Interactions Among Alternative Modes of Household Energy Production:

A Case Study of Colombo, Sri Lanka

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I. Introduction

In recent years, decision makers in many countries have realized that energy sector investment planning and pricing should be carried out within the framework of a national energy master plan which determines energy policy, supply-demand management and planning. However, in practice investment planning and pricing are still carried out on an ad hoc and at best partial or sub-sector basis. Thus, for example, planning in the petroleum and electricity sub-sectors has traditionally been carried out independently of each other, and of other energy sub-sectors. As long as energy was cheap such partical approaches were acceptable; with today's rising energy costs and fluctuating relative fuel prices, the importance of analyzing interactions among different energy sub-sectors in the process of optimal resource allocation has become evident.

A framework for integrated national energy planning, particularly in the LDC context, should include important considerations such as: the interrelationship and substitution possibilities between different energy sources, the difference between private and social costs and benefits (e.g., shadow pricing and exter-

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nalities), the modification of the economic efficiency objectives in investment and pricing policy necessitated by other financial and socio-political considerations, and the coordinated use of policy tools (e.g., pricing-investment, physical-technical controls, public education-propaganda).[1] Furthermore, given the frequent overemphasis on commercial fuels in energy sector analysis, the important role of traditional fuels such as firewood should be recognized.[2]

In this paper, we use a case study of Sri Lanka to illustrate energy sub-sector interactions in a developing country. More specifically, the use of woodfuel, kerosene and liquid petroleum gas (LPG) for domestic cooking is analyzed, including the effects of fuel prices, capital costs of different energy conversion devices and associated thermal efficiencies (e.g., open versus closed wood stoves). The importance of using correct shadow prices (which represent economic opportunity costs instead of distorted market prices) to establish the least cost mix of fuels to meet given energy needs is emphasized. The policy implications of this analysis are also discussed (especially for energy pricing) in an environment in which the relative scarcity of different fuels may change dynamically over time.

The basic 1976 energy balance for Sri Lanka[3] is summarized in Table 1. About one-third of the gross energy needs are supplied from commercial fuels (excluding re-exports of residual oil) and the rest from traditional fuels, chiefly wood. Petroleum products account for almost 90 percent of commercial fuel use resulting in a heavy import bill for crude oil. The principal focus of this paper is on domestic cooking, which is dominated by woodfuel use, some kerosene and a very small amount of LPG. Although thermal generation of electricity was negligible in 1976, this situation will change substantially in the early 1980's. Therefore, the mix of outputs from Sri Lanka's petroleum refinery and their use in the electricity producing and other sectors are also of crucial importance.

1 See Munasinghe (1979).

2 See for example Munasinghe and Warren (1979), pp. 414-417. A survey of non-commercial energy uses in LDC's is found in Cecelski (1979).

3 1976 population approximately 14 million and GNP per capita about US$190.

Table I

ENERGY BALANCE FOR SRI LANKA, 1976
(million GigaJoules of gross input value)

	Secondary Electricity	Commercial Use	Railway Transport	Truck Transport	Air Plane Use	Auto Travel	Bus Travel	Rail Travel	Home Lighting	Cooking	Exports	Total Use
Elec. Generation	—											
Total Elec.		3.35	—	—	—	—	—	—	0.73[a]	—	—	4.08[b]
Gasoline	—	—	—	.46	—	4.13	—	—	—	—	.02	4.61
Diesel & Fuels	—	2.63	.53	5.09	—	—	4.39	1.22	—	—	—	13.86
Kerosene	—	1.02	—	—	—	—	—	—	6.62[c]	2.21	—	9.85
Aviation Gasoline	—	—	—	—	.46	—	—	—	—	—	3.26	3.72
Residuals	.36	5.18	—	—	—	—	—	—	—	—	18.86	24.40
LPG Bottled[d]	—	.03	—	—	—	—	—	—	—	.03	—	.06
LPG Piped		.05	—	—	—	—	—	—	—	.01	—	.06
Total Petroleum	.36	8.91	.53	5.55	.46	4.13	4.39	1.22	6.62	2.25	22.14	56.56
Wood & Wastes	—	n.a.[e]	—	—	—	—	—	—	—	40-60	—	40-60
Grand Total												

