaper.

Elkan then proceeds to argue that the problem of wood depletion arises because the price at which the woodfuel is sold in the towns fails to cover its true economic cost. Specifically it fails to cover the replacement cost (i.e. replanting). However, it is also pointed out that many replanting programmes are unable to pay their way because they cannot compete with `free` wood from the common lands. Elkan therefore advocates a planting programme based on trees which could supply building poles. Such programmes would offer better economic prospects and at least help to minimize the environmental damage created by deforestation.

The paper`s conclusion is twofold. First that eventually fuelwood`s increasing scarcity will translate itself through into effects on prices and these can be expected to rise sharply. The second conclusion is one which has emerged from many of the papers given at these workshops, namely that the fuel problem is really a problem of poverty. Given the relatively gloomy economic prospects for much of Africa this is not an encouraging conclusion.

John Soussan`s paper addresses the issue of fuel transitions within the household. It starts from the general premise that biomass fuel consumption per capita and per household is declining and being edged out by commercial fuels. However the pace of this energy transition is so slow as to appear imperceptible. The paper then considers the main factors which would be likely to precipitate an energy transition. The three main determinants derived on a priori grounds are:

1. economic development (income levels)

2. rates of urbanization

3. the relative scarcity (as reflected in relative prices)

of biomass and commercial fuels.

Some empirical evidence drawn from the Beijer Institute energy studies of Kenya and Grenada is then analysed. The importance of the determinants is confirmed but an even more interesting conclusion emerges. It is clear that in both countries the use of more than one fuel for cooking is the norm. Furthermore, households switch between the fuels as part of a conscious strategy based on a trade-off between convenience and cost. This suggests that the process of transition is far more complex than earlier may have been believed since it is apparent that households do not simply switch successively from one fuel to another.

This is an important conclusion when it comes to considering future energy patterns. It means that the complexities make forecasting even more difficult and that a transition can be reversed if the economic context (i.e. relative prices) alters.

Peter Pearson's paper reports on work in progress on an investigation of medium and long-term energy transitions in Asia. His interest lies in the processes through which, as an economy develops, commercial fuels may tend to grow and eventually dominate and largely replace traditional fuels as the principal energy source. While not all countries are likely to go through the same transition at the same rate (and some may not have such a transition at all in the not-too-distant future), a significant number of countries have experienced or ar currently experiencing one. It is argued that the significance for policy-making and forecasting, of an understanding of the processes involved in these transitions, has not sufficiently been appreciated.

Two striking examples of energy transitions are discussed, those of the USA and South Korea. The USA went from around 90 per cent dependence on woodfuel in 1850 to less than 10 per cent in 1920, with the transition embracing first coal and then petroleum. South Korea, a century later, went from nearly 60 per cent dependence on woodfuel in 1961 to less than 10 per cent by 1979 (the equivalent changeover took about 30 years in the USA). Although recognising that there are clear dangers of naive generalisation and extrapolation from other countries' experience, Pearson suggests that it is worthwhile trying to investigate the transitions in order to try to identify different types of transitions and the factors that can influence them.

These factors have both micro and macro dimensions, and Pearson concentrates on the latter. He is concerned with what influences the absolute level of consumption of traditional and commercial fuels, and especially their relative shares in total energy consumption. The relevant variables are, of course, associated with the pace and character of each country's development, and include, among many others, the rate and pattern of economic growth, the expansion of the manufacturing sector, mechanisation, the process of urbanisation and the spread of consumer durables.

The paper discusses some preliminary empirical work, involving regression analysis of pooled cross-section and time-series data on sixteen Asian countries. Various measures of energy consumption, including the share of commercial energy in total consumption, are related to a set of independent variables acting as indicators of the processes of economic development. While the initial results offer tentative confirmations of a number of the expected relationships between energy transitions and broad development indicators, the need for caution (particularly in view of the quality of some of the data) and for further work, is stressed.

The paper concludes with a discussion of ways forward, including: alternative specifications of the form of the equations; improved versions of existing variables; the incorporation of important missing explanatory variables ; and the use of techniques and approaches other than regression analysis and quantification, which might aid in the selection of appropriate sub-sets of the data and in the understanding of the processes involved in energy transitions.

TRADITIONAL AND COMMERCIAL ENERGY : SOME THOUGHTS ON TERMINOLOGY, BOUNDARIES AND ACCOUNTING TREATMENTS

W.N.T. Roberts (Energy Consultant)

I INTRODUCTION

1. Energy as a field of endeavour, whether by academics or other professionals, administrators or politicians, purists or hard-headed businessmen, is beset by more than its fair share of methodological problems. Some generally accepted solutions to some of these problems in relation to fossil fuels and electricity may need to be re-examined when considering how - indeed whether - to include information on fuelwood, charcoal, agricultural residues, muscle-power and 'low-tech' solar, wind and water power into existing energy data systems (on the assumption that in due course 'sufficient' information of 'adequate' reliability on these various energy sources can be compiled and maintained). This paper concentrates on some particular problems concerning terminology, boundaries and accounting treatments. For completeness it includes in its scope some of the 'high-tech' energy sources that are likely to be of economic importance during the next decade.

II TERMINOLOGY

2. The dichotomy of energy into Commercial (CE) and Non-commercial (NCE) energy has never been entirely satisfactory. This is not just because of the increased importance now given to Traditional energy (TE) in Third World countries and the fact that significant quantities of fuelwood and charcoal are in fact sold. The dichotomy has from the outset ignored the fact that auto-generated electricity, and heat produced jointly with electricity or recovered from some industrial and chemical processes is generally not sold. Nor is most energy that is used within the energy producing industries, or re-cycled urban waste used for district heat or for electricity generation. If it is argued that these non-marketed components of 'commercial' energy are nevertheless the result of financial (as well as technical) decisions, it could also be argued that non-traded traditional energy is the result of conscious decisions (at some stage) about the relative opportunity costs of different ways of satisfying household and other energy requirements.

However, even if one wished to keep to the simpler criterion of 'commercialisation' it would not now be practicable to re-define 'Commercial' and 'Non-commercial' so as to cover only those energy sources - whatever their origin - that are, respectively, always marketed and never marketed. The term 'Commercial' is now too widely used to mean 'Fossil fuels and electricity' to be tampered with.

3. Some writers on LDC energy issues approach the terminological problem from the 'other end' and speak of 'Traditional' and 'Non-traditional' energy (NTE), meaning by the latter Fossil fuels and electricity (and, by implication, 'high-tech' solar, wind and water power). This classification may make sense in an LDC context, but for the Developed Countries fossil fuels and electricity are 'traditional'. The dichotomy 'Conventional'/'Non-conventional' energy suffers from the same weakness of being too tightly linked to time and place: nuclear power was 'non-conventional' in Developed Countries until it became fairly widespread, and some Developed Country literature called Traditional energy 'non-ventional' - which it would be in such countries, but not in Developing Countries. Strictly logical categories of "A" and "Non-A" do not, however, have to be used, whatever meaning is given to "A".

4. The term 'Traditional Fuels' is a very good descriptor for what it covers, but what it does cover goes rather wider than the energy sources it is usually used to describe (namely, fuelwood & charcoal, leaves & sticks, crop & livestock residues, small workshop industrial residues eg husk & shells, bark and sawdust, bagasse from sugar factories...). This becomes clearer when one goes on to consider some of the 'New & Renewable Sources of Energy' (NRSE). These include high-tech solar power, windpower and waterpower - where the last-mentioned embraces devices for capturing the energy in ocean waves, tides, currents and thermal and saline gradients. TE includes in principle all the low-tech solarpower ('passive solar' for drying food & fibre), windpower (wind mills, pumps & other devices, and 'passive wind' drying and ventilation, and sailing boats), and waterpower (mills, pumps & other devices such as bellows for forges, and transport using natural water flows and currents). One could go further and argue that natural sunlight for illumination and photosynthesis should also be treated as part of TE. After all, before the discovery or invention of fire-making, using vegetable or animal material to keep a flame alight, the limitation on hours of daylight placed a very real constraint on the size of the 'domestic product'.

5. Whether or not in practice one should strive to measure all the above forms of TE depends on an assessment of the balance between (a) the cost of building up the data, on the one hand, and (b) the cost of the economic and social welfare errors that policy makers may commit by not possessing all the data, on the other. The outcome of such an assessment depends in part on one's scale of values and one's system of weighting.

6. Animate energy (AE) in the form of animal and human muscle power is another type of TE that is usually left out of account. It raises yet further problems - quite apart from the attribute that it may or may not be the subject of market transactions. Logically, at least the physical work output of muscle-power should be included in any complete assessment of the energy supply and use situation and outlook in a Developing Country. But where is the boundary of 'physical' work? Clearly one should include musclepower used in all agricultural operations and in rural (and urban) transport of goods - on pack animals, on sleds, in carts, on people's heads, shoulders and backs, and by bicycle and trishaw - and musclepower used in transport (rural and urban) of people. Musclepower used in fuel gathering, processing and marketing should also presumably be included. So should that used in rural workshops of all kinds be included. But what about musclepower used in domestic food preparation and in other tasks in or around the family dwelling? What about that used in making goods for sale - eg pottery or weaving? And how about all the muscle-power used by manual workers in the 'modern' sector of an LDC? Mining, (and mining of course includes the extraction of non-energy minerals)? The other Energy Industries? Manufacturing? Transport and Construction? Distribution and Services? And where is the boundary between physical effort and other effort that can also be replaced by CE-powered devices (eg manually operated office machinery and electrically operated equipment)? Even walking up stairs can be substituted for by riding up in lifts. Brainpower, too, can be replaced by CE-powered devices (eg pen-and-paper... bead abacus... slide-rule... manually operated desk calculator... electronic calculator... microcomputer... mainframe computer).

7. These are just a few examples of one particularly fuzzy boundary among many fuzzy boundaries encountered when trying to define the scope of an energy information system. One practical if arbitrary solution to this particular problem is to restrict the coverage of AE to animal musclepower whilst recognising that the levels of total energy supply and use are in

consequence understated. Energy policy and planning are, when all is said and done, really concerned essentially with changes from present levels - whatever those may be - and, for a wide range of practical policy issues, actual and expected changes in a country's energy situation may be adequately observed and assessed without complete and continuous information on levels. This is one particular application of a more general principle that does not only apply to the energy sector.

8. To return to NRSE, this grouping of energy sources, strictly interpreted, consists of five components:

(i) All of TE except 'fuelwood mining' - ie gathering in excess of growth;

(ii) Part of CE - ie geothermal and large-scale hydro and, in the future, nuclear fission with breeder reactors and nuclear fusion;

(iii) Fuelcrop plantations - eg fast-growing fuelwood, sugarcane and other crops for alcohol, coconuts for 'fuel oil';

(iv) High-tech solar, wind and water power, and heat pumps;

(v) High-tech oil from coal, tar-sands & shale, and synthetic natural gas.

9. One could add another component, Biogas, but this is really only the possible extension to other Regions of a long-established low-tech process for deriving a useful secondary energy source from primary Biomass (viz animal - including human - waste material), hitherto confined to China.

10. Set out thus, NRSE is a particularly heterogeneous collection of energy sources, not all of which are both new AND renewable (eg the items in the fifth group). Although this collection of energy sources is understandably at the centre of much energy policy concern when oil prices are high, it is not a particularly convenient grouping for many analytical purposes. Annex I sets out in a rather more helpful arrangement the relationship between the 'dimension' Renewability on the one hand, and the more useful descriptors Commercial, Traditional and Novel energy (NE) on the other. The sub-group Biomass has also been highlighted in view of the attention given to it currently. This sub-group in fact falls partly in the Traditional group and partly in the Novel group. (The now less-used split between Conventional and Non-conventional energy sources has also been incorporated in the Table.)

II BOUNDARIES

11. This paper refrains from making specific recommendations on whether or not an energy information system should include in TE all or any of the low-tech solar, wind and water power mentioned above, or animal and human musclepower. The United Nations manual on 'Concepts & Methods in Energy Statistics'[(1)] recommends that "An overall energy balance should cover all flows of energy including the so-called 'non-commercial' sources. Coverage of such sources should be as extensive as possible.." The main text of that document did not, however, discuss the low-tech solar, wind and water sources in detail and the applicability of the recommendation to them is not entirely clear. But when the main text discusses AE, it does propose that human as well as animal muscle power should be covered, in terms of the fossil fuel equivalent of the work that is done.[(2)] To be consistent with this, all forms of inanimate TE - including all the low-tech solar, wind and water power - should be included as well. Not all economists and other analysts would agree with this. Many would maintain that the impact of AE and all other sources of TE on the market for CE can be adequately assessed by looking at the broad factors that influence the acquisition and use of appliances that use CE. Others argue very persuasively that a considerable body of information on supplies, uses and - if they exist - prices or opportunity costs (and much other information besides) about TE is essential for a proper assessment of the likely effects of policy decisions directed at CE.[(3)] Exactly what information and with what frequency is not however always clear.

12. If one is really concerned with complete descriptions of energy and energy-related aspects of economic activity in order to have a proper basis for the formulation and implementation of energy (and energy-related) policies, and for appraising the effects of those policies, then the whole range of 'non-commercial' economic activities currently omitted from a country's National Accounts should be looked at critically. Such reviews have been carried out by various people in Academia and in some of the International Organisations during the past decade,[(4)] and these draw attention to the exclusion, or inadequacy of the treatment, of own-account production in the rural sector - and this would presumably include rural energy production, preparation and use - own-account capital formation, services rewarded in kind, goods exchanged in barter, imputed incomes from the ownership of dwellings and other physical capital, and some other activities.

13. Since 'integrated energy planning' depends on the assessment of the situation and outlook for all forms of energy in the context of the whole of a country's economy, and the formulation of policies for the future course of energy development in that same all-embracing context, it is not clear how 'IEP' can be pursued without at the same time widening the scope of a country's National Accounts & Balances. Further discussion of this would take this Paper outside its own intended boundaries, but the Paper would be incomplete if it did not draw attention to this larger methodological (and data) problem.

III ACCOUNTING TREATMENTS

14. On the assumption that agreement can be reached on where to set the boundaries for AE - and the rest of TE - for inclusion in an energy information system, there remain for consideration the different ways in which the chosen TE sources can be measured and accounted for in the system. The other components of NRSE pose fewer problems because they yield relatively easily measurable outputs of heat or electricity and, according to the UNSO manual, it is in that form that the energy from such sources should be recorded for an Energy Balance (EB).(5) A comprehensive Energy Information System (EIS) would of course include a wide range of 'capital account' data (including estimates and some guesses - thus giving 'guestimates') on resources (forest stocks, livestock numbers, land use patterns, solar incidence, wind regimes, water volumes, levels and flows), plant (charcoal kilns, windmills, watermills, sawmills, rural workshops, rural and urban energy-using devices), and distribution systems (fuel gathering, transport, storage and marketing) in addition to 'current account' data on prices (where applicable), flows of energy from the various resources (national and foreign) directly or indirectly (via transformation) to each main use within each sector of final energy use. A fully comprehensive EIS would also include a lot of data on energy-related variates (distribution and size of rural and urban population by household, age, sex, activity, income level...; size and distribution of estimated GNP by various parameters; transport fleet size and age structure; journey pattern by mode, distance and load;....). It is however in the 'current accounts' (consisting of Energy Commodity Accounts - ECA - expressed in whatever original unit of measurement is appropriate for each 'energy commodity', and Energy Balances - EB - expressed in a single unit of account such as a multiple of the Joule and/or tonnes of oil equivalent) that the main problems of principle arise because of the

variety of ways in which the various components of TE could be accounted for. These problems will now be considered under a number of headings.

Balance format

15. EBs may be constructed in numerous different ways each of which has some advantages and some limitations. The matrix balance (with columns for energy sources and rows for energy transactions) is now well established internationally and has been adopted increasingly by national governments and other bodies working in the energy sector.(6) Although the matrix balance was first devised by a Developed Country (Germany) and first applied internationally to Developed Countries (OECD/IEA), it can easily be extended to include TE and NE simply by adding appropriate extra columns and rows. Annex II shows the EB formats used for Developing Countries by UNSO and by OLADE. (In such a balance, the Supplies and Consumption sub-matrices can easily be interchanged so as to provide a 'bottom up' balance for projections.)

