Crisis and Opportunity Fuelwood

Three-quarters of Kenya's primary energy requirements are met by fuelwood and agricultural residues. A rapid population growth rate and inefficient energy use patterns and technologies will result in a national fuelwood shortfall of one-third by 1990. Regional consequences may be considerably more severe. Forest resource management techniques such as agroforestry, reforestation, plantations and industrial forests are essential to the health of the Kenyan economy.

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Many developing nations have confronted a double energy crisis over the past decade. Jolts in world petroleum prices have depleted foreign exchange reserves, contributed to mounting debt burdens, caused a deterioration in the terms of trade, and generally undermined strategies for socioeconomic development. However, a second energy crisis—the depletion of indigenous wood resources—is equally profound.

Awareness of this "other energy crisis" has grown in recent years, as has concern for its long-term economic, social and ecological consequences. With escalating costs of imported fuels, retarded socioeconomic development and continued rapid population growth, pressure on wood resources has increased in many countries. The resulting problems include increased time allocated by rural households to fuelwood gathering, deforestation, deterioration of soil conditions and agricultural productivity, and the subsequent destabilization and devolution of the rural economy over the long term.

In 1980 a major research and development effort to analyze the fuelwood problem and develop policy initiatives was launched by the Beijer Institute in Stockholm in close collaboration with the Kenyan government (1). This required the generation of basic data on the patterns of energy use in Kenya, because of the paucity of data, especially in the non-commercial sector. Much of the data was gathered through field surveys and long-range forecasts of energy supply and demand at a high level of sectoral and regional disaggregation. A computer-based resource planning model emphasizing land use and biomass availability identified problem areas in the balance of fuelwood supply and demand over time. Technologies, projects and policies that could begin to solve such problems over the 1980–2000 period were assessed and, at a later stage of the effort, policy documents and project-appraisal exercises were undertaken.

CURRENT ENERGY PATTERNS

An "energy balance" was developed tracing the pattern of energy use in Kenya, for 1980, from primary sources through secondary conversion processes to the final point of consumption. The latter was disaggregated by key sectoral/end-use components. Of the total primary energy requirement of 443 petajoules (PJ) (2), 74 percent comes from non-commercial sources (fuelwood and residues). Final end-use consumption was about 332 PJ with about 111 PJ of energy consumption in the energy sector itself (charcoal production, electrical generation, and fuel refining) and in transportation and distribution.

The percentage of energy demand in Kenya by major consuming sector and fuel types for 1980 is shown in Table 1. While the urban domestic sector consumes only six percent of the total, it accounts for 50 percent of total charcoal consumption. Surveys show that consumption of the lowest-income urban households is almost entirely wood based. Low- to middle-level urban households use kerosene for lighting and to a more limited degree for heating. The use of bottled gas is also evident at middle-income levels. Finally, with rising income, electricity is used for an increasing variety of appliances.

Eighty-five percent of the total population of Kenya is rural. One-half of total energy consumption and three-quarters of fuelwood consumption originates in the rural household sector. Regardless of income class, biomass constitutes the overwhelming basis for rural energy consumption. The rural household sector is largely preindustrial in its sector-use patterns. Cooking and heating account for 98 percent of demand. Lighting, the other end use reported by a significant number of households, accounts for the remainder. It is important to note in this context that most wood is obtained from trees outside the forest areas, i.e., from agricultural land.

The other important sector for wood and charcoal usage is labeled "industry" in Table 1. About eight percent of the national total is consumed by certain rural-based industries dependent on wood for agricultural processing (drying and curing for tea, tobacco and sugar), tanning, and for use in pottery/brick, and baking facilities. Finally, the "informal industry" sector consumes significant amounts of fuelwood and charcoal, particularly in rural areas. These include diverse small cottage industries and rural services. Consumption for wood and charcoal is estimated, respectively, at 10 percent and eight percent of national demands.

Turning to the energy-processing sector, there are three important types of intermediate energy conversion in Kenya at this time. They are, respectively, the conversion of wood to charcoal, the conversion of crude oil to refined petroleum products, and the generation of electricity. Only wood conversion concerns us here. Of the 20 million tons of wood fuel in Kenya in 1980, seven million tons were converted to charcoal (3). Virtually all of the charcoal was produced in traditional earthen kilns at low efficiencies, yielding about 0.7 million tons of charcoal. On the other hand, the energy content of charcoal is about twice that of fuelwood and the conversion efficiency of charcoal stoves (*jikos*) is typically about twice that of traditional open fires in Kenya, so the apparent 10 to 1 loss in converting wood is reduced to 2.5 to 1 when these two factors are considered.