[a] Includes very small component for cooking.
[b] 98 percent of this total is primary electricity (hydro) and the rest is secondary electricity (thermal). Losses = 12 percent.
[c] 25 percent of domestic use is assumed to be for cooking.
[d] LPG purchased by Colombo Gas Works is used about 50-50 for bottle and piping. For bottles we assume consumption is split equally between household and other users; for piped gas households are assumed to take 20 percent. The leakage factor of the pipeline system, estimated at 65 percent, is ignored here.
[e] It is not known how much tea drying is still done with wood. If one-fourth to one-half were the proportion and we assume a metric ton of wood has a value of 10-14 G.J., the range of consumption might be about 2.0-4.0 G.J.

II. Analytical Framework

In the idealized world of perfect competition, the interaction of atomistic profit maximizing producers and atomistic utility maximizing consumers gives rise to a pareto-optimal. In this state, prices reflect the true marginal social costs, scarce resources are efficiently allocated, and for a given income distribution, no one person can be made better off without making someone else worse off.

However, conditions are likely to be far from ideal in the real world. Distortions due to monopoly practices, external economies and diseconomies (which are not internalized in the private market), interventions in the market process through taxes, import duties and subsidies, etc., all result in market (or financial) prices for goods and services, which may diverge substantially from their shadow prices or true economic opportunity costs. Moreover, if there are large income disparities, the passive acceptance of the existing skewed income distribution, which is implied by the reliance on strict efficiency criteria for determining economic welfare, may be socially and politically unacceptable. Such considerations necessitate the use of appropriate shadow prices instead of market prices. These shadow prices should be used instead of market prices (or private costs) in evaluating alternative programs to determine the least cost mix of fuels to supply given energy needs. In this paper, we use the term efficiency prices to denote shadow prices based on economic opportunity costs that reflect only the efficiency considerations of resource allocation.[4]

In the context of a general equilibrium model, the shadow price of a given resource represents the change in the value of the national objective function such as aggregate consumption due to a marginal change in the availability of that resource, subject to a set of distorting constraints.[5] However, a general equilibrium model sufficiently detailed to be of practical use can rarely be realized, especially in the LDC's because of analytical difficulties, lack of data, and the time and manpower required to build and use it. Therefore, we are forced to use a partial equilibrium

4 Income distributional considerations which may be used to derive social weights (applicable to costs and benefits according to income level) are ignored. See for example Squire (1975), Little (1974) and Sen (1972).

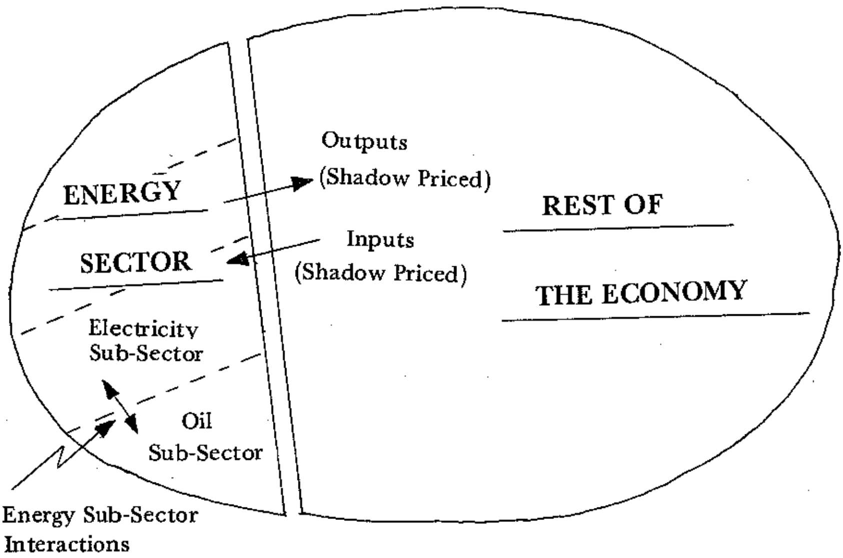
5 See for example: Dasgupta (1974), pp. 1-13 and Warr (1977) pp. 865-872.