Accounting levels

16. An EB shows energy supplies at each of three levels and, if sufficient information is available, it can show a fourth level as well:

(i) Primary energy and equivalents (PE & PEE)
(ii) Secondary energy (SE)
(iii) Final energy (FE) - also called Supplied Energy
(iv) Useful energy (UE)

Strictly speaking these descriptors apply to the actual energy derived from each type of source but they are sometimes used more loosely to designate the sources themselves. PE is the energy extracted, collected or captured 'from nature' (eg crude oil, fuelwood or windpower). PEE has two components -

(a) net foreign trade and stock-changes in secondary energy (SE), which are 'primary' supplies for the producing or importing country; and

(b) the fossil fuel input that would be required to produce the electricity actually generated by hydropower, geothermal or nuclear heat.

The concept behind this second component has direct implications for one possible accounting treatment of TE in general and AE in particular.

17. SE is the output from the energy transformation industries (petroleum products, charcoal, biogas, fuel alcohol...). FE is the energy, whether PE or SE, that is delivered to each final use sector. UE is the energy effectively available as heat, light or work on the output side of a final user's equipment of appliance. Usually there is not sufficient information for completing an EB as far 'down-stream' as UE although this concept is in principle the most important one when attempting to make projections for an economy as a whole - consumers, both intermediate and final, demand not energy or energy sources but energy services viz heat, light and work.

Accounting conventions

18. The definition of the second component of PEE given above is not intended to be - nor is it - a complete description of the actual conventions that can be used in accounting for primary electricity in an EB. There are three different conventions that can be - and are - used, and each could (mutatis mutandis) be adopted for the three components of TE (Animate, Biomass and 'Conventional' or 'unimproved' solar, wind and water power). These conventions all relate to the basis for quantifying the primary input to electricity generation and are as follows -

(a) actual physical energy input
(b) primary energy equivalent input
(c) electrical energy output

19. The simplest case to consider is geothermal generation. For this, (a) would record the quantity of heat captured from the geothermal source and fed to the turbine. This would reflect the actual physical flows involved (viz the heat input, the electricity output and the true heat losses from the process), but it is rarely adopted in practice. In the context of energy planning, with oil conservation and substitution at its centre, a more illuminating convention is (b) - which shows all methods of electricity generation on the same basis and thus highlights the quantity of fossil fuel (usually but not always oil) saved by geothermal or other primary electricity generation. The third basis is, however, equally defensible on the ground that (apart from washing, cooking and space-heating) geothermal heat is always transformed into electricity before being applied to its major end-uses.

20. Hydropower can be treated in each of the same three ways, but in this case, (a) would reflect the kinetic energy in the water inflow to the turbine. Once again (c) is defensible because - apart from the direct use of water power to perform mechanical work in watermills and pumps, hydro power is always first transformed into electricity. In the case of nuclear generation, (a) and (b) almost coincide and will differ only to the extent that the thermal efficiencies of nuclear and classical thermal stations differ. There is no universal agreement on which is the 'best' or 'most useful' convention, and each has its proponents. In recognition of this, UNSO gives figures on both bases (b) and (c) in its published EBs for Developing Countries. The practices of UNSO and the other main international agencies are summarised below -

AGENCY	HYDRO	GEOTHERMAL	NUCLEAR
UNSO	(b) & (c)	(b) & (c)	(b) & (c)
OECD/IEA	(b)	(b)	(b)
SOEC	(c)	(c)	(a)
OLADE	(a)	(a)	(a)

21. Let us now consider the application of each of these three conventions to TE. Both conventions (a) and (b) treat the activity or entity yielding an energy output as being itself a transformer of primary energy, whilst convention (c) treats that activity or entity as being itself a source of (notionally if not actually) primary energy that is supplied directly to final energy users.

Animate energy:

22. For simplicity it is assumed that human musclepower is excluded (but the same kind of logic could be applied to it if necessary). Using convention (a), there would be new columns in the EB for AE, for Feed and for Dung and there would be a new transformation row for Work Animals. Following the established EB matrix convention on signs for transformation inputs and outputs, in the Work Animals row there would be a negative entry in the Feed column and positive entries in the AE and Dung columns corresponding respectively to the work and dung outputs of such animals. There would also be the usual negative entry in the Total column reflecting the animals' efficiency of feed conversion. (Part of their feed intake would of course be a maintenance ration, and maybe part would be a breeding

ration, and part a fattening or milk production ration - these are part of the complexity of adopting convention (a) for AE.) The feed input figure would be repeated with a positive sign in the row for Primary Production or it might be divided between the rows for Primary Production, Imports and Stock-changes, depending on the actual or estimated origin of the feed.

23. On the basis of convention (b), the input entry in the row for Work Animals would be the energy content of the petroleum products that would be needed to produce the same work output. A variant on this would be to show the PEE that would be needed to carry out the same quantity of completed work using modern CE-powered prime movers and equipment. The difference between these two variants would reflect the relative efficiencies of traditional and modern equipment and working methods. If convention (c) is used, there need be no new column for Feed nor a transformation row for Work Animals. The work output of such animals would appear directly in the Primary Production row of the AE column, with one or more entries in the Final Use rows for Agriculture, Transport etc. Variants on the single-column treatment of AE would be to enter in that column the estimated work-ration of total feed consumption, or the Fossil Fuel input equivalent (ie the PPE) of the actual work output, or the PEE needed to accomplish the same tasks.

24. The UNSO manual makes no specific recommendations on which convention should be adopted but it did express the view that convention (b) was likely to be of most practical value for the purposes of energy policy. This view did not make completely clear which variant of (b) would be the more useful, but the second of the two variants clearly has some advantages in the context of projections.(7)

Biomass:

25. Traditional primary biomass (fuelwood, crop and animal residues) may be used directly for energy purposes or it may be transformed into traditional secondary biomass (charcoal, biogas). These energy sources all fit naturally into an EB matrix by simply adding appropriate new columns and new transformation rows for Charcoal Kilns and Biogas Digesters, using convention (a). There would seem to be no reason for considering conventions (b) or (c). There is, however, the inconvenient fact that because of the very low efficiencies with which most combustion devices use traditional

biomass, very large amounts of primary biomass are required, and these quantities would swell the figures for Total energy supplies and uses - whether expressed as PE or FE - in an EB that includes both CE and TE. As a result, analyses of the relative shares of different energy sources in total supplies and uses, growth rates and comparisons between countries would be significantly altered.

26. This problem can be avoided in one of three ways. The simplest is to construct two separate EBs, one for CE and one for TE. (NE would become part of CE when the quantities involved became large enough for inclusion in an EB.) The Total column for TE could be added as an extra column after the Total for CE sources in the EB giving details for CE energy, so as to show the relative importance of CE and TE in Developing Countries. This is the practice of UNSO.[(8)] The most rigorous (and ambitious) way would be to include TE in the same EB as CE and to develop the data for all energy sources 'downstream' to the level of UE. This, after all, is the only satisfactory level at which to examine the scope for inter-fuel substitution - subject to all sorts of constraints such as the stock, age-structure and replacement cost of existing energy-using equipment and the technical characteristics of each energy source. A third and more pragmatic method would be to adopt convention (b) in one of its two variants described above when considering AE.

27. The Novel biomass sources (plantation crops for fuel) can be treated without serious problems according to convention (a) or (b). It is important however to restrict the coverage of sugar cane and the like - at least for EBs - to that part of the crop produced specifically (or actually used) for alcohol etc., rather than include all of the crop on the ground that in theory all might be used for alcohol production.

'Conventional' low-tech solar, wind and water power:

28. Pragmatism suggests the exclusion of all energy sources whose use does not require specialised equipment. This is nevertheless a very poor justification and it should perhaps be called casuistic rather than pragmatic, since it is really the data problems rather than the practical significance of such energy sources that make one seek for a plausible reason for excluding such sources. The same principle (use of specialised equipment) cannot be used for the exclusion of low-tech windmills, water-mills, pumps or sailing boats. In principle the energy used by all these devices should be included. The simplest basis for doing so would be to adopt convention (b) in one of its variants.

29. Novel energy: For completeness, the accounting treatment of NE (high-tech solar, wind and water power, and heat pumps) also needs to be considered. (Oil from coal, shale or tar sands, and synthetic natural gas fit readily into the EB accounting framework as they can be recorded in terms of the energy content of the oil or gas produced.) For solar, wind and water power, the UN recommendation is that such energy sources should all be recorded in terms of the heat, electrical or mechanical output of the collecting device[9]. It can however be argued that, by analogy with 'classical' large-scale hydropower generation of electricity, at least tidal, wave and OTEC - and mini and micro hydro - used for generation should be accounted for in the same way, namely by expressing the electricity output in terms of the primary energy equivalent input. If this convention is adopted in these cases, then the same convention should be used in the case of wind-powered electricity generation, and from this it follows that for complete consistency in the accounting treatment of electricity generation, photovoltaic electricity should also be accounted for in the same way. As already pointed out, however, in its published EBs for Developing Countries, UNSO shows figures on two bases for 'classical' hydropower (and for geothermal and nuclear electricity)[10] and the same two bases could be adopted for NE generation of electricity as well.

30. Heat pumps are very unusual as energy 'transformation' devices. It would be more accurate to describe them as 'capturing and harnessing' devices. Their peculiarity is that they make available between two and three times as much energy as they themselves use in accomplishing this result. They use the refrigeration cycle in reverse: low-temperature ambient heat is absorbed as the latent heat of evaporation of a contained fluid material, and this heat is then released into a lower-volume space (such as a building) through the compression and condensation of the fluid material.

31. This form of heat energy can easily be fitted into the EB accounting framework in one of two ways. The first is to treat heat pumps as transformation devices and in consequence provide a new row 'Heat pumping' in the Transformation section of the EB, and a new column 'Heat'[11]. In this new row, there would be a negative entry in the Electricity column for the energy used in pumping, a larger positive entry in the Heat column for the energy made available, and a 'negative loss' positive entry in the Total column for the net inflow of ambient heat from the environment.

32. The second and simpler accounting treatment would not require a new Transformation row (or the implied 'transformation' of electricity into a larger quantity of heat). The heat captured and concentrated by heat pumps could be recorded in the Primary Production row in the Heat column, and the electricity - and, in the future, perhaps natural gas - could be recorded in the row for the Energy Sector's own use of energy (with a suitable footnote).

October 1986

Footnotes and references

(1) "Concepts and Methods in Energy Statistics with Special Reference to Energy Accounts and Balances", Studies in Methods, Series F No. 29: United Nations (1982). See in particular the following sections -

	Pages
New Sources of Energy	4
Commercial and Non-commercial Energy Sources	17-19
Primary Energy Input to Renewable Sources of Energy	29-32
Animal and Human Energy	32-33
Energy Balances for Developing Countries	151-153

(2) Ibid. Page 33.

(3) See for example "Integrated Policies for Traditional and Commercial Energy in Developing Countries", PJG Pearson & PJ Stevens, in Development Policy Review. Volume 2 (1984)

(4) See for example "The Subsistence Component in National Income Accounts", EK Fisk, in 'The Developing Economies', Institute of Developing Economies, Tokyo (1975), and "Towards Distinguishing between Traditional and Modern Activities in the National Accounts of Developing Countries", H Schimmler, Development Centre, OECD Paris (1979)

(5) "Concepts and Methods" page 31.

(6) The matrix format was first launched internationally by OECD/IEA in 1975, based on the accounting frameworks of some of its Member Countries. SOEC adopted a matrix format in 1978, followed by OLADE in 1980. In 1978, an Expert Group convened by UNSO recommended the general use of this format, following examination of a Consultant's Report that had reviewed critically over 30 different energy accounting conventions used by various Countries, International Agencies and other institutions. That exercise resulted in the "Concepts and Methods" manual cited in Footnote (1).

(7) See Footnote (2). The first variant would give a better description of the amount of energy used by current working methods, though for some purposes convention (c) might be preferred.

(8) See Annex II.

(9) See Footnote (5).

(10) "Energy Balances and Electricity Profiles", United Nations (1986).

(11) "Concepts and Methods" page 76 and Footnote 62.

Acronyms

IEA . . . . International Energy Agency (Paris)

OECD . . . . Organisation for Economic Cooperation and Development (Paris)

OLADE . . . . Latin American Energy Organisation (Quito)

SOEC . . . . Statistical Office of the European Communities (Luxembourg)

UNSO . . . . United Nations Statistical Office (New York)

ENERGY - SOME CLASSIFICATIONS

TYPE \ RENEWABILITY			RENEWABLE	NON-RENEWABLE
CONVENTIONAL	COMMERCIAL		Hydro power (large scale) Geothermal Nuclear (breeder)	Fossil fuels Nuclear (other fission)
CONVENTIONAL	TRADITIONAL	OTHER	Solar (air drying) Hydro (mills, pumps &c.) Wind (mills, pumps & sails)	
CONVENTIONAL	TRADITIONAL	BIOMASS	Fuelwood 'cropping' from natural forest/charcoal Twigs, leaves, sticks &c. Crop residues (husks, shells &c.) Animal residues (tallow, dung) Industrial residues (wood waste, sawdust &c.) Animate (animal & human muscle power)	Fuelwood 'mining'/charcoal
NON-CONVENTIONAL	NOVEL	BIOMASS	Plantation & marine crops (for pyrolysis, distillation &c.) Biogas	
NON-CONVENTIONAL	NOVEL	OTHER	Solar (collectors, photo-voltaic) Hydro (mini & micro) Wind (wind motors) Tidal, wave power Ocean thermal gradients Heat pumps	Nuclear (fusion) Petroleum from coal, shale, tar sands &c. Synthetic natural gas

W N T R
London (UK)

October 1986

TABLE I: UN Statistical Office Energy Balance Sheet

ENERGY BALANCE SHEET

Unit: terajoules

Commodities / Transactions	Hard coal, Lignite & Peat	Briquettes & cokes	Crude petroleum & NGL	Light petroleum products	Heavy petroleum products	Other petroleum products	LPG & Other petroleum gases	Natural gas	Derived gases	Nuclear, hydro and geothermal electricity		Electricity	Total commercial energy		Traditional fuels	Total energy	
										Conventional fuel equivalent	Physical energy input		Conventional fuel equivalent	Physical energy input		Conventional fuel equivalent	Physical energy input
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)
1 Production of primary energy																	
2 Imports																	
3 Exports																	
4 Marine/aviation bunkers																	
5 Stock change																	
6 Total energy requirements																	
7 Energy converted																	
8 Briquetting plants																	
9 Coke ovens & coke plants																	
10 Gasworks																	
11 Blast furnaces																	
12 Petroleum refineries																	
13 NGL processing plants																	
14 Electric power plants																	
15 Heating plants																	
16 Other conversion industries																	
17 Net transfers																	
18 Consumption by energy sector																	
19 Losses in transport & distrib.																	
20 Cons. for non-energy uses																	
21 Statistical differences																	
22 Final consumption																	
23 By industry & construction																	
24 Iron & steel industry																	
25 Chemical industry																	
26 Other industry & construction																	
27 By transport																	
28 Road																	
29 Rail																	
30 Air																	
31 Inland & coastal waterways																	
32 By households & other cons.																	
33 Households																	
34 Agriculture																	
35 Other consumers																	

(UN 1985)

TABLE 2: Structure of OLADE Energy Balance Sheet

O L A D E
ORGANIZACION LATINOAMERICANA DE ENERGIA
LATIN AMERICAN ENERGY ORGANIZATION

UNITS : TEP X 1000 — CONSOLIDATED ENERGY BALANCE THERMAL

COUNTRY :
YEAR :
DATE :

	1 COAL	2 FIRE-WOOD	3 OTHER PLANT ANIMAL FUELS	4 CRUDE OIL	5 FREE NATURAL GAS	6 ASSOC. GAS	7 HYDRO-POWER	8 GEO-THERMAL ENERGY	9 NUCLEAR ENERGY	10 SUB TOTAL ONE	11 COKE	12 CHAR-COAL	13 LIQUID GAS	14 GASO-LENE	15 KERO-SENE	16 DIESEL	17 HEAVY FUELS	18 OTHER ENERGY FUELS	19 NON-ENERGY PRODUCTS	20 GAS	21 ELEC-TRICI-TY	22 SUB TOTAL TWO	23 TOTAL
1. PRODUCTION																							
2. IMPORTATION																							
3. INVENTORY VAR.																							
4. TOTAL SUPPLY			PRIMARY ENERGY											SECONDARY ENERGY									
5. EXPORTATION																							
6. UNUTILIZED																							
7. GROSS INT. SUPPLY																							
8. TOTAL TRANSFORM.																							
8.1. COKE PLANTS								ENERGY SECTOR															
8.2. COAL PLANTS																							
8.3. BIOMASS																							
8.4. REFINERIES																							
8.5. GAS PLANTS																							
8.6. PUBLIC ELEC. PLANTS					(TRANSFORMATION CENTERS)																		
8.7. AUTO PROD. ELEC.																							
9. OWN CONSUMPTION																							
10. LOSSES (TRS. DIS. STO)																							
11. ADJUSTMENTS																							
12. TOTAL ENERGY CONS.																							
12.1. NON ENERGY CONS.																							
12.2. FINAL ENERGY CONS.					TOTAL FINAL CONSUMPTION																		
12.2.1. RESIDENTIAL, COM. PUB.																							
12.2.2. TRANSPORTATION																							
12.2.3. AGRICULT./LIVESTOCK																							
12.2.4. INDUSTRIAL																							
12.2.5. UNIDENTIFIED CONS.																							