Despite such losses, charcoal remains an attractive fuel in Kenya and promises to increase in importance. Charcoal has a higher energy content per unit weight and is thus transported and traded over longer distances than wood. Urban areas, the primary charcoal consumers, are located along major transport routes. *Jiko* use is considered a more convenient and attractive technology than simple wood burning and is generally an expression of income mobility.

The commodity status of charcoal makes it an attractive choice for entrepreneurs who can derive income from its production and distribution. Charcoal production and transport are currently marginal economic activities. The system works only because both production and transport are beneath real market prices. Any attempt to rationalize the price of charcoal production and transport would have a se-

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in Kenya

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vere impact on producers, (i.e., the rural poor) and the consumers, (i.e., the urban poor).

WOOD RESOURCES

Kenya has great diversity in the ecological character of its land, due primarily to the wide range of altitudes and rainfall regimes throughout the country. Only about 20 percent of the land is designated high or medium potential. These are the lands upon which agricultural production and closed forests are primarily located and where the bulk of the population and a large part of national economic activity are supported. With the land frontier effectively closed to further expansion, more pressure will come on this high- and medium-potential land.

Of the high- and medium-potential ecological zones, 25 percent is presently cropped, 40 percent is uncropped agricultural land (a large portion of which is associated with grazing requirements), and about 12 percent is in natural forests or plantations (excluding forests within the national parks). Other land uses include urban and rural settlement land, parks and reserves, and rangeland. Large areas of rangeland exist in medium-potential land in the coastal and eastern provinces. These figures indicate the constraints in attempting to expand existing agricultural and wood-resource bases.

Using detailed surveys and measurements, wood stocks and annual yields (gross biomass additions) on a per-hectare basis were estimated for each of seven provincial subregions, within each subregion by several ecological zones, and within each zone by some 17 land-use categories. The latter included farm types by size and selected crop types, urban and rural "built environment" reserves, forest, grassland and rangeland.

On a national basis, total standing wood stocks amount to about 935 million tons, with about 70 percent of these found in the sparsely populated semi-arid savanna and rangelands. Total yields are estimated at [illegible] million tons annually with just under [illegible] of these in the semi-arid zone. Natural forests account for about 10 percent of wood stocks and yields. Cropped and uncropped farm lands account for about 10 percent of wood stocks and 40 percent of wood yields. In other words, trees outside the forest provide the important yields, [illegible] trees that are accessible to the majority of the people.

In addition to the physical inventory of wood resources, such factors as the geographic and socio-economic conditions affecting access to and distribution of wood fuels must be also considered. The accessibility of wood resources for each land type has been estimated and reflects the distance of population to wood resources, limits to household labor time budget allocated to fuelwood gathering, availability of tools and labor, and privatization of land.

The national supply of wood is broken down by province and type of wood demand for 1980 in Table 2. In the high population density provinces—Central, Nyanza and Western—over half the wood is supplied from non-sustainable stocks. There is currently insufficient wood available on a sustained-yield basis to meet all of the wood demand in the regions, with wood stocks, on a national basis, being depleted at almost 10 million tons a year.

PROJECTIONS

A computer-based system, the LDC Energy Alternatives Planning (LEAP) model, designed for disaggregated projections of end-use demand resources, regional biomass availability, land-use constraints and other parameters, was developed to generate a set of future scenarios for Kenya (4). A "business-as-usual" projection (base case) provides a benchmark for identifying issues and evaluating alternative energy-policy initiatives. The base case is built on the best estimates of current socio-economic variables (e.g., targeted economic growth, evolving demographic patterns) and assumes continuity in Kenyan energy policy.

Demographic trends are important in formulating projections, particularly as, through changing rates of household formation, they influence rural household demand, the largest sector of energy consumption. Kenyan population is growing more rapidly than any other national population in the world, at an annual rate of 3.9 percent. Health and medical services have been expanded but there has not yet been a significant decline in family size. Study projections indicate that Kenya's population will continue to grow at 3.86 percent annually (1). Economic growth is projected at an average annual rate of about 5.8 percent, or two percent per capita, to the year 2000, with significant variation among economic sectors.

Projections of final energy consumption were performed at the end-use level over some 42 subsector categories. The aggregated projections found total energy demand growing at 4.6 percent per annum,

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Table 1. Composition of end-use consumption by sector and main fuel type for 1980 in percent.

Sector	Wood (63%)	Charcoal (8%)	Residue (3%)	Petroleum Products (24%)	Electricity (2%)	Total (100%)
Urban homes	1	50	–	5	36	6
Rural homes	72	37	100	5	–	53
Agriculture	–	–	–	9	10	2
Industry	26	12	–	24	31	24
Commercial	1	1	–	1	22	1
Transportation	–	–	–	56	1	14
	100	100	100	100	100	100

Table 2. Provincial and national wood supply and demand for 1980, in millions of tons. (* = Related to net charcoal export from province.) Figures may not add to totals due to rounding