approach to examine the market for each energy sub-sector. Linkages with other sectors of the economy and between energy sub-sectors have to be selectively taken care of by appropriate shadow prices, e.g., shadow wage rate, opportunity cost of capital, shadow prices for fuels, and so on.[6]

In summary, what is meant by integrated energy pricing policy in the economic sense is not a general equilibrium analysis; instead, interactions of the energy sector with other parts of economy, as well as interactions between competing energy sub-sectors are handled by examining selected linkages and using appropriate shadow prices or opportunity costs as shown in Figure 1. In practice, quite useful results can be obtained from even simple models and considerations as shown below.

Figure 1

PARTIAL EQUILIBRIUM FRAMEWORK



6 The partial equilibrium method has been criticized, on the basis of non-marginality, for its lack of simultaneity, and because of the judgmental element involved in choosing which linkages are to be analyzed and which are to be neglected, when the impact of some disturbance is to be evaluated. However, in principle, these objections can be met by using an iterative process of successive (convergent) approximations, and by considering a sufficient number of linkages, so that the partial equilibrium shadow prices closely approximate the corresponding general equilibrium values.

The demand for energy products is best considered as the demand for the useful service energy provides, in the spirit of Kelvin Lancaster's new consumer theory.[7] Thus, for example, households demand energy to cook their meals; they produce the requisite heat by combining capital equipment, fuel, and some labor. The total cost of producing the energy output will depend upon technical parameters such as the efficiency of conversion, and energy input value of fuel; and upon economic parameters such as initial capital charges, fuel costs, and labor costs. To produce cooking heat, one may use a number of different modes and fuel combinations; wood with open and closed stoves, coal, charcoal, kerosene in wick or pressure stoves, LPG, piped gas, and electricity. Since each of these methods will face varying values of the technical and economic parameters noted, the overall costs may vary.

In an equilibrium disregarding personal predilections for one or the other type of cooking method, the private marginal cost of cooking heat will equate across these different methods. In practice, this will not happen for two principal reasons. First, different cookings methods have other characteristics besides technical efficiency and economic cost, e.g., charcoal is traditionally shunned in favor of wood; kerosene is messy and has an unpleasant smell; LPG is considered dangerous, and so on. Secondly, the imperfections of the capital markets--particularly for the small amounts of cooking equipment in volved--means that at a given time the capital unit owned cannot be sold for its economic value, and the switch over to the lower marginal-cost method will only occur with some time lag. Furthermore, even if private marginal costs are equated, this need not be the case for marginal efficiency costs. A case in point may be fuel wood in Sri Lanka, which some forestry experts feel bears a high social cost because the forest cover of the country is endangered by the cutting of wood for fuel. If indeed this is the case, then the private cost of wood understates its economic opportunity cost, and a private market equilibrium of cooking modes wherein the private marginal cost of cooking with wood equals the private marginal costs using other means, is socially undesirable for it means that the marginal efficiency cost of wood cooking is likely to be higher than with other methods, unless other fuels are also heavily subsidized (e.g.,

7 Lancaster (1966), pp. 135-145.

kerosene)

III. Private Marginal Costs of Cooking in Colombo Area

In what follows, we provide an illustration of this approach applied to the case of cooking fuels in urban areas of Sri Lanka, Colombo in particular. Technical and economic parameters for this are not well established or easy to come by,[8] therefore, the estimates are indicative at best and must be taken with a large margin of error. However, given the critical situation of rising petroleum prices, potential deforestation and the mid-term exhaustion of major hydro sites, it is necessary to focus on the allocative efficiency of alternative energy forms by analysis of the type described. What we present here can be elaborated with more precision for the parameter values, but even with such rough approximations, the calculations can indicate general policy directions that are likely to be useful.