OBSERVATIONS — GROSS SECONDARY ENERGY PRODUCTION

ENERGY TRANSITIONS IN SOUTH ASIA

Gerald Leach (IIED)

Introduction

This paper is about the household sector, for which we can make a basic assumption. Families attempt to move up the ladder of fuel preferences for cooking and heating towards greater convenience, cleanliness, time saving and "modernity". This progression also leads to greater energy efficiency for cooking and water heating, but not usually for space heating.

In South Asia the usual progression is: low to high grade biofuels, kerosene, bottled gas (LPG), natural gas (in Pakistan) and electricity. There is little use of charcoal, but coal briquettes (soft coke) are widely used in some Indian states at all income levels. Kerosene and cheap LPG stoves are not full substitutes for biofuels since one cannot easily grill or bake on them (eg, nan, chapatis, etc). Only high cost gas or electric stoves with grill and oven provide the full range of desired cooking facilities. Because of this, and due to irregular fuel and power supplies, the use of multiple fuels/technologies is common, especially the combination of biofuels and kerosene. Other factors in fuel choice include handling and storage qualities, bulk, safety and health considerations (eg, smoke), the smell and taste imparted to food, and the start-up time and controllability of fuel/cooking equipment combinations.

This progression is driven by income, but also by scarcity of biofuels. (For example, in some arid parts of Pakistan poor peasants are selling cattle and other capital assets to acquire LPG systems). The progression is also strongly affected by fuel prices, the cost of end use equipment, and fuel availability.

Some recent large, nationally representative energy or household expenditure surveys in India, Pakistan and Sri Lanka allow us to map this progression by income at a given time and also over time [1-3]. Some key results will be presented.

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* The paper is based on a 102 page May 1986 report, 'Household Energy in South Asia', sponsored by the Development Directorate, European Commission; Forestry Department, UN FAO; and the Energy Department, the World Bank. A revised and updated version will be published shortly.

Biofuel shares and income

Cross-sectional data for 1978-79 (India, Pakistan) and 1981-82 (Sri Lanka) show that in rural areas the share of biofuels in total household energy is virtually constant at around 90% for all income levels: see Figure 1. High income families may be satisfied with biofuels (they grow their own and have servants to collect them). Much more probably the transition is severely constrained by limited availability of premium ("non-traditional") fuels. Price cannot be a major constraint in India and Pakistan, where kerosene and LPG are much cheaper than firewood on a useful heat basis.

In urban areas, where premium fuels are more easily available, biofuel shares fall steeply with income in India and Pakistan, from 80% to around 30-35% in the highest income brackets. But in Sri Lanka they do not. Firewood is cheap compared to kerosene and is readily available: 40-50% of poor Sri Lankan urban households get firewood from their own land, compared to 2.5% in India.

Biofuel shares and settlement size

The availability argument is supported by Indian data on fuel shares by settlement size: see Figure 2. The share of premium fuels increases from 40% in small towns (20-50,000 population) to 80% in large cities (over 500,000 population). This calls into question the usual crude distinction between "rural" and "urban" areas.

There is also firm evidence that the reason why poor urban families do not switch from firewood to much lower priced kerosene is difficulty in obtaining kerosene and not the investment cost in a kerosene stove. For example, a 1985 survey of low income urban households in Lucknow, India [4], found that very few families cooked with kerosene although they realised that it would cost them only 40% as much as cooking with firewood. A kerosene stove would have cost them the equivalent of one to four days of household income (ie, Rupees 15-60, US$ 1-4). Kerosene shortages and long queues at the local kerosene stores were the main reasons given for not using the fuel.

The switch into LPG cooking, however, involves investment costs which deter all but the highest income households. For example, in Colombo in 1983 the entry cost for LPG cooking was Rupees 1820 (US$ 77), comprised of gas cylinder deposit Rs 750, regulator Rs 200, and Rs 870 for the cheapest 2-ring burner. This sum represented at least one month's income for the poorest 70% of households and five month's income for the poorest 12% [3]. The India 1979 survey [1] estimated that the initial investment for LPG cooking was 34% of annual household income for the poorest 30% of urban households, and 16% for the next highest income group which made up 43% of the survey sample. For the highest income group the investment was only 3% of annual income.

Fuel prices

In India and Pakistan the real price of residential gas and electricity has fallen steeply since 1970 while urban firewood prices have risen by some 40% and 20% respectively. Kerosene has always been cheaper than wood on a useful heat basis. Consequently, in these countries relative prices have encouraged the (urban) energy transition. In Sri Lanka, on the other hand, kerosene prices have risen sharply relative to firewood prices, encouraging a reverse transition.

Figure 3 shows the retail urban market price of the major cooking fuels in the three countries, in constant (inflation corrected) currency expressed as an index with 1969-70 = 100. The Indian data are the average for 10 large cities [5]; the Pakistan data are the average of 7 major urban centres [6]; the Sri Lankan data are for Colombo [7]. Figure 4 shows the price of kerosene per unit of energy content as purchased (assuming 35 MJ/litre) divided by the unit energy price of firewood (assuming 16 MJ/kg). If one takes the efficiency of kerosene in cooking as approximately 2.5 times greater than that of firewood, a ratio of 2.5 or less means that kerosene is cheaper on a useful heat basis than firewood. The Figure shows that this condition has always applied, since 1970, in India and Pakistan, while for most of the period the reverse has been true of Sri Lanka.

Urban transitions

In India, the 1979 survey and a more recent 1984 urban survey [9] show that a massive transition from biofuels to premium fuels has occurred: see Table 1. Overall, the share of biofuels for cooking and heating (on a useful heat basis) fell from 42% to 27% while the kerosene and LPG shares rose from 19-36% and 7-12% respectively. All income groups took part in these changes, some more than others.

In Sri Lanka, a more modest shift in the same direction occurred during 1973-79 but seems to have reversed over 1979-82 as the kerosene price was allowed to soar in real terms: see Table 2.

In Pakistan, an even greater urban transition than in India has probably taken place. Residential natural gas and electricity use has grown at an annual average of 24.1% and 17.3% during 1972-1985, almost wholly in urban areas. Kerosene use has also grown faster than population. Fuel prices are sharply skewed in favour of premium fuels and the urban middle class. Unfortunately, data from a large 1984-85 survey which would allow comparison with 1978-79 is not yet available to allow one to pin down the scale of this change.

Macro implications of the household transition

Finally, it is interesting to consider the broad economic implications of a major transition out of biofuels. Using the 1979 Indian survey data, one can imagine that through easier access to premium fuels every rural household adopts the fuel mix for cooking and heating of urban households in the same income group. The effects of this supposed change in reduced biofuel and increased premium fuel consumption are shown in Table 3. All told, biofuel use falls by some 45% or 65 million tons wood equivalent (assuming 16 GJ/ton for wood, 14.5 GJ/ton for crop residues, and 10 GJ/ton for animal wastes). Consumption of premium fuels rises by 9.4 million tons oil equivalent.

The latter figure was only 10% of primary commercial energy use in 1979 but it was 32% of primary oil consumption in the same year. Most of the 9.4 MTOE increase would probably be in oil products, although some would be coke and electricity. If one prices the 9.4 MTOE at US$ 20 per barrel oil equivalent and assumes that it must all be imported, the extra import bill is close to US$ 1400 million, or 14% of India's export earnings in 1979.

This crude calculation does, of course, ignore the basic problem of the low purchasing power of the mass or rural households and the formidable infrastructure development that would be needed to bring premium fuels to rural areas. However, although the numbers are quite large, the transition described here does not appear inconceivable from a macro-economic viewpoint if it is spread out over, say, a decade. The economic benefits to agriculture and the environment of reducing biomass fuel consumption by 45% would certainly be very large.

Conclusions

In South Asia, rapid transitions out of biofuels are occurring due to rising income, where premium fuels are available, and where the price regime is favourable. That this is so will not surprise economists. So far, the transition appears to be largely confined to urban areas. The interesting question is when and under what conditions of infrastructure development and/or expressed demand the mass of rural people will be willing and able to follow their urban cousins along the transition path.

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8. Natarajan, I. (1986) - personal communication, National Council of Applied Economic Research. The 1983-84 survey is ready for publication but is awaiting clearance by the sponsors.

Table 1
Fuel shares for cooking and heating in urban India by household income: 1978-79 and 1983-84 (percent)

Firewood	1978-79	60.0	40.9	25.1	17.4	12.1	42.4
	1983-84	53.5	30.8	17.9	9.9	9.6	27.4
Kerosene	1978-79	13.2	21.3	21.5	22.0	18.9	18.7
	1983-84	23.8	36.9	40.2	38.2	32.8	35.7
LPG	1978-79	0.8	4.6	14.2	26.9	32.9	6.6
	1983-84	1.2	4.6	15.7	27.9	39.3	11.5
Percent Households	1978-79	31.5	42.8	20.7	2.6	2.4	100

Table 2
Percent of households by type of main cooking fuel: Sri Lanka 1973, 1979 and 1982

	Year	Urban	Rural
Firewood	1973	64.5	93.5
	1979	58.1	92.5
	1982	65.3	95.2
Kerosene	1973	28.4	4.1
	1979	30.6	6.5
	1982	14.0	2.5
LPG & Electricity	1973	7.1	2.4
	1979	11.3	1.0
	1982	20.7	2.3

Table 3
Changes in fuel use if rural households adopt urban consumption patterns: India 1979

Income group:	Low-Low	High-Mid	Mid	Mid	High	All
Biofuel reduction:						
M tons wood equiv.	22.1	23.9	13.9	2.5	2.1	64.5
(percent)	(32)	(51)	(69)	(78)	(69)	(45)
Premium fuel increase:						
M tons oil equiv.	3.3	3.8	1.9	0.2	0.2	9.4

Figure 1
Share of biomass fuels in household energy by household income, rural and urban

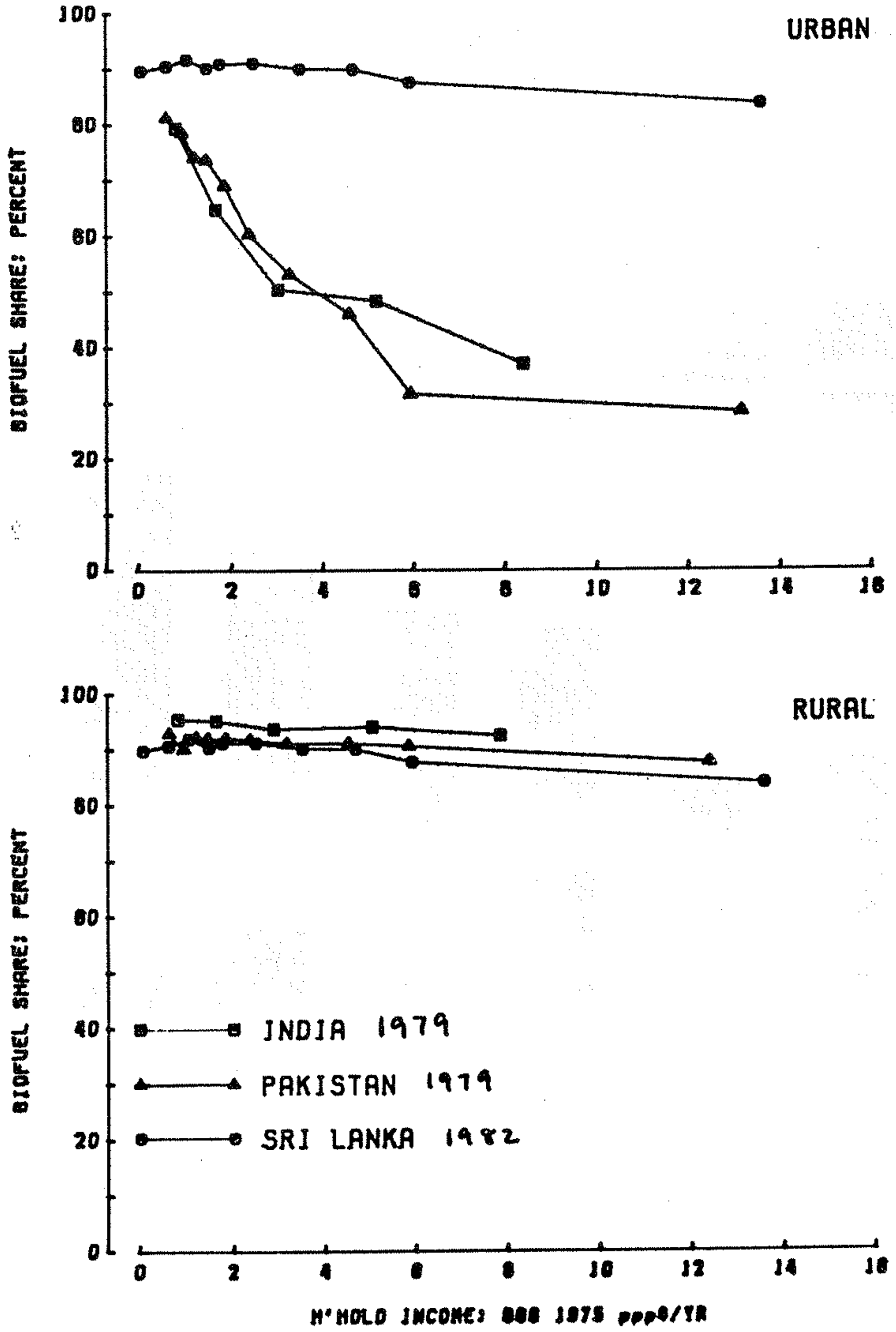


Figure 2
Share of premium fuels in household energy by settlement size, India 1979

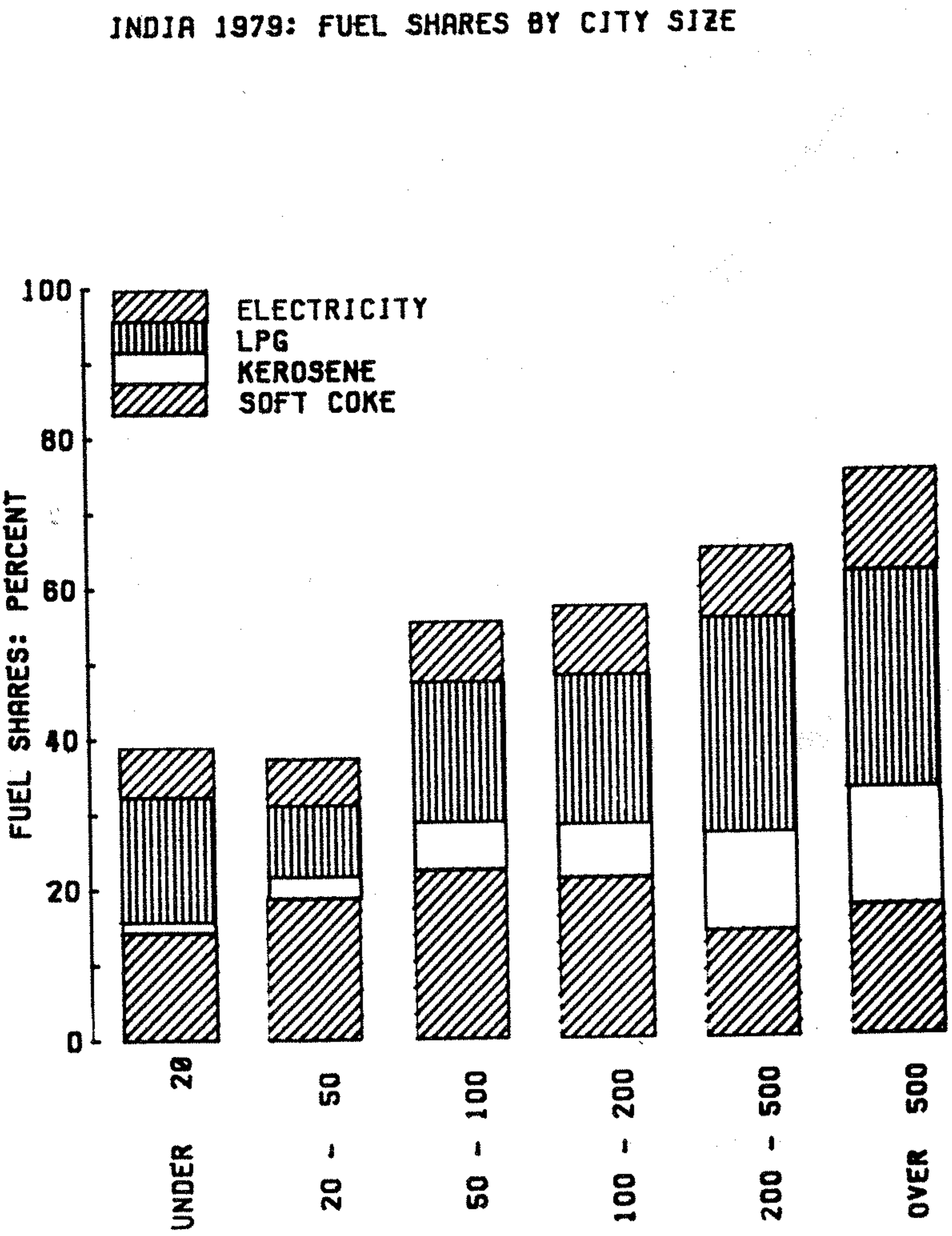


Figure 3
Residential urban fuel price indices, constant currency, 1970-1986

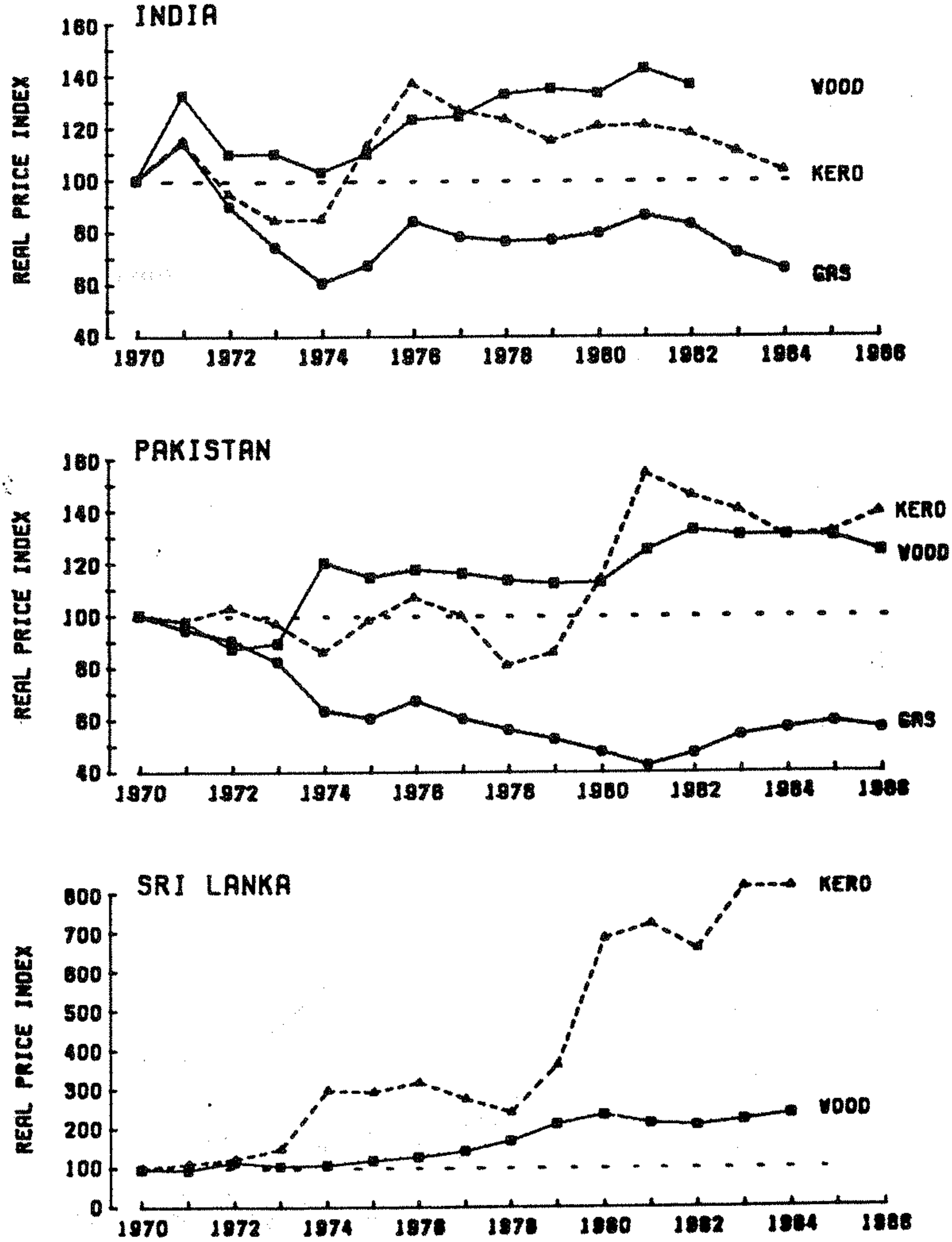
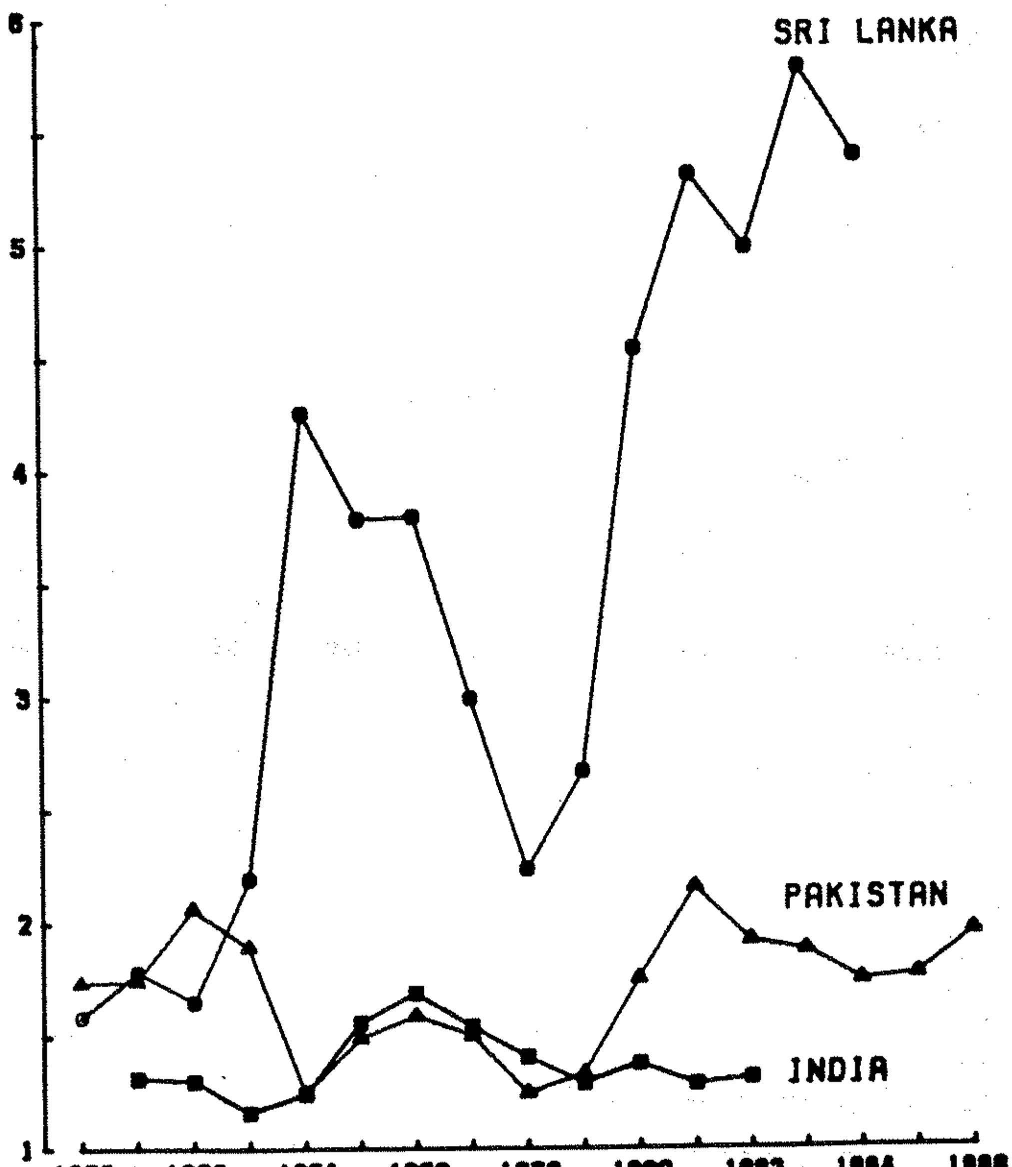


Figure 4
Kerosene price compared to firewood price, 1970-86
(Kerosene Rupees/MJ / Firewood Rupees/MJ)



ALTERNATIVES TO FUELWOOD IN AFRICAN TOWNS

Walter Elkan*

Introduction

Fuelwood and charcoal are the most widely used sources of energy in Africa. But the woodlands from which they are obtained are shrinking, as ever more land is being used to grow crops; and this poses a serious threat to the continued availability of fuelwood.

In this paper we therefore pose the question whether the popular solution of a programme of planting trees might arrest this process and thereby assure a continuting supply of relatively cheap fuelwood. We conclude that this is unlikely to succeed. Further, we shall argue that once indigenous supplies of wood are exhausted there appears to be no obvious escape from a substantial increase in the price which consumers who presently use wood will have to pay for their fuel, irrespective of whether they continue to use fuelwood or whether a switch takes place to the so-called 'conventional' fuels, viz. kerosene (paraffin), LPG or electricity.

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An earlier draft of this paper benefited greatly from comments by Gerald Foley and Julian Bharier.

Fuels used

In African towns fuelwood and charcoal are the predominant sources of energy used by households, and also by those informal sector industries that use fuel - bakeries, brewers, metalworkers and cafes. The urban middle classes now often cook on electricity, but the great majority continue to use fuelwood.

In addition to fuelwood a little kerosene is used for light. Most households have a simple lamp made in the informal sector out of disused oil cans. In East Africa they are referred to as 'candles'. Or people simply put a wick into an empty glass jar filled with kerosene. Some households now also have a one-burner kerosene stove on which to boil a saucepan of water. But only the relatively well-to-do use electricity.

The amount of fuelwood or charcoal used in towns depends on its price in relation to income. The quantity used is almost always less than in rural areas - not because incomes are lower but because the price is higher. In rural areas, fuelwood is a 'free' good. Households collect brushwood and dead branches of trees from neighbouring commons, and although they may have to go ever further afield as nearby wood is used up, the distance is rarely so great that they prefer to pay someone for it. But towndwellers have generally to pay for their fuelwood, as there is not enough wood left in close proximity to the towns to make foraging feasible or worthwhile.

It would be useful to know how much of their incomes urban households spend on fuel. It is sometimes thought to be as much as 40%. This is improbable, and a maximum of 20% is perhaps a more reasonable order of magnitude. Among people on low incomes who constitute the majority, by far the greater part goes on fuelwood or charcoal, and only a very small amount is spent on kerosene, mainly for light. In Nairobi it was estimated to account for 4% of total household expenditure on fuel and light.[1]

Why fuelwood is used

The reason why fuelwood is so widely used is partly that it is the cooking fuel to which people are accustomed. In Uganda, for instance, food is thought to taste better when it has been cooked on wood. Also in some places, prone to power cuts, the supply of fuelwood is thought to be more reliable. But the principal reason is that despite the progressive disappearance of natural forests, it continues to be cheaper to use than any of the alternatives, such as electricity, LPG or kerosene. Some of the alternatives are in any case not really on offer. For instance in the poorer peri-urban areas of many towns, houses are not sufficiently well built to make it safe to supply them with electricity. Before one could think of replacing fuelwood with electricity in such areas one would first need to re-build them! Where cost is all important people will use fuelwood. It is only the better-off at present who can afford the higher cost of using the more expensive, albeit more convenient 'conventional' fuels such as electricity, gas or kerosene.

1. O'Keefe, P. et al. (eds) Energy, Environment and Development in Africa, Vol. 1: Kenya, Beijer Institute, Stockholm, 1984.

The Problem

This raises the central problem which this article is intended to address. Fuelwood is at present relatively cheap because, as we shall see, it has not been specially grown as a commercial enterprise, so that its price in the towns reflects only the cost of getting it there. But although the urban demand for fuelwood may be only a small proportion of total national consumption, it is a highly concentrated demand and as indigenous timber is being used up in the vicinity of towns it will have to be brought from ever further afield, thus raising its cost. It may be possible to delay the process by introducing more fuel efficient ways of cooking and of converting wood into charcoal, but that can only be done at a cost, though hopefully the savings derived from improved technology will outweigh the cost. Even then, sooner or later, indigenous wood will be largely exhausted altogether and one then faces the choice of creating new, commercially grown supplies of fuelwood, or bringing about a shift to the use of conventional fuels. The problem is that both alternatives will increase the cost of household cooking, as we shall see, and it may be that poorer people will simply end up having ever fewer cooked meals. That is a gloomy prospect. Nor is it simply a prospect since it is in fact happening already. Poor people living in the peri-urban shanty towns have long ago ceased to have a cooked meal every day and some probably go without a hot meal for weeks.

Fuelwood versus kerosene

The observation that consumers find fuelwood cheapest is at first sight puzzling in view of the rapid rate of deforestation in many countries which would lead one to expect the price of wood to have escalated. Besides, in an effort to promote the substitution of kerosene as a way to reduce the pressure on fuelwood supplies, many Governments have deliberately subsidised kerosene. Yet they have largely failed to persuade the poorer consumers to switch from using fuelwood. One reason is that even subsidised kerosene is likely to be much more expensive than wood or even charcoal. In Malawi, for instance, it costs about three to four times as much.[2] In Nairobi, kerosene is three times the price of charcoal which, in turn is almost three times the price of fuelwood.[3]

But this is by no means always the case and there are many instances of African towns where kerosene is as cheap or cheaper than fuelwood and even charcoal. Even there, however, fuelwood continues to be used. Table 1 sets out the relative cost of different household cooking fuels in a number of countries in Central, East and West Africa. The countries are those for which information is available from World Bank/UNDP Energy Assessment Reports and the data relate to the early 1980s. We have omitted Uganda and Ethiopia because of the exceptionally unsettled economic conditions that prevailed at the time. We have also omitted the BLS countries because of South Africa's powerful influence on prices there. The data relate to the principal towns. They make no allowance for differences in the cost of the appliances used, but relate purely to the cost of fuels. An asterisk (*) denotes the fuel most commonly used by lower income households, and the prices are those paid for the quantities typically purchased. The figures should be regarded as no more than rough orders of magnitude. There are wide variations of energy efficiency even using identical appliances and fuel prices vary from market to market. But the figures are nevertheless instructive.

2. French, D. 'Economics of bioenergy in developing countries' in Egneus, H. et al. (eds), Bioenergy 84, Vol. V (Elsevier), London 1986.

3. O'Keefe, op. cit., p.133.

Table 1

Comparative cost of different cooking fuels in the principal towns. East, West and Central Africa. Around 1983.