We focus upon urban areas because for the immediate future the choices available there are substantial and extending these same choices to rural areas would involve considerable cost of networks such as LPG and electricity. Furthermore, the low incomes in rural areas would preclude high-capital-cost options unless substantial subsidy and/or credit facilities were to be provided by the government. Our calculations are limited to five options: wood in open fires and in closed stoves, kerosene in wick-type stoves and in pressure-type stoves, and LPG. For this last, a range of values is given for lack of precise technical parameters. We do not consider charcoal because of the apparent traditional resistance to it, and we exclude piped gas and electricity because they are more limited as options to upper-income households.

Marginal cost calculations are usually done relative to some natural quantitative unit, which for the case of energy may be a kilowatt hour, or a BTU or a GJ. In this instance, however, we shall compute the marginal cost as the annual cost of providing cooking heat for an average family of six people. The family or

8 In particular, the literature gives values of wood's energy content that vary from as little as 10 G.J./metricton to 18 G.J./metricton. Estimates of the energy content are given in Cedkki (1978) and Earl (1975). Also as noted in Sec. IV, even private market prices of wood are not well known in Sri Lanka.

household is the natural purchasing unit for this product, and we assume it does not decide to cook less or more, but rather it decides to switch from one mode to another. With the exception of open fires, the sunk-cost aspect of capital-equipment means the decision is decidedly long term, and therefore the marginal-cost perspective of the decision maker is likely to be with respect to the total cost for a fixed period of time. In estimating these total costs, we exclude any labor involved for two reasons. First, the labor used in generating cooking heat as such--distinct from the labor used in the culinary process itself--is in-significant except in the case of wood. Second, even with wood the labor cost is very low because of the low shadow price of labor; this is even more true where the labor is done by members of the family for whom, and at times when, alternative opportunities are non-existent. The amount of useful energy output for a year's cooking may be estimated at 5.42 G.J.[9] Thus, the annual marginal cost as defined will be given by:

$$MCA_i = \frac{5.42/e_i}{EV_i} \cdot P_i + rK_i$$

where e_i is the energy efficiency of the mode i, EV_i is the energy input content in G.J. per unit of fuel type i, P_i is the price of fuel i, r is the annual capital charge, and K_i is the cost of the capital stock required in mode i.

Approximate capital costs (K_i) for the various modes are shown in Table II; they range from zero for an open fire (a few stones) to 700 RS for a simple one-burner LPG stove plus the cylinder. For the kerosene and LPG options, the most rudimentary one-burner commercial stoves are taken as the basis for the computations. Larger tow-burner models of better quality can be as much as 600-700 RS for kerosene, and over 1,000 RS for LPG. On the other hand, rudimentary handcrafted equipment can probably be made for much lower costs, perhaps as low as $7.00.[10]

For the case of LPG, marginal efficiency costs must include the potential capital costs incurred by the Colombo Gas Works to per-

9 Based on estimates of firewood used by an average family of six in the *Consumer Finances Surveys* (1953, 1963, 1973), and an energy content of 14G.J./metricton--the mid-point of the range noted in Footnote 8.

10 At the Gannaruwe biogas site in Sri Lanka, a hand-fashioned gas burner was said to cost less than 100 RS.

Table II

APPROXIMATE CAPITAL COSTS IN RS OF COOKING EQUIPMENT PER FAMILY

Mode	Total Capital Cost	Annual Cost at r =	
Open Fire	0	.15	.20
		0	0
Closed Stove	100	15	20
One Burner Kerosene Stove			
wick	200	30	40
pressure	300	45	60
One Burner LPG Stove	250		
Cylinder	450		
Private Total (LPG)	700	105	140
Additional LPG Social Cost*	625	95	125
Total LPG Social Cost	1,325	200	265