	Fuelwood	Charcoal	Kerosene	LPG	Electricity
Gambia (p23)	1.0*	banned	2.0	1.4	2.9
Liberia (p65)	1.0*	0.8*	1.6	3.0	1.4
Ivory Coast (p91/3)	1.0	1.5*	1.2	0.8	1.8
Tanzania (p81)	1.0	0.8*	1.0	0.3	0.3
Zambia (p56)	not used	1.0*	1.1	1.2	0.2
Niger (p65/7)	1.0*	0.7	0.8	1.0	1.6
Senegal (p48)	1.0	0.5*	0.6	0.7	1.3
Mauritania (p26)	1.0	0.3*	0.4	0.3	1.0

Sources: World Bank/UNDP Energy Assessment Reports, various countries 1982/5, Washington, D.C.

Notes:

1. The page number in brackets refers to the page in the relevant Energy Assessment Report.

2. The prices used are based on useful energy heating units of estimated cooking efficiencies. These cooking efficiencies are not uniform throughout the eight countries, and are in any case only estimates subject to wide margins of error - depending on what utensils are used, how the wind blows etc.

3. Asterisk (*) denotes principal fuel used for cooking. In Liberia, fuelwood is being replaced by charcoal. In Zambia the relative cost is based on charcoal because fuelwood is not used in urban areas.

4. Where the Report gives figures for both older and improved appliances, we have used the former, as the improved appliances had not made great headway in the early 1980s. Where it gives official prices and free market/black market/parallel market prices, the latter are used. In Liberia where separate prices are quoted for the suburbs and the inner city, we have used the mean. In Mauritania we have used the lower of a range of prices given for each fuel. In Mauritania we have used fuelwood as the base price although, in fact, it is for obvious reasons hardly used at all.

5. Only some of the Energy Assessment Reports provide the relevant data. One or two which give data have been omitted here because it is unclear what exactly the figures mean. Some use replacement costs of wood instead of market prices.

The table shows that, if one concentrates on kerosene, which in the short to medium term is really the only feasible alternative to fuelwood or charcoal, then the difference in cost is generally not great. If it were not for subsidies, kerosene would be invariably a little more expensive, but that may have changed since the steep fall in the price of oil. Even if one assumes that fuelwood has continued to go up in price, it is unlikely that kerosene will now be substantially cheaper than fuelwood or charcoal. Even where kerosene is cheaper than woodfuel, there has not been any real shift away from woodfuel.

The principal reason why kerosene has made no great headway is that its use requires a cooker that is very much more expensive than the three stones needed for an open fire, or even the charcoal burner which is commonly used and which in most countries, as in Kenya, is made from scrap metal by small operators in the Informal Sector. These charcoal burners are crudely made and poorly finished but they are very cheap. A crudely made kerosene stove would not work. Kerosene stoves have therefore to be made in factories, and are mostly imported from India, China, Britain or elsewhere. By the time transport, and distribution costs are added, even the Indian and Chinese stoves, which are cheap in their countries of origin, cost infinitely more than the simple charcoal stove which is sold directly to the consumer and therefore incurs no transport or distibution costs.[4]

4. For an estimate of the cost of different kinds of burners and their efficiencies see World Bank Energy Assessment Report for Liberia, p.79.

Anderson and Fishwick have made the same calculation, using the same sources, for a number of countries including two that figure in Table 1. But they have added in the discounted cost of the appliances needed to use the different fuels. Table 2 compares their results with ours from Table 1.

Table 2

Comparative cost of different cooking fuels with and without allowing for the cost of cooking appliances

	Senegal		Niger	
	Fuel only	Including cost of appliance	Fuel only	Including cost of appliance
Fuelwood	1.0	1.0	1.0*	1.0*
Charcoal	0.5*	0.9*	0.7	1.4
Kerosene	0.6	1.7	0.8	1.7
LPG	0.07	1.3-1.9	1.0	2.0
Electricity	1.3	3.3	1.6	2.8

Sources: Table 1, and Anderson, D. and Fishwick, R., Fuelwood Consumption and Deforestantion in African Countries, World Bank Staff Working Paper No. 704, Washington DC, 1984, p.30.

Anderson and Fishwick's figures show that if one ignores the cost of appliances, one does so at ones peril. Kerosene, instead of costing about the same as the principal fuel used in Senegal, and a little less in Niger, turn out to cost twice as much in Senegal and 70% more in Niger when the relative cost of the appliances is taken into account. Another way to drive home the point is to look at the actual cost of the appliances.

Zambia provides an example of the relative cost of cookers using charcoal, kerosene and electricity (see Table 3).

Table 3

Cost of Cooking Appliances in Zambia 1982

	Zambian Kwacha
Charcoal "Mbabula"	1.00 - 5.00
Kerosene Stove	30.00
Electric Hotplate (one burner)	100.00
LPG Burner	70.00

Source: World Bank Zambia: Issues and Options in the Energy Sector, 1983, p.58.

In poor countries the capital outlay required to switch from fuelwood to kerosene for cooking is out of the reach of the great majority even when it might pay them to switch because kerosene is actually cheaper than charcoal. In addition to the cost of acquiring a new stove, the switch to kerosene, would involve buying flat-bottomed metal saucepans, to replace the very much cheaper round bottomed earthenware cooking pots. Because the stoves and utensils are more expensive they are also more likely to be stolen, which is another deterrent to having them, if one lives in conditions where theft is all too common.

The one purpose for which kerosene is going to be widely used as we have seen is to provide light because that does not require an expensive appliance.

Sometimes subsidising kerosene has appeared to succeed in encouraging people to switch from fuelwood, because it has led to a great increase in kerosene consumption. But in e.g. Zambia and elsewhere it was eventually realised that the increased consumption of kerosene was not the result of a switch in household use, but was due to the fact that lorry owners discovered that one could use it in place of (unsubsidised) diesel. Efforts to make that illegal have proved difficult to enforce.

Why is fuelwood relatively cheap?

Why has fuelwood continued to be relatively cheap? First and foremost because it is the natural wood cover that is being used, not commercially grown timber. So long as supplies last, indigenous wood is therefore treated as though it were a free good and is being 'mined' without thought for the future.

Another reason why fuelwood may be relatively cheap is that Governments have sometimes controlled, and artificially depressed, its price in urban areas. The reason for keeping down fuelwood prices is much the same as the reason why Governments have often tried to keep down the price of food viz. to protect towndwellers from increases in the cost of living. In the case of food, farmers have reacted by growing less and this has led to a growing dependence on imports to make sure that towndwellers had enough to eat. But the rural supplies of fuelwood are rarely in a position to react in the same way as the farmers; they cannot afford to stop producing for the market. They tend to be very poor people with no alternative opportunities of earning an income. Often they have no access to land or to farm work. Instead they try to eak out a meagre existence by scavenging for firewood wherever they can and either turning it into charcoal or bundling it up and carrying it to the roadside for collection. Lacking alternative opportunities of earning an income, and uncertain whether another trader will come and offer them more, they sell at whatever price they can. That price certainly does not reflect the true economic cost of the wood, which is the cost of replanting wood that is being cut down at a faster rate than the rate at which naturnal replenishment takes place. The price paid by the roadside may also be depressed by the knowledge of a statutory maximum price in the urban area, even when, as is usually the case, that maximum price is honoured more in the breach than the observance! A trader can persuade the charcoal burner that his demand for a higher price is unreasonable on the grounds that there is a fixed retail price laid down by the Government - even when he knows quite well that this maximum price can be evaded. The net effect is that fuelwood prices in the towns are lower than they would be otherwise.

Another reason why fuelwood is usually relatively cheap is that transport costs are often very low and therefore do not constitute a very high proportion of the retail price. In Malawi for instance, although wood is now brought at least 40 kilometers to urban markets, transport costs are estimated to be no more than 30% of the market price.[5] In Zambia a 1978 survey put the transport costs of charcoal at 20% of its retail price, but it may be higher now because the distance over which it has to be carried is now greater.[6] Transport costs are frequently low because wood and charcoal are often brought to the towns as a return load on lorries that have already covered the cost of the trip by a consignment of merchandise in the other direction, taking the merchandise up-country.

A few towndwellers manage to obtain their supplies of fuelwood even more cheaply. They bring back some wood or charcoal when they have visited relatives in their home villages. Buses loaded high with bundles of wood or sacks of charcoal are a common sight, and the car owning middle classes keep

5. French, D., op. cit., p.165.

6. World Bank, Zambia: Issues and Options in the Energy Sector, Washington DC 1983.

themselves substantially supplied in this way - insofar as they use fuelwood rather than, or in addition to, electricity.

Alternatives to wood

For a majority of towndwellers, as we have seen, fuelwood or charcoal are at present the principal fuel used for cooking, and there is a resistance to the use of the alternative of kerosene, mainly because it is effectively more expensive. A widespread switch to kerosene would in any case pose the difficulty that it has to be paid for in foreign exchange. Foreign exchange would also be needed to buy the stoves unless it proved feasible to manufacture them locally without making them even more expensive. It is sometimes suggested that the foreign exchange cost of a total switch to kerosene would not really be very great. A calculation for Senegal, based the assumption that towndwellers would switch completely to kerosene put the increase in the total oil import bill at no more than about 7%.[7] The argument that countries without oil cannot afford to switch from fuelwood to kerosene because of the balance of payments implications may therefore have been exaggerated, though few counries can really afford <u>any</u> increase in their oil import bill, even now that oil has become much cheaper. But that does not in any case dispose of what is really the principal difficulty with such a switch to kerosene, viz that at present relative prices of the two fuels and the relative costs of the appliances in which they are burnt, kerosene would be much more expensive to use. Very similar reasoning can be applied to the alternatives of electricity and gas. The cost of domestically generated hydro electricity has a very large

7. Foley, G. (1985) Exploring the Impact of Conventional Fuel Substitution on Woodfuel Demand (Working Paper), Earthscan, International Institute for Environment and Development, London.

import component because virtually all the equipment and cables have to be imported, but even if the increased import bill following a switch from fuelwood to electricity were thought to be manageable, there would remain the principal difficulty of going over to electricity viz its much higher cost to the consumer. The same reasoning applies equally to gas.

In Nigeria a solution might be to capture the gas from the oil wells which is at present flared and to pipe it to the towns. Gas flaring at present absorbs one and a half times the total amount of energy consumed in Nigeria. Piping it to the towns would involve a major piece of investment with a large foreign exchange component. Gas would then be available to cook on, but it would be a great deal more expensive than the fuelwood used at present. To argue that because the gas is presently wasted, it could be turned to better use without cost is a myth.

The fuelwood solution

If conventional fuels are going to be more expensive as well as involving some cost in terms of scarce foreign exchange, does the answer perhaps lie in taking steps to grow more timber for fuelwood, either in peri-urban plantations or by persuading farmers to grow trees for sale? This has often been advocated especially by the World Bank and other foreign aid agencies. In the Sahel region where the problem is perhaps most accute, some $US160 million of foreign aid has been spent over the last decade on establishing fuelwood plantations, and substantial investments have taken place in other parts of Africa and elsewhere. They have not paid their way and are not likely to do so in future, so long as they have to compete with indigenous wood which is virtually 'free' to rural consumers and for which urban consumers pay little more than the cost of getting it to the towns.

David French has calculated in relation to Malawi that at the prices ruling or likely to rule for indigenous wood the loss incurred by any government seeking to grow wood for sale would be very large indeed, and if it was grown on a sufficient scale to meet the prospective demand for wood it would require a subsidy the equivalent to about 10% of Malawi's GNP. An alternative would be to encourage small farmers to set aside part of their lad to grow trees for fuelwood. But the sales proceeds from the land used to grow trees for fuelwood would be very much less than farmers could obtain from growing eg. maize or other crops. French therefore argues that the best hope is to follow a strategy of persuading farmers to plant enough trees and the right species to protect the soil and to ensure that land does not dissolve into sand. The right species are more likely to be those suitable for building poles which fetch a higher price than, say, eucalypts used for fuelwood.[8] Malawi may not be typical, but its unusually small towns must mean that, if anything, the demand for commercial fuelwood will be easier to satisfy in Malawi rather than more difficult.

Once indigenous wood is totally used up the situation will, of course, be different. Commercially grown timber will no longer have to compete with 'free' indigenous wood and the prices charged for it need then only be competitive with conventional fuels, and it will still have the advantage of not requiring expensive equipment to use. Whether it then makes better sense to go for this solution rather than switch to conventional fuels is at present

8. French, D. <u>op. cit.,</u> pp.161-170.

a largely open question. But one thing is perfectly clear. Once indigenous sources of fuelwood are exhausted, the price of fuel - whether it be conventional fuel or fuelwood - will be very much higher than at present.

Summary and Conclusion

There is no difficulty in explaining why, at present, the majority use fuelwood or charcoal rather than kerosene or other 'conventional' fuels. It is what people are used to, and most studies show it to be substantially cheaper, in part because fuelwood appliances are infinitely cheaper.

But sooner or later indigenous wood will become so scarce that fuelwood prices will rise to levels appropriate to commercially grown timber. This will constitute a very steep rise in price making the cost of using it comparable to conventional fuels. But such a rise in the price of fuelwood does not mean that there will then be a wholesale switch to conventional fuels. First, real incomes are more likely to remain constant or fall than to rise in the foreseeable future. The majority will therefore not be able to spend more on fuel - fuelwood or any other - and will simply have fewer cooked meals. Nor will they be any better able to buy the more expensive appliances or to protect them from thieves.

It is now sometimes argued that it is a vain hope to be able to solve the fuelwood problem with a fuelwood solution, and that the real answer must lie in a gradual switch to conventional fuels. This argument is buttressed by calculations to show that replacing fuelwood by eg. kerosene would not greatly add to total world consumption of oil or even greatly increase Third World countries import bills for oil.[9]

Maybe the fuelwood problem cannot be solved by a fuelwood solution. But the proposed alternative, is going to be feasible only on three conditions. First, world oil prices would have to remain at the very much lower levels to which they have recently fallen. The experts are divided on whether this is likely to happen.

Secondly, the cost of manufacturing conventional fuel appliances would have to be greatly reduced. That may not be easy to bring about.

Thirdly, real incomes would have to rise to the levels at present only enjoyed by the middle classes. That is what development is all about. But the experience of the last 10 years gives no grounds for optimism on this score.

The 'conventional fuel' solution to the fuelwood problem may therefore be no more practicable than the fuelwood solution which it is supposed to replace.

In these circumstances there will be pressure on governments to reduce the price of fuel by subsidising it. It is very improbable that they will be able to do so or will wish to. At a time when subsidies are being removed from food it is unlikely that governments will want to subsidise the means of cooking it.

9. Foley, G., <u>op. cit.</u>

The urban fuel problem is really a problem of low per capita incomes. The only real way to solve it is by economic development that raises incomes to the levels at which people can afford to buy fuel at what it costs to produce it. How to bring <u>that</u> about raises an even more difficult set of questions!

FUEL TRANSITIONS WITHIN HOUSEHOLDS

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The question of fuel transitions is a challenging one. The much discussed problem of biomass fuels in Third world countries is critically an issue of fuel for cooking, as it is activity in the household sector which consumes the bulk of the biomass fuel used. In very poor countries, such as Nepal and Ethiopia, biomass fuels for cooking form 90% or more of total national energy consumption. Less poverty stricken LDC's use a lower proportion of these fuels, but this often reflects increased consumption of commercial fuels in other sectors of the economy more than a move away from the use of biomass fuels in households. It is only in the Newly-Industrializing Countries, such as South Korea, which have experienced a sustained process of economic growth and restructuring that biomass fuel consumption has declined significantly. Even Brazil, which is usually classed as a NIC, used about 25% more biomass fuel in 1980 than in 1970. In few Third World countries is biomass fuel use declining.

Such figures can be misleading, however, as in many Third world nations the consumption of biomass fuels is growing at a significantly slower rate than either the population or the formation of households. In other words, biomass fuel consumption <u>per capita</u> and <u>per household</u> is declining, whilst that of commercial fuels <u>in the household sector</u> is increasing (to continue an example, consumption of LPG and electricity in Brazilian households more than doubled in the 1970's - a rate of increase far in excess of population growth).

What this all suggests is that the pattern of energy use in households is indeed changing, with biomass fuels declining in importance and commercial fuels becoming more dominant - in other words, an energy transition. The pace of this transition, however, is so slow as to appear almost imperceptible. What is really happening in the household sector? This paper attempts to provide some answers by, firstly, outlining the main factors likely to precipitate an energy transition and, secondly, considering some empirical evidence of such transitions from detailed household surveys conducted as part of the Beijer Institute energy studies of Kenya and Grenada.

The first point is obvious: energy transitions are related to economic development. The process involves a shift from free or cheap indigenous fuel sources to more expensive, frequently imported fuel sources. The ability to pay for this requires economic development at the national level (especially where foreign exchange is required) and increased prosperity for the households changing fuels. This involves issues of both economic growth and income distribution.

The second factor is closely associated with economic development: the process of urbanisation. A wealth of empirical experience tells us that urban familes use a greater proportion of commercial fuels than rural households. This is partly a question of supply - free biomass fuels are rarely available to the urban population - and partly one of prosperity - in most

Third World countries urban incomes are higher. As such, as Third World countries become more urban, the nature of household energy demand will change regardless of the pattern of economic development occurring.

The third factor is changes to the biomass fuel supply. If biomass fuels become scarcer, and in particular if they become commodified or (if already a commodity) more expensive, then households are more likely to turn to commercial alternatives. This can occur in either urban or rural areas. In other words, pressures on biomass fuel supplies will lead to changing patterns of fuel consumption <u>within</u> each sector.

The final factor is the corollory of the third: if commercial fuels become cheaper and/or more readily available, then their consumption in the household sector is likely to increase. The development of distribution systems is crucial here, as it is frequently the physical unavailability (rather than the price) of commercial fuels such as kerosene which constrains consumption. In some cases this may involve the introduction of a new source of fuel which requires a permanent infrastructure - for example, the development of natural gas in Bangladesh or of HEP in numerous other countries.

The points listed above are abstract speculations. What does empirical experience tell us?

Annex 1 summarises the results of a survey of cooking fuels in 646 households in five medium-sized Kenyan towns (Meru, Iseolo, Machakos, Kismu and Mombasa). They key points are as follows:

1. There is a clear income effect. Wood use declines linearly with increasing income, the use of LPG and electricity increases with increasing income and the use of charcoal and kerosene is highest amongst middle-income groups.

2. The use of more than one fuel for cooking is the norm, and a number of households use three or more fuels for this end-use. As different fuels are generally associated with different cooking appliances, it is common to find complex kitchens which contain a number of fuel/technology combinations.

3. This results in considerable variation in the quantity of each fuel used by households within each income group; indeed, this variation is greater for many fuels than the variation between income groups. A further factor which partly explains such variation is household size, which again varies considerably.

Annex 2 summarises the results of a survey of 244 households conducted in a number of rural and urban settlements in the island nation of Grenada. Again, the survey was part of a Beijer Institute study, and was executed by the present author. The main conclusions are as follows:

1. Differences exist in the pattern of fuel use between rural and urban areas. Commercial fuels are used less frequently and in smaller quantities in rural areas, while wood is used by only a very small proportion of the urban population.

2. Within each sector, a clear income effect was again found, with as expected consumption of preferred but expensive commercial fuels with increasing incomes. This partly reflects different fuels used for cooking and is partly due to higher income households using energy for a far wider range of activities.

3. For all sections of the population,the use of two, three or even four fuel/device combinations for cooking was again common. Overall, nearly three-quarters of Grenadian households use more than one cooking fuel. This is particularly true in rural

Grenada, where 29% of households use 3 or 4 fuel/appliance combinations.

4. In the execution of the survey, many of the households interviewed said that the use of more than one cooking fuel was a conscious budgetting strategy. It represented a trade-off between the convenience and the cost of fuels. Typically, a household would buy a fixed quantity (e.g. a bottle of LPG, a tin of charcoal) per week or month and use it while it lasted. It would be supplemented with cheaper, less preferred alternatives (charcoal for the better-off, wood for the others), which would be used exclusively if the expensive but favoured fuel ran out.

What conclusions can be drawn from these two surveys? Comparing the Kenya urban survey with the Beijer Institute rural household survey shows that the energy transition in Kenyan households is mainly an urban phenomenon. In Kenyan towns and throughout Grenada, the transition appears to involve a long period of adaption. The crucial feature of these changes is that they occur over time within individual households, and during the transition these households will be extremely flexible in combining different quantities of different fuels in response to fuel costs and availability, income availability and other households needs. As such, the fuel transition in the household sector appears not to be a question of households successively switching from one fuel to another. The multiple use of fuels by households means that they can respond very rapidly to changes in cost or supply conditions, and suggests that for many, past changes are far from irreversible. How policy-makers respond to this pattern of transition is an open question - and one to which I suspect there will be no easy answers.

ANNEX 1:

DOMESTIC ENERGY CONSUMPTION IN MEDIUM-SIZED KENYAN CITIES

SURVEY RESULTS

The results of the survey of household energy consumption in medium-sized Kenyan cities reveals a pattern in which the purposes for which energy is used and the fuels used varies greatly by income. Five income groups were identified (Table 1.1).

TABLE 1.1 INCOME GROUPS IDENTIFIED IN THE KENYAN SURVEY

Group	Income Kenyan Shillings/Month	Households Number	Per cent
1	0- 258 Ksh/M	17	3
2	259- 759 Ksh/M	177	27
3	760-1518 Ksh/M	196	30
4	1519-2554 Ksh/M	176	27
5	Over 2554 Ksh/M	79	12
Total		645	100

The survey found that across all income groups for the five towns the range of energy-using activities increased with increasing income and the types of fuels used changed from predominantly biomass fuels amongst the households with the lowest income through a mix of biomass fuels and commercial fuels to a pattern of energy use in which petroleum products and electricity dominated. This held true for all five settlements. In a preliminary analysis it was determined that variation between the five towns was not significnt. It was consequently possible to complete the analysis and present the results on an aggregate basis.

The pattern of household energy use discovered was extremely complex. Many households used individual fuels for more than one end-use (see Table 1.2). Similarly, it was extremely common to find individual households which used more than one type of fuel for any one end-use.

TABLE 1.2 **HOUSEHOLDS COOKING BY FUELS USED**
(Per cent of Income Group)

Fuel/Income Group	1	2	3	4	5	Total
Wood	82.4	37.9	29.6	15.3	6.3	26.5
Charcoal	64.7	80.8	92.3	86.9	69.6	84.2
Kerosene	17.6	54.2	64.3	59.1	20.3	53.5
Gas: Burners	5.9	-	6.6	27.8	54.4	16.4
Oven	-	-	2.00	13.6	26.6	7.6
Electricity: Burners	-	-	-	10.8	68.4	11.3
Oven	-	-	-	10.2	68.4	11.2

FUELS USED FOR COOKING

This pattern is demonstrated in Table 1.2, which shows the percentage of households in each income group which use particular fuels for cooking, which is by far the most important end-use in terms of the quantities of fuel used. By necessity, all households cook; a fact reflected in the 100% response to this question. Many combinations of fuel use for cooking were found, but a clear income pattern is revealed. As the table shows, only a very few per cent of the households in the three lowest income categories use gas or electricity, which are the most expensive fuels, for cooking. In income group 4, roughly one in four households use gas and one in ten use electricity for cooking, with many of these using both burners and ovens. Amongst the highest income groups, over half use gas and over two-thirds use electricity for cooking, with again both burners and ovens being the norm. These figures mean that in a number of cases individual high-income households use both gas and electricity for cooking; with gas burners and an electric stove containing both burners and an oven usually found. The extent to which the use of the more convenient but expensive commercial fuels for cooking is a function of income is dramatically demonstrated by these figures. These results are no surprise, of course, but are of great significance in that they indicate strongly both the effects of price on fuel use and, consequently, the severe limits which are imposed upon any potential fuel-switching strategies intended to restrict urban charcoal and fuelwood demand by the substitution of commercial alternatives.

The complexity of fuel use for cooking among high-income families is compounded by the fact that over 20% use kerosene and nearly 70% use charcoal. There are even a few high-income families which use wood. Many high-income households must consequently use three, or even four, different types of fuel for cooking.

Each fuel is used in a different type of stove, with the cost of these appliances again imposing a major income constraint upon the pattern of fuel use. It is consequently clear that, in medium sized Kenyan cities, gas and electricity are rich men's cooking fuels, but even amongst the highest income groups they are supplemented by other fuels such as wood, kerosene and, in particular, charcoal.

For households in income groups 2, 3, and 4, charcoal and kerosene are the main cooking fuels, with again most households using at least two types of fuel and the use of wood decreasing and gas and electricity increasing with increasing income. Indeed, throughout urban Kenya charcoal is by far the most commonly used cooking fuel and the urban charcoal market penetrates to even the most remote provinces, providing a major source of off-farm income but creating widespread fears about substantial adverse environmental consequences. Kerosene is used by between 54% and 65% of households in income groups 2, 3 and 4; an indication of its importance as a fuel which is widely used either as the main cooking fuel or, far more commonly, in conjunction with charcoal and/or other fuels.

Income Group 4, which consists of households with a middle-to-high income, displays the greatest complexity in the range of cooking fuels used. At least 10% of the sample use each of the five cooking fuels listed and, as the figures in Table 1.2 indicate, multiple use of 3 or 4 fuels is common. The reasons behind this are difficult to ascertain, but they probably reflect the ability of households with this level of income to purchase a range of cooking appliances in association with a consciousness of the differing costs of fuels. Preferred fuels cost more, and will consequently be used judiciously. The use of a wide range of fuels permits far greater flexibility in budgetting for fuel expenditure, as cost and convenience can be traded off to reflect income availability. This pattern will hold true for all households showing the multiple use of fuels, but is particularly strong for the households sampled in income group 4.

Income groups 2 and 3 show less variation, with the more expensive fuels being less commonly used and wood being commensurately more important. The use of 2 or 3 cooking fuels is still the norm, however, and it appears likely that the cost of cooking appliances for gas and electricity is as important a constraint on their use as the cost of the fuels themselves. For these two income groups, which comprise the bulk of the lower- and middle-income population of medium-sized cities in Kenya, the general pattern of fuel use for cooking is consequently of charcoal supplemented by kerosene and/or wood. For such households, therefore, the critical relationship is the relative cost and availability of charcoal and kerosene within the urban market. Given that most households already use both fuels for cooking, and consequently possess the appliances in which they are used, any major change in their relative prices is likely to impact rapidly on the demand for both the fuel which has changed in price <u>and</u> the alternatives which can be readily substituted for it should the nature of their price differentials change. This form of relationship between important commercial fuels and indigenous biomass fuels is of crucial importance within the energy economy, and is explored in greater depth below.

For the few very poor households in income group 1, wood and, to a lesser extent, charcoal dominate the use of fuels for cooking. This reflects the absolute nature of income constraints for the poorest of the urban poor. For such people, any money spent on fuel is a hardship and the notion of access to the more expensive fuels such as gas and electricity is one which has little relevance in the face of the absolute poverty they face.

As we shall see, these income constraints are reflected not only in the far lower incidence of use of fuels other than wood. They can also be seen in the lower levels of household consumption amongst poor families which do use such fuels.

The aggregate picture for fuel use for cooking consequently displays a predictable, but no less significant for that, pattern of variation between income groups. To summarise, the incidence of wood use declines consistently with income, with a dramatic drop from income group 1 to income group 2 and a gradual tailing off after that. In contrast, the use of the more expensive fuels, gas and electricity, is largely confined to higher income groups, and amongst them increases rapidly from group 4 to group 5. Charcoal and kerosene are by far the most widely-used fuels, and the incidence of their use amongst the five income groups approaches something like a normal distribution curve. For all groups, charcoal is widely used, but is less predominant in groups 1 and 5 and is most commonly used in group 3. Kerosene is less popular, with around 20% of households in groups 1 and 5 using it and again the largest proportion of users being found in group 3; in this case 64.3%. These general patterns reveal a great deal. They demonstrate in particular the frequency of use of two or more fuels for cooking (a point stressed above) and the overwhelming importance of income as a determinant of fuel use.

TABLE 1.3

Household Consumption Of Charcoal In Kilograms (Gigajoules)

End-Use Combinations	Total Annual Consumption KG	(GJ)	Number Of Households	Average Annual Consumption KG	(GJ)	Standard Deviation. KG
Cooking Only						
Income Group 1	3066	(100)	8	383	(12)	255
" " 2	48038	(1566)	71	677	(22)	391
" " 3	60550	(1973)	80	757	(25)	359
" " 4	56530	(1843)	76	744	(24)	437
" " 5	23286	(759)	42	554	(18)	369
Total	191468	(6242)	277	691	(23)	396
Cooking/Ironing						
Income Group 1	2093	(68)	3	698	(23)	288
" " 2	61282	(1998)	72	851	(28)	432
" " 3	93521	(3049)	100	935	(30)	530
" " 4	76470	(2493)	77	993	(32)	524
" " 5	12183	(397)	13	937	(31)	549
Total	246412	(8033)	266	926	(30)	501

TABLE 1.4

Household Consumption Of Kerosene. In Litres (Gigajoules)

End-Use Combinations	Total Annual Consumption Litres	(GJ)	Number Of Households	Average Annual Consumption Litres	(GJ)	Standard Deviation Litres
Cooking Only						
Income Group 1	-	-	-	-	-	-
" " 2	732	(26)	3	224	(9)	120
" " 3	3228	(113)	20	161	(6)	98
" " 4	5956	(209)	43	138	(5)	79
" " 5	1560	(55)	9	173	(6)	88
Total	11476	(403)	75	153	(6)	88
Lighting Only						
Income Group 1	424	(15)	5	84	(3)	61
" " 2	8998	(316)	55	163	(6)	158
" " 3	7531	(264)	42	179	(6)	83
" " 4	4922	(173)	26	189	(7)	142
" " 5	192	(7)	1	192	(7)	-
Total	22067	(775)	129	171	(6)	210
Lighting/Cooking						
Income Group 1	180	(6)	2	90	(3)	25
" " 2	11648	(409)	73	160	(6)	94
" " 3	17492	(614)	91	192	(7)	143
" " 4	12145	(426)	51	238	(8)	216
" " 5	1814	(64)	6	302	(11)	263
Total	43496	(1527)	224	194	(7)	156

Note: Consumption figures for a number of households in the survey were not obtained. They have been excluded from the above table.

TABLE 1.5

Household Consumption Of Gas. In Kilograms (Gigajoules)

End-Use Combinations	Total Annual Consumption KG	(GJ)	Number Of Households	Average Annual Consumption KG	(GJ)	Standard Deviation KG
Cooking Only						
Income Group 1	156	(7)	1	156	(7)	-
" " 3	1687	(76)	13	130	(6)	111
" " 4	8192	(370)	45	182	(8)	115
" " 5	6684	(302)	41	163	(7)	91
Total	16719	(756)	100	167	(8)	105
Cooking/Water Heating						
Income Group 4	78	(4)	1	78	(4)	-
Lighting/Cooking						
Income Group 4	520	(24)	3	173	(8)	-
" " 5	195	(9)	1	195	(9)	
Total	715	(33)	4	179	(8)	

TABLE 1.6

Household Electricity Consumption.
Kilowatt Hours (Gigajoules)

End-Use Combinations	Total Annual Consumption KWH	(GJ)	Number Of Households	Average Annual Consumption KWH	(GJ)
Lighting					
Income Group 1	821	(3)	1	821	(3)
" " 2	3944	(14)	7	563	(2)
" " 3	19600	(71)	34	576	(2)
" " 4	58317	(209)	57	1023	(4)
" " 5	5747	(21)	8	718	(3)
Lighting/Refrigeration					
Income Group 3	10251	(37)	6	1708	(6)
" " 4	39809	(143)	25	1592	(6)
" " 5	18531	(67)	8	2318	(8)
Lighting/Cooking					
Income Group 4	9789	(35)	6	1631	(6)
" " 5	10188	(37)	5	2038	(8)
Lighting/Other					
Income Group 4	8464	(30)	3	2821	(10)
" " 5	22903	(82)	4	5726	(21)
Lighting/Refrigeration/Cooking					
Income Group 4	16859	(61)	7	2408	(9)
" " 5	45326	(163)	11	4121	(15)
Lighting/Refrigeration/Other					
Income Group 3	2337	(8)	1	2337	(8)
" " 4	3299	(12)	1	3299	(12)
Lighting/Cooking/Other					
Income Group 4	6124	(22)	2	3062	(10)
" " 5	125450	(453)	16	7841	(28)
Lighting/Cooking/Refrigeration/Other					
Income Group 4	31011	(111)	4	7753	(28)
" " 5	167984	(600)	22	7636	(27)

ANNEX 2

DOMESTIC ENERGY CONSUMPTION IN GRENADA

TABLE 2.1 DOMESTIC SECTOR FUEL CONSUMPTION IN 1982

Fuel	Energy Content (Thousands of Gigajoules)	
Woodfuel	378	43%
Charcoal	240	27%
Liquid Propane Gas	62	7%
Kerosene	148	17%
Electricity	45	5%
Total	873	100%

The survey was conducted by 24 young Grenadians trained by the author in August 1983.