* Based on proposed Gas Works project of expanded delivery to 40,000 houses.
Source: Estimates from author's observation, information provided by Colombo Gas Works and other unpublished Sri Lanka data.

mit expansion of the use of LPG, because at present the facilities for storage and distribution are fully used up. A feasibility study of such an expansion was done for the Colombo Gas Works recently and from this one can attribute such capital costs at 25 million RS for 40,000 households, or 625 RS per household or family. Annual capital-use cost would be given by the appropriate capital charge "r" (rate of discount in cost benefit approach), which we show as taking two values of .15 and .20,[11] resulting in private

11 We use relatively higher "r" values to bias the calculations in favor of firewood, thereby fortifying the conclusion that LPG which has a high capital cost, may be the most economically efficient mode.

capital charges annually of 15-20 RS for wood stoves, 30-40 RS for kerosene stoves with wicks, 45-60 for kerosene pressure stoves, and 105-140 for LPG equipment. Efficiency costs (at the given r values) would be the same except for LPG, where it rises to 200-265 RS. Clearly, the capital cost element is strongly unfavorable in the case of LPG and highly favorable in the case of wood. The various modes ranked in ascending order of capital cost are: open fire, wood stoves, kerosene wick stoves, kerosene pressure stoves, and LPG stoves.

The fuel cost component, at 1979 private market prices, changes this ordering considerably as can be seen in Table III, under the "Fuel Cost" column. Kerosene has the lowest fuel cost, LPG is next,[12] while wood is most expensive regardless of the type of converter used. The very low capital charges for wood cooking are not enough to outweigh the high fuel cost; and the overall marginal cost (last two columns of Table III) for open fires is decidedly higher than for the other modes, which with a closed stove it is about comparable to LPG if the latter's "high requirements" are taken, but more expensive than LGP if the "low" value is considered for LPG. Both wood and LPG have marginal costs much higher than kerosene stoves of either type. Even if the capital costs of kerosene stoves were in fact substantially greater--say 500 RS instead of 200-300 RS--this conclusion would still hold, as the overall marginal cost for kerosene would be in the range 315-380 RS, still below all the other options. For the private decision maker-the household or family unit--it seems clear that in terms of cost, kerosene is the best option at 1979 prices. Fragmentary and casual evidence on usage patterns suggests that a very large number of urban households, perhaps 60 percent or even more, still continue to use wood, while only about 35 percent use kerosene, the rest using gas (mostly bottled LPG, and some piped) and electricity. Why is there such a very high use of wood given its costs are nearly twice that of kerosene, and why such a low use of LPG given it is only somewhat higher than kerosene, but far less costly than wood? Various explanations can be put forward. The high price of wood is recent, doubling in the last two years, while

12 Lack of data on LPG precluded comparable computations of efficiency and energy content. We took instead an estimate of annual usage by a "customer" as shown in a Colombo Gas Works feasibility study. The study gave two values (100 and 150 KG) which we use as a low and high.

Table III

PRIVATE MARGINAL COST OF COOKING HEAT IN URBAN AREAS, PER FAMILY/A
(required output = 5.421 G.J.)

Mode	Efficiency	Input in GJ	Input Value in GJ	Units Required	Unit Price (Rs)	Fuel Cost (Rs)	Capital Cost (2r) r = .15 (Rs)	Capital Cost (2r) .20 (Rs)	Overall Cost at Market Prices r = .15 (Rs)	Overall Cost at Market Prices .20 (Rs)
WOOD										
Open Fire	.15	36.13	15/Ton	2.4 MT	264/MT	635 Rs	0	0	635	635
Closed Stove	.20	27.1	15/Ton	1.8 MT	264/MT	475	15	20	490	495
KEROSENE										
Wick Stove	.43	12.6	.1569/IG	80.3 IG	2.48/IG	280	30	40	310	320
Pressure Stove	.51	10.6	.1569/IG	67.6 IG	3.48/IG	240	45	60	285	300
LPG										
High Requirement	—	—	—	150 kg	2.6/kg	390	105	140	495	530
Low Requirement	—	—	—	100 kg	2.5/kg	260	105	140	365	400

Source: Author's estimates as described in text and earlier tables.

kerosene prices have been steady at 3.48 RS in that period. Therefore, in 1977, the marginal costs were about equal, and since adjustment involves time lags of recognition, and capital investment needs, the process may be only beginning. Further, we have noted that traditional preferences favor wood for its "taste" qualities, and in fact the equilibrium is perhaps one in which wood does have a somewhat higher cost. As to LPG, it is even less well known to low-income people than kerosene (the latter having been used for lighting for sometime), may be considered risky, and it may be considered inconvenient given the refilling--say 50 RS per annual for taxi fares to take bottles to a depot--and our figures may be a slight underestimate. This is not likely to be enough to make its cost approach that of wood. Further, it may be argued that only owning one bottle is inconvenient as refilling must be done at inconvenient times, or that to avoid this one must invest in an additional bottle. At a cost of 450 RS per bottle, this means an additional 75-100 RS per annum in costs; these two factors may therefore add a perceived cost of 100-150 RS to LPG use, making it comparable to wood at current prices. Inasmuch as it is arguable whether these cost items are essential, we have not included them in the total, but it is important to recognize this "inconvenience" cost associated with LPG in trying to understand the apparent differences in marginal costs that exist. Such factors may result in a market equilibrium wherein observed marginal costs are not equal.

IV. Marginal Efficiency Costs of Cooking in Colombo Area

In the preceding discussion, comparative costs of alternative cooking methods were based upon current market prices. As such, the marginal costs computed are appropriate only to analyze and understand how private individuals made their choices of cooking methods. This is a critical aspect of any actions taken to implement policy goals for after all policies are intended to induce certain behavior by individuals. In addition to this, however, policy *goals* must be decided upon, and in this the objective of social optimization is pertinent. Therefore, the cost comparison of alternative methods must also be done using social opportunity costs, or shadow prices. Wood may be in short supply and its cutting may be causing deforestation; the market price of wood of 264 RS/metricton may therefore understate the economic opportunity cost. Kerosene prices at 3.48 RS/gallon undoubtedly understates the opportunity cost, being kept low by the government subsidy policy. LPG which is in excess supply in Sri Lanka, on the other hand, a near-zero opportunity cost at the refinery rather than the value of 1.4 RS/kg currently paid by the Colombo Gas Works.

Although it is not possible to specify with precision the opportunity costs for these three fuels, particularly for firewood, it is reasonable to approximate these in ranges to permit analysis of the relative marginal costs in question. Since the dicergence of private and efficiency costs of firewood is not well established, we calculate first the efficiency costs assuming the market price of wood is a correct reflection of marginal efficiency cost, as shown in Case I of Table IV. Kerosene's opportunity cost is reasonably firmly established on the import-price basis at about 9 RS/gallon. LPG costs are less clear, though they are certainly below the 2.6 RS/kg market price currently charged consumers. Operating costs for the proposed expansion of the Gas Works sales are about 1.3 million RS for 5.5 million kilograms of LPG, or about .25 RS/kg. If we add to this the ex-refinery efficiency cost estimated to be about half the current price of 1.4 RS/kg, this implies a total efficiency cost of about 1 RS/kg. To bias our estimate against LPG, and to reflect the fact that any substantial increase in use of LPG would change the excess supply situation of the Ceylon Petroleum Corporation (CPC) refinery,[13] we take 2 RS/kg as the shadow value of LPG in efficiency prices. In addition to the fuel cost of LPG, investments beyond the private ones of stove and cylinder must be undertaken. This consists primarily of additional storage tanks, land and some distribution equipment, and is estimated by the aforementioned feasibility study as about 25 million RS for 40,000 customers, or 625 RS per household. The resulting total annual capital charges are shown in Table II as 200-265 RS.