In all, 244 interviews were successfully completed, representing something over 1% of the households in the country. Separate samples were drawn for rural and urban areas, as it was expected that there would be significant differences in patterns of domestic fuel use between towns and rural areas. The questionnaire contained a number of questions relating to the household's economic status, and the information these questions provided was used to divide each sector into high-, middle- and low-income groups.

The results of the household survey show a number of distinct trends in domestic energy use, with clear differences apparent between rural and urban communities and between income groups within each of these communities. There are also a number of characteristics which reflect the overall energy economy of the country. Most families use a complex combination of fuels, with more than one energy source frequently used for any one end-use. This is particularly true for cooking, which constitutes the main domestic energy use for all but a few high-income families, and many households use a number of different devices to prepare food (Table 2.2). Most families use both purely commercial fuels such as kerosene, gas and electricity and biomass-derived fuels such as charcoal, wood and coconut husks and there appears to be a complex interaction between the different fuels as households carefully balance the income they can spare for energy with the availability of and their preferences for different types of fuel. There is a clear hierarchy of fuels in terms of preference, convenience and esteem; a hierarchy which is paralleled by the increasing cost of both the fuels and, importantly, the devices in which they are used.

At the bottom of the hierarchy are wood and coconut husks, which for most households constitute an energy source of last resort. Both are non-commercial; they are gathered rather than purchased and are freely available in most parts of the country. These fuels are burnt in simple hearths, rather than in wood stoves, and appear to be used with little conception of efficiency or conservation. Woodfuel and coconut husks are rarely the main cooking fuel. Only 5 households in the sample (2% of the total) relied solely on a hearth for cooking and these fuels are typically used to supplement other preferred energy sources. The large quantities of wood consumed in Grenada are a consequence of the technology of use, and reflect the ease with which wood is gathered on the island, rather than illustrating the dominance of woodfuel within the domestic energy sector. Although we say in Table 2.1 that woodfuel constitutes 43% of the energy consumed in Grenadian households, it appears that much of this energy dissipates carelessly into the atmosphere without making an effective contribution to energy needs.

The use of woodfuel displays a marked difference between urban and rural areas. Only 12% of the urban households interviewed used hearths for cooking, and even in these cases it is only used to supplement other fuels. In contrast, woodfuel and, to a lesser extent, coconut husks make a significant contribution to energy use for cooking in rural areas, with levels of use amongst low-income households in particular, being high. Wood is not the dominant fuel for even these families, however: wood is used by only 62% of the low-income households surveyed and, as Table 2.2 shows, is typically used in conjunction with charcoal and/or either kerosene or gas. In rural Grenada, the incidence of wood use and the quantities used decline with increasing income, with few high-income households in particular, relying on this energy source to any significant degree. Wood and husks are invariably gathered in rural areas. The survey produced no evidence to suggest that there exists any supply problems, with few respondents travelling any distance or spending significant amounts of time gathering wood.

Above wood on the fuel hierarchy is charcoal, which is by far the most widely used energy source for cooking in both rural and urban areas. In the rural sample, nine out of ten of the households surveyed owned a coal pot (a simple open brazier) and there was no variation in this pattern between income groups. The importance of the coal pot to the family did vary widely between income groups though, with charcoal constituting the dominant cooking fuel for many low-income households but only being used to supplement preferred alternatives for many higher-income families. As Table 2.2 shows, 59% of low-income rural households use a coal pot alone or a coal pot supplemented by a hearth. This contrasts with figures of 30% for the middle-income group and only 17% for the high-income group. The corollary of these figures are those for charcoal use in conjunction with commercial fuels. 31% of low-income families use charcoal or wood and charcoal in combination with either gas or kerosene, figures which compare with 57% and 72% for the middle- and high-income groups respectively. It can be seen from these statistics that charcoal is the most important fuel in rural areas, with most households using it on a regular basis. This is true for all income groups, but the role charcoal plays in the household energy budget varies considerably between groups. For poorer families charcoal is the preferred fuel, given constraints imposed by income, and is mainly supplemented by wood and husks, whilst for households with higher incomes most fuels used are purchased and charcoal is used to supplement kerosene and, in particular, bottled gas.

As is true throughout the country, the main biomass-derived fuel in the island`s towns is charcoal, and a sizeable majority of the sample own a coal pot. The proportion doing so is smaller for the high- and middle-income groups (71% and 74% respectively)

TABLE 2.2

GRENADA DOMESTIC ENERGY SURVEY; APPLIANCE COMBINATIONS FOR COOKING

		HEARTH ONLY (%)	COAL POT ONLY (%)	LPG STOVE ONLY (%)	WICK STOVE ONLY (%)	HEARTH COAL POT (%)	HEARTH LPG STOVE (%)	HEARTH WICK STOVE (%)	COAL POT LPG STOVE (%)	COAL POT WICK STOVE (%)	HEARTH COAL POT LPG STOVE (%)	HEARTH COAL POT WICK STOVE (%)	COAL POT LPG STOVE WICK STOVE (%)	OTHERS (%)	TOTAL
RURAL (75% TOTAL POPULATION)	HIGH-INCOME (13%)	0	11	0	6	6	0	0	33	0	39	0	0	6	100%
	MIDDLE-INCOME (24%)	3	12	3	0	18	3	3	18	3	27	3	3	3	100%
	LOW-INCOME (63%)	5	21	4	0	38	1	0	8	4	13	6	0	1	100%
URBAN (25% TOTAL POPULATION)	HIGH-INCOME (18%)	0	0	29	0	0	0	0	43	14	3	0	7	7	100%
	MIDDLE-INCOME (40%)	0	3	16	10	6	0	0	45	13	0	0	0	6	100%
	LOW-INCOME (42%)	0	25	13	6	9	0	0	22	22	0	0	0	0	100%

than for other sections of the island`s population, however, and in these households charcoal is rarely the main cooking fuel. This is reflected in the smaller quantities of the fuel used by these households, with the high-income group in particular using significantly less than lower-income urban and all rural households. In contrast, charcoal is the main cooking fuel for 34% of low-income urban households and is important for the majority of the rest. 47% of the low-income households surveyed use charcoal in conjunction with either gas or kerosene. The latter two fuels are generally seen as more satisfactory, but are significantly more expensive and are used with care. Overall, charcoal is clearly of major importance in the urban areas, but is perhaps less dominant than in other parts of the country and in particular is at best only a supplementary fuel amongst the higher-income groups.

Within Grenada`s household energy economy, charcoal is an intermediary fuel in all ways. Most households buy charcoal, and towns such as St. George`s and Grenville have a number of charcoal dealers in their main markets. A quarter of the rural households surveyed make their own charcoal however, and many other families (particularly in rural areas) buy or barter for charcoal from friends or neighbours, rather than purchasing the fuel in the commercial markets. In consequence, in Grenada charcoal is not a purely commercial fuel and is clearly very different in nature from the various petroleum products used in Grenadian households.

Many families which make charcoal do so on an irregular basis, using dead trees from their farms as and when they become available. The scale of production is small and the technology simple, with pits typically being no larger than 2 or 3 metres long and a metre deep and firing lasting only one or two days. The energy efficiency of this method of production is extremely low, with 80% to 90% of the wood`s calorific value lost in the production of the charcoal. As with the gathering and consumption of wood, this reflects the existing ready availability of wood in the lush tropical forest and tree crop farms which cover much of Grenada. Data was obtained from the Ministry of Agriculture and Forestry concerning the annual wood growth in Grenada. As Table 2.3 shows, the 1982 figure of 92,750 tonnes exceeded the demand for wood for fuel of 83,000 tonnes, suggesting that even present, highly inefficient patterns of use are not leading to any significant pressure upon the environment`s ability to cope with the demand for wood for fuel.

The projections of future developments give cause for concern, however, as if present patterns of consumption continue and demand grows in line with the growth of population anticipated by the Census Bureau, then by 1992 demand for wood for fuel will exceed annual wood growth, leading to increasing pressure upon stocks and possibly giving rise to the cumulative cycle of deforestation and environmental deterioration found in so many other parts of the Third World. If this were to occur, the steep slopes and tropical storms which characterise the island would result in rapid soil erosion, possible water retention problems and yet further decline in the island`s biomass productivity. That such a possibility exists seems unlikely when one looks at

TABLE 2.3

GRENADA: WOOD STOCKS, GROWTH AND DEMAND 1982-2002

		1982 (THOUSAND TONNES)	1987	1992	1997	2002
WOOD STOCK	Tree crops	811	801	792	776	744
	Forest	905	887	869	842	796
	Other	150	157	161	164	165
	TOTAL	1866	1845	1822	1782	1705
Annual Wood Growth		92.75	91.42	90.05	87.87	83.91
Demand on wood resources						
	Woodfuel	24.1	25.2	26.3	27.5	28.7
	Charcoal	58.9	62.0	65.0	68.4	71.8
	TOTAL	83.0	87.2	91.3	95.9	100.5
Wood growth minus demand		9.75	4.22	-0.85	-8.03	-16.59

the lush greenery of contemporary Grenada, but experience from many parts of the world tells us that such seeming plenty can quickly prove an illusion.

Of course, predictions based simply upon present trends and demographic projections are a very crude guide to future possibilities, as demand for wood fuel and charcoal will depend upon many variables. Not least amongst these are the cost and availability of the petroleum-based fuels used in Grenadian households, as the survey identified an close relationship to exist between these fuels and biomass-based energy sources.

The two petroleum-based fuels used for cooking are bottled liquid propane gas, which is widely used, and kerosene, which is less important. Bottled gas in particular is regarded as the most desirable cooking fuel, but both the gas and the stoves in which it is used are far more expensive than the biomass-based alternative, and in consequence this fuel is used more widely by middle- and, in particular, high-income households than by low-income families.

Bottled gas is a widely-used fuel in Grenada`s towns, with 58% of the urban households surveyed owning a gas stove. There is a clear income gradient in this, however, with only 38% of low-income families possessing a stove, compared to figures of 68% for the middle-income group and 86% for the high-income group. Bottled gas is the main cooking fuel used by high-income families and the average quantity used (7.9 lb per week) is far higher than that used by other sections of the community. It is also important for middle-income households, but is more frequently used in conjunction with other fuels. 45% of this category use both a coal pot and a gas stove, and the quantities of fuel used (averaging 6 kg of charcoal and 5.5 lb of gas per week) suggest that both are used on a regular basis.

Kerosene stoves are used by 26% of the urban households interviewed, and there is no significant income factor in the use of this fuel for cooking; the proportion of low-income families using kerosene stoves (28%) is almost identical to that of high-income households (29%). The quantity of kerosene used does increase significantly with income, however, suggesting that it is the main fuel for the high-income families owning a kerosene stove but is used in conjunction with charcoal by lower income households.

Seventy-seven per cent of high-income families in rural areas use gas, compared to 57% of middle-income households and just 26% of the low-income group. This clear income variation reflects the economics of domestic energy in Grenada. Bottled gas is widely regarded as the preferred cooking fuel but both the cost of the gas itself and the price of the appliances involved puts this option beyond the reach of many sections of the community. As is the case with other fuels, in rural areas, gas is almost always used in conjunction with other fuels, most typically charcoal alone or wood and charcoal. These complex combinations of fuels used for cooking have been found throughout the island of Grenada.

As Table 2.4 shows, over a fifth of the households surveyed owned three or four cooking appliances and used three or four different fuels for cooking alone. They reflect a pattern whereby fuel preferences are traded off against available income, and in consequence there is considerable variation in the combinations which are dominant in different income groups.

TABLE 2.4 NUMBER OF COOKING APPLIANCES BY SECTOR

	1 Device	2 Devices	3 Devices	4 Devices
Rural	25%	49%	28%	1%
Urban	35%	58%	3%	5%
Total	27%	52%	18%	3%

Where two or more devices are used, fuels lower down the hierarchy are used to supplement the more favoured but more expensive alternatives. In many cases households will purchase a fixed quantity of fuel on a weekly or monthly basis and either use it until it runs out and turn to less-favoured energy sources or ration the fuel and continually supplement it with other of lower esteem and cost. This pattern is true for different fuel combinations, with charcoal typically the lynch-pin. For example, many low-income households will buy one tin of charcoal (approx. 4.3 kg) per week and supplement it with wood and husks, whilst higher-income families may buy a 20lb bottle of gas once a month and supplement it with charcoal and, occasionally, wood. Households carefully budget for the cost of energy and balance their needs and resources by these complex patterns of multiple fuel-use. There consequently exists a close relationship, and even a level of interchangeability, between petroleum-derived and biomass-based fuels. This is one of the most important characteristics of the domestic energy economy of Grenada, as changes in the availability or price of one fuel will have immediate repercussions for level of demand for other, seemingly not closely related, domestic fuels. For example, any significant rise in the price of bottled gas will lead to greater levels of use of biomass-based fuels, with all of the environmental implications this entails, whilst, conversely, a diminishing in the ready availability of wood for hearth and charcoal-making will lead to increased demand for imported petroleum-derived fuels; a matter of concern for an economy such as Grenada`s.

The pattern of fuel-use for lighting and other purposes is less complex than for charcoal. A few households surveyed own kerosene powered refrigerators or charcoal-burning irons, but apart from these, all households using energy for purposes other than lighting and cooking relied exclusively on electricity. The use of energy for `other` purposes therefore depends on the availability of both an electrical connection (which is far from universal) and money to buy expensive electrically powered consumer items. In consquence, `other` end-users are far more common amongst high-income groups and in urban areas, where electrical connections are cheaper and easier to obtain. This pattern is precisely what one would expect, but the survey revealed a clear pattern to substantiate these expectations.

In Grenada`s towns, only 28% of the low-income households surveyed used energy for purposes other than lighting and cooking, and in most cases these households owned one other appliance, such as a refrigerator or a television, only. These figures contrast sharply with those found for both high- and middle-income households. Ninety-three per cent of the high-income group and 94% of the middle income group owned `other` appliances, with many families owning several and the range of types of appliance far greater than those found for low-income households. All but one of the high-income households and most middle-income households owned both a refrigerator and an iron and the possession of appliances as diverse a television, freezer, sewing machine and electric mixer by one family was found.

In the rural communities surveyed, a pattern of variation in energy use according to income is also apparent for end-uses other than cooking and lighting. Only 20% of the low-income group used energy for `other` purposes, and apart from a couple of households the use was restricted to refrigerators or irons (powered by either electricity or charcoal). In contrast, 61% of middle-income households and 78% of high-income households had `other` end-uses and televisions, stereos and radios were more common. Even these devices were far from universal, however, and none of the more sophisticated consumer items found amongst the more affluent sections of the urban community were found in the rural sample.

Apart from a handful of households which use lamps powered by gas canisters, house lighting in Grenada comes from either kerosene lamps or electric lighting. Again, clear differences exist between rural and urban areas and the three income groups for the use of electric lights but 88% of the households interviewed own one or more kerosene lamps and for most low-income families these are the only source of lighting. Even households with electrical connections usually own at least one lamp; a reflection of the continual power cuts which affect most parts of the country. This again results in more than one fuel being used for a particular end-use, but for lighting this is a pattern born of necessity, rather than a reflection of the careful balancing of needs and income found in the pattern of fuel use for cooking.

In town most areas are served by electricity, and consequently nearly all households which can afford it have electricity connections. This is clearly reflected in the results of the survey, with 86% of high-income household and 84% of middle-income households possessing electric lights. In contrast, only 41% of the low-income households in the survey had electric lights, with the remaining majority depending exclusively on kerosene. In many cases this reflected the cost of having an electrical connection installed rather than of the fuel itself, a cost which is prohibitively high for many poor families.

The pattern of fuel use for lighting in rural areas shows a similar income-related pattern, but is modified by the non-availability of electrical connections in some of the more remote section of the island. Seventy-eight per cent of the high-income rural households have electric lighting, compared to 58% for the middle-income group and just 19% of the low-income group. Again, the cost and availability of electrical connections was frequently cited as being more important than the cost of the fuel itself in determining this pattern.