Under these conditions, the Case I results show kerosene to be the *least* economic alternative, with a cost ranging from at least 650 RS to 760 RS. This exceeds the open-fire cost of 635. The *most* economic method is less clearly identifiable, because of the uncertainty as to the amount of LPG required. If the low assumption is correct, LPG is doubtless the least-cost method; if the high value is taken, the use of a closed stove may be most economical. In

13 Sri Lanka's refinery is operated to meet needs of high demand middle distillates, resulting in surpluses of certain other products; more than half of the potential LPG is therefore flared off.

Table IV

COMPARATIVE COOKING COSTS PER FAMILY/ANNUM AT SOCIAL OPPORTUNITY COST[a]

Mode	Capital Cost r = .15	.20	Price	Total	Annual Social Cost r = .15	r = .20	Fuel Costs Price	Total	Annual Social Cost	
WOOD (MT)										
Open Fire	0	0	264	635	635	635	396	950	950	950
Closed Stove	15	20	264	475	490	495	396	712	727	732
KEROSENE (IG)										
Wick	.30	40	9.0	723	753	763	9.0	723	753	763
Pressure	45	60	9.0	608	653	668	9.0	608	653	668
LPG (kg)										
High	200[b]	265	2.0	300	500	565	2.0	300	500	565
	(105)	(140)		(405)	(440)				(405)	(440)
Low	200	265	2.0	200	400	465	2.0	200	400	465
	(105)	(140)		(305)	(340)				(305)	(340)

[a]Economic opportunity cost is assumed to be 9Rs/IG for kerosene and 2.0Rs/kg for LPG.

[b]Values from Table II. The values in brackets are the private capital costs. For purposes of private, the bracket values in LPG are to be compared with the costs for other fuels.

Source: Author's estimates as described in text and earlier tables.

any event, there is no question that the market prices of kerosene greatly understate its relative cost and probably results in an inefficient allocation of resources, overutilizing kerosene. The incorrect pricing of fuels may also be overstating the cost of LPG usage, which again leads to some inefficiency--albiet less significant than for kerosene--with less LPG being used than a social optimum might dictate.

Note that if the assumed efficiency costs of Case I were to be reflected in market prices, the private costs would favor LPG even more strongly (see bracketed values for LPG), because some of the investment costs for LPG are not private ones.

The cost advantage of LPG would become quite definite if the opportunity cost of firewood were to exceed its market price. Case II in Table IV shows the values for an efficiency price that is 1.5 times the current market price for wood. This is taken to illustrate the point, even though it would suffice to have the efficiency price rise to 1.2 times market price to give LPG a clearer advantage. Were the true cost of wood to be this high, its use as cooking fuel would begin to exceed kerosene methods, resulting in an overall marginal cost of 537-615 RS, still well below the kerosene costs.

In conclusion, we find that efficiency pricing of kerosene and LPG, while taking market prices for wood, makes kerosene come out as the high-cost method and LPG the probable low-cost option. Higher efficiency costs for wood enhance the cost advantage of LPG, but if the wood price rise is substantial, kerosene may eventually once again be the low cost option, given the severe volume limitations of LPG, and a consequent sharp rise in its marginal costs. This suggests a possible reliance on kerosene as an economical cooking fuel at some future time, with an intermittent period of expanded use for LPG. Refocusing upon kerosene suggests the need to investigate the robustness of the LPG cost. If we consider only the higher-case assumption and assume that stove costs are double (500 instead of 250 RS), while other costs are left the same since they are more solidly founded, we find that the supplies at the costs compiled are quite small in volume relative to the total cooking-fuel market. They apply perhaps to 40-50,000 households, in a market of 200,000 or more.

V. Conclusions and Policy Implications

The calculations presented here are partial ones excluding some cooking methods, and contain a number of uncertanities pertaining to technical energy-value contents and to prices. Nevertheless, they are robust enough to permit some tentative conclusions.

1. LPG, which is essentially disregarded in energy policy discussion in Sri Lanka because of its very small volume, may have a very important role to play in easing the fuels problem in urban areas. Its marginal efficiency costs are probably lower in cooking than those of competing fuels--wood and kerosene--especially so if market prices of wood understate the social opportunity cost. Though this is a small contribution to the problem, so too is the cost of the investment project in the Colombo Gas Works at about 50 million RS, *including* the costs of bottles for re-sale to customers. More important, there are future possibilities of gas usage beyond this relying upon coal gasification methods, perhaps using imported coal from South Asian areas such as India, Thailand, Indonesia, or even China or East African deposits. Even though this is a long-term possibility, its prospects might fruitfully be investigated very soon, to take advantage of lower priced coal contracts that may be arranged now before the surge of coal demand expected in a decade.

This coal gasification could possibly extend the supplies of urban gas considerably without too sharp a rise in the marginal costs of the present, further justifying an economic refurbishment of the aging pipeline system in Colombo, which at present suffers 65 percent atmospheric losses. The importance of the medium-term future project of bottled, LPG expansion in this context, is to provide an initial demonstration to consumers, in the nature of propaganda and education about the use of gas for domestic cooking. In addition, it will provide some dynamism to the LPG supply enterprise; a helpful basis for later investment projects such as pipeline revitalization and coal-gasification. The potential contribution of gas would then be far more significant, servicing 60,000-70,000 customers via bottles and 40,000-50,000 with the 172 million revitalized pipeline system. This accounts for about half of the households in Colombo's present population.

2. In the event of a sharp increase in deforestation problems and a consequent high efficiency cost of wood, pressures upon an LPG switch over might lead to rising marginal cost of this product, resulting in a return of kerosene as an economical alternative. Thus, despite the apparent inefficiency of kerosene use now, policy options should be kept open for a flexible refocusing upon its promotion as a way to save upon scarce firewood. This is made particularly more important by the greater potential of kerosene in rural areas, compared to LPG, because the former's distribution costs are lower excluding the need for heavy metal cylinders, plus the existence of a baisc rural network for kerosene now used for lighting only.

3. The far greater thermal efficiency of closed stoves (recall we have over-estimated the efficiency of open fires) makes this option potentially important in certain opportunity cost circumstances, for example, further dramatic OPEC price rises. It suggests also that the even more efficient process of charcoaling and use of closed stoves should be investigated as yet another mode of cooking before undertaking any definitive policy directions in this regard.

A number of important conclusions in the context of energy use patterns in developing countries can be drawn from the specific case study. The first and most important one is that user choices among alternative energy sources will not only be determined by the financial costs of each alternative fuel delivered to the point of use and compared on a net heat content basis. Equally, or more important may be the auxillary costs to the user of converting and utilizing each type. These will be made up by the costs of labor, capital and land related to receiving, unloading, storage, handling, ease of control in use and potential riaks, waste material disposal and system maintenance. Reliability of supply and transportation and uniformity of quality will also be important considerations. Habits and the availability and reliability of experienced operators may significantly affect use, particularly in situations in which the potential choice lies between a known, customarily-used energy material and new alternatives of unknown characteristics where resistance to change may be formidable. Lack of knowledge and experience is perhaps one of the most formidable barriers to change in energy use patterns in developing countries. Only if all of these factors are systematically and carefully taken into consideration will it be possible to bring about desirable changes.

Another important issue raised in this paper is that market prices to users frequently do not reflect the true national economic costs of energy use. Appropriate shadow pricing is necessary to determine the difference, if any, and either changes in market prices or regulations affecting alternative choices should be used to bring about a realistic choice pattern reflecting economic opportunity costs.

For governments, the fact of the rapidly rising relative costs of energy should act as a strong stimulant to evaluate systematically existing and projected future energy use patterns on a disaggregate basis and relate them to existing or potentially available sources of supply; evaluate the economic opportunity costs of use of the latter; and attempt to bring about desirable changes in future energy utilization patterns in all sectors of the economy. Such promotional activities, however, must take full account of the many related technical, economic and social-psychological factors that affect and influence energy uses and fuel choices.

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