The results of the survey discussed above display a number of clear patterns in the domestic energy economy of Grenada. Cooking is by far the most important use of fuels for all but the more affluent sections of the urban population, and for this task many households utilise a number of fuel sources in a sophisticated balance of cost and convenience. Households use preferred but costlier fuels within clearly identified budgeting constraints and supplementing these fuels as necessary with less-preferred alternatives which are cheaper or, for woodfuel and some charcoal, freely available. A clear hierarchy of fuels, in terms of prestige and convenience, is identifiable and clear differences in patterns of fuel use between both rural and urban sectors and income groups within each of these sectors is apparent. Any increase in the level of urbanisation and/or growth in the population`s affluence is likely to result in increased demand for petroleum-derived fuels, and in particular bottled liquid propane gas and fuel-oil-derived electricity. This will necessitate further imports of expensive oil products, increasing the strain upon scarce foreign exchange earnings.

Conversely, if the price of such products rises sharply, a contingency which seems likely given the events of 1973-4 and 1978-9, then many families are likely to find the cost of oil-based fuels prohibitive and cut back on the quantitities used. The results of the survey suggest that this could be done with little difficulty, as households readily switch between wood-based and petroleum-derived energy sources. Similarly, if any overall development fails to take place and the population grows at the expected rate then the increased demand is likely to be for wood and charcoal more than for gas, kerosene and electricity, for these are the main fuels used by the poorer sections of the community, and are particularly dominant in rural areas.

Which, if any, of these scenarios transpires is hard to predict, for each depends upon the complex interaction of a number of variables. It is this complexity that the present study has highlighted, for the results of the survey conducted in Grenada demonstrate that imported, commercial fuels and biomass-based, largely non-commercial fuels interact in a complex pattern at the household level as families carefully budget for their fuel needs and the income available to meet these needs.

Investigating Medium and Long-Term Energy Transitions in Asia

Peter Pearson

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This paper reports on some preliminary investigations of medium and long-term transitions between the use of traditional forms of energy (hereafter, TE), such as woodfuel, charcoal and animal and crop residues, and commercial forms of energy (CE), like coal, petroleum and electricity, in less-developed countries (LDCs). In my view, understanding these transitions is important for energy policy-making and forecasting for both TE and CE.

It is now well-known that the energy problems of LDCs, unlike those of more-developed countries, usually have two major dimensions: problems over the availability and affordability of CE; and problems with supplies of TE, and with the environmental consequences, such as deforestation, soil erosion and flooding, often associated with them. What links these two sets of problems is that they involve changes in the absolute levels and relative importance of different fuels and fuel-using appliances. To understand these changes, it is necessary to analyse them as part of the long-term transitions within and between TE and CE, that are intimately bound up with the processes of economic development. Thus a proper understanding of the energy situation in an LDC requires both: (i) a knowledge of the current linkages between CE and TE that influence short-term substitution between fuels and fuel-using appliances, and (ii) a knowledge of the longer term transitions between TE and CE, whereby CE use may grow (often very rapidly) and come eventually to dominate and even replace TE as the principal energy source (Pearson and

Stevens, 1984, 1986).

While not all countries are likely to go through the same transitions at the same rate (and some countries may not pass through a long-term transition at all in the foreseeable future), a significant number of countries have either experienced or are currently experiencing one. The significance of an understanding of these medium and long-term transitions for policy-making and forecasting has not yet fully been appreciated. Most of the analysis of CE growth rates has tended to concentrate on the immediate and most proximate factors that influence them, without seeing them in the context of long-term transitions and paying relatively little attention to TE. It is fairly obvious that investigating energy transitions is likely to be important for the understanding of the TE situation, but it is also relevant for decisions about CE as well. For example, future CE use can depend on, amongst many other factors, the rate at which handicraft production is mechanised, the rate at which and the manner in which transport and agriculture are mechanised, and the rate at which households switch from woodstoves to kerosene stoves and lamps.

We now turn to consider the long-term transitions more closely. Some countries have made remarkable transitions from dependence on traditional forms of energy towards commercial fuels in the course of their development. The USA offers an interesting illustration of this. America went from around 90% dependence on woodfuel in 1850 to less than 10% by 1920, with the transition embracing first coal and then petroleum (Schurr et al., 1960). Clearly, the growing demand for and evolving shares of coal and then petroleum in this period depended not only on the technology, availability and prices associated with coal, petroleum and electricity, but also on the price, availability and decreasing substitutability of woodfuel.

As was argued earlier, in order to understand and forecast LDC energy demand, it is important to appreciate what kind of transitions (if any) a country is making and at what stages it is in those transitions, since there is both long-term substitution and a degree of short-term switching between traditional and commercial fuels. Refusing to consider these transitions would be like trying in America in 1880 to predict the demand for coal in 1910, without reference to wood use. However, the majority of LDC commercial energy forecasts have been carried out just like this. Of course, this is partly because the data on TE are mostly both limited and unreliable. However, one of the reasons underlying the poor data is that until very recently neither forecasters nor policy-makers thought it worthwhile to devote attention and resources to TE.

Now consider a very different example, that of South Korea, an LDC that has recently experienced a series of major transitions between CE and TE. It is more than coincidence that the country has also experienced unusually rapid, export-oriented industrialisation as well as urbanisation (Watanabe, 1985). In a period of less than 20 years, South Korea transited from nearly 60% dependence on woodfuel (and serious deforestation problems) to 90% dependence on commercial fuels. Total energy supplies grew at an average of more than 8% per year between 1962 and 1979. The initial shift involved an extraordinarily rapid development of anthracite coal in the early 1960s, when coal output grew at an annual average of about 15% per year, and coal's share in primary energy climbed from 33% to 44% between 1961 and 1965. There was then a second transition, from coal to oil, from about 1965 onwards. Consequently, by 1969 coal's share had fallen back to around 33%, while petroleum's share grew from 12% to 40% (Yoon Hyung Kim, 1983). More recently, and partly stimulated by the first two oil shocks, the Korean government has been encouraging coal production and fuel imports, as well as energy conservation and nuclear power.

Is it likely that we could easily generalise from the experience of individual countries and so predict accurately future energy evolutions in other countries? Many would probably argue that the examples provided by America's now distant transition and Korea's spectacular recent transitions are special, even unique, cases. The problem is that for any country, the transitions between TE and CE are intimately bound up with that country's resource base and with its underlying structures and processes of economic, social and political development. Clearly these processes need to be investigated before we could hope to make appropriate, effective use of knowledge derived from other countries' energy transitions. As an example, it cannot confidently be asserted that the pace and character of development in LDCs will be such that all countries will actually undergo major energy transitions in the not-too-distant future (consider sub-Saharan Africa or Nepal).

It is all too easy, moreover, to jump to simplistic conclusions about the factors that determine energy transitions, as the following example shows. If we bear in mind the enormous changes in technology that have occurred over the past hundred years, it might seem eminently reasonable to predict that South Korea's evolution from around 60% to only 10% dependence on woodfuel must have required only a small proportion of the time that it took the USA to make a similar transition. However, it took Korea about 20 years (between 1960 and 1980) and America only about 30 years (between 1880 and 1910).

Although these dangers of naive generalisation and extrapolation from other countries' particular experience must be taken very seriously, it nonetheless seems worthwhile trying to investigate the transitions in order to see what can be learned. For if it were possible to identify different types of transitions and the factors that have influenced them, this might help us both in forecasting and policy-making. Thus a given country's energy transition might be better understood, its problems better diagnosed and its policies more effectively formulated, by drawing on information about transitions from other countries, than simply by confining the analysis to that country's own past experience. If, for example, a typology of energy transitions could be developed, then it might be possible to use it to help identify potential supply bottlenecks and to focus on more effective investment or managerial development programmes.

The factors that influence energy transitions have both micro and macro dimensions. At a micro level it is necessary to try to understand what influences household, farm and enterprise decisions to choose and switch between fuels and appliances. This demands improved conceptual understanding of the underlying processes and a greater quantity of higher-quality data (for critical reviews of data, see Barnett et al., 1982; Desai, 1985; Howes, 1985). As an example, household energy demand is particularly important but as yet the processes of energy (and other) decision-making within households cannot be said to be well understood. Given their importance, it is worth illustrating the complexities involved.

Household energy demand for any given fuel can broadly be specified as a function of the following variables: the fuel's own price and the prices of substitute and complementary fuels (with explicit prices for traded fuels and implicit prices/opportunity costs for non-commercial fuels); tastes, which change over both time and space (with migration, especially), typically towards more commercial fuels and more 'modern' appliances; household economic, social and physical characteristics, including income, wealth, age/sex composition, divisions of labour and decision-making, and the physical characteristics of the dwelling; season and temperature; the characteristics of the fuels (ease of use, versatility, smokiness, for example) and of the appliances; and the stock of appliances, fixed in the short run and variable in the long run. However, much work remains to be carried out if micro-level demand is to be properly understood. And if interfuel substitution and transitions between TE and CE are to be analysed adequately, micro-level analysis is vital (see also Pearson and Stevens, 1986).

At the macro level we are especially concerned with the factors that influence the absolute level of consumption of CE and TE and their relative shares in total energy consumption over medium and long periods of time. As yet there seems to have been relatively little investigation of the determinants of these shares, in particular. It would, of course, be expected that factors associated with the pace and character of a country's development would affect both the levels and shares of consumption. These factors include variables such as the growth of national income, expansion of the manufacturing sector, mechanisation, the process of urbanisation and the spread of consumer durables.

Preliminary investigations of data for a number of Asian countries broadly confirm the influence of some of these variables on absolute and relative demand for CE and TE, although as yet the work only casts a limited amount of light on the underlying processes that influence energy transitions. However, further work is intended to investigate these transitions in more detail. So far this work has been carried out by pooling a time series of energy data for a cross-section of countries, including in particular several Developing Member Countries of the Asian Development Bank (Asian Development Bank, 1982). To these energy data has been added a variety of economic data from other sources, principally the World Bank (see, for example, World Bank, 1983a) and the International Monetary Fund (International Financial Statistics, various years).

The countries include: Afghanistan,Bangladesh, Burma, Fiji, Hong Kong, India, Indonesia, South Korea, Malaysia, Nepal, Pakistan, Papua New Guinea, Philippines, Singapore, Sri Lanka and Thailand. The data points are 1960, 1965, 1970, 1975, 1978 and 1980, and it is intended to add more recent figures. The dependent variables are: oil consumption, total CE consumption, total TE consumption; and the ratio of CE consumption to total energy consumption (CE plus TE). It is this last variable (CE/Tot E) which is the most interesting for the direct investigation of transitions between TE and CE.

The independent variables include: real gross domestic product - total (GDP) and per capita (GDP/Cap); total population (Pop); total TE consumption (TE); real energy prices; the percentage of population that lives in urban areas(Urban %); value added in manufacturing as a percentage of GDP [ManVA/GDP] (as a proxy for industrialisation); the labour force in agriculture as a percentage of the total labour force (LabAg %); the ownership of cars per 1,000 of population (Cars/000); ownership of radios per 1,000 of population [Radios/000](as an indicator of increasing 'modernisation' and the spread of knowledge and changing tastes); TE per 1,000 of population (a kind of inverse development indicator, not telling us much directly, but indirectly warning of the importance of processes that affect TE and CE use that are not reflected adequately in the GDP and urbanisation variables); and a number of other relevant but less important independent variables.

Preliminary results (see Table 1 for a selection of these) from linear regressions relating the dependent and independent variables cited above, tend to confirm a number of the expected relationships between energy consumption and broad development indicators. Initial investigations with the data have suggested a number of points: (1) the presence in the data set of a single, extremely large country, India, can make a considerable difference to the results; (2) largely because of the impacts of the two oil-price shocks, it makes sense for part of the analysis to separate the data set into two time-periods, 1960-1970 and 1975-1980; (3) the behaviour and responses of high and low-income countries not surprisingly appear to be significantly different (consider, for example, the contrasts between Pakistan and South Korea) and its, therefore, worth splitting the data into sub-sets for relatively high and low-income countries; (4) again, it was no surprise that several of the explanatory variables are highly correlated, with the resulting multicollinearity problems in the regressions making it difficult to disentangle the separate influences of these variables; and (5) the influence of oil prices is proving difficult to incorporate, not least because of the problems of converting to a common currency unit in real terms, using pooled cross-section and time-series data for many different countries in situations where the appropriateness of official exchange rates may be in doubt.

The results set out in Table 1 are preliminary and need to be interpreted with great caution, not least because of the probably unsystematic unreliability of some of the data (especially the data on TE) and because there are some missing observations. However, in my view they suggest that it is worth pursuing this approach further through: (a) alternative specifications of the form of the equations (for simplicity the initial regressions were all specified to be linear, although in fact we might expect some of the relationships to be non-linear); (b) alternative, improved versions of existing explanatory variables; (c) omitted but important explanatory variables whose incorporation might

Table 1

Preliminary results from Regressions of Energy Consumption on Development Indicators for some Asian Countries (t-ratios in brackets)

All Countries (except India)

CE/Tot E = 36.6 + 0.58Urban % (6.1) + 0.07Rads/000 (3.7) - 44TE/000 (-3.1)

R-squared = 71.3

All Countries (1960-1970)

CE/Tot E = 39.2 + 0.05GDP/Cap (7.6) - 63TE/000 (-4.5)

R-squared = 74.0

All Countries (1975-1980)

CE/Tot E = 9.9 + 0.02GDP/Cap (3.4) + 218ManVa/GDP (3.5)

R-squared = 69.6

High-Income Countries

CE/Tot E = 95.7 - 218TE/000 (-13.9) + 24ManVA/GDP (2.1)

R-squared = 92.2

Low-Income Countries

CE/Tot E = 1.5 - 69TE/000 (-5.6) + 0.96Urban % (4.3) + 0.13GDP/Cap (6.4)

R-squared = 77.5

CE = -2901.0 + 0.37GDP (8.2) + 21191ManVA/GDP (3.9) + 21.7Radios/000 (2.3)

R-squared = 84.9

TE = 1766.2 + 0.26GDP (5.4) + 0.12Pop (2.5) - 18.2Radios/000 (2.1)

R-squared = 62.4

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significantly alter the results; and (d) the use of techniques other than regression analysis (for example, discriminant analysis) which might aid in the selection of appropriate sub-sets of the data.

Points (b) and (c) are to some extent related and can be illustrated further. For example, just making use of the variable indicating the share of manufacturing value added in GDP fails to make allowance for the size distribution of manufacturing establishments. This distribution tends to be very skewed, with a small proportion of larger establishments producing most of the value added. The skewness varies over time and across countries, so a variable measuring the inequality of the distribution could add a helpful dimension to the data on industrialisation. Such data are available for a number of countries. In a similar vein, although not easy to obtain in a time-series, the data on GDP and GDP per capita might be supplemented by statistics on the distribution of income and wealth (especially land holdings). Another example would be more data on transport, including bicycles, scooters and motor cycles, and passenger transport vehicles, since ownership of cars may not be a sufficiently discriminating indicator of what is going on in a sector that constitutes a major source of fuel demand and fuel transitions.

An omitted but potentially significant set of variables relates to a country's external orientation and dependence, which can materially influence both the rate and pattern of economic growth. Relevant variables would include the ratio of exports to GDP, oil imports as a proportion of export values, and debt-servicing.

Another set of very important omitted variables relate to what Reynolds calls ´political variables´. This heading includes not only a country´s political orientation but also, ´continuity of governments, growth orientation (or its absence) in the political leadership, administrative competence of government, effectiveness of policies in agriculture, foreign trade, and other key sectors´, although Reynolds also stresses the difficulties in quantifying these variables (Reynolds, 1985, p.107). Nevertheless,it may be possible to make use of data on such things as state ownership of industry (especially energy industries), the degree of price distortion (World Bank, 1983b) and systems of land tenure. However, in all the cases described in this and the previous paragraphs, the difficulty of obtaining sufficient reliable data on some of the variables should not be underestimated.

Finally, it is worth reiterating that simply producing econometric results is not the primary aim of this investigation. The interesting and important problem is how to get a better understanding of the processes that influence and shape energy transitions. Therefore, econometric analysis can only be part of the story and needs to be complemented by an examination of energy transitions in the context of each country´s evolving economic and political situation.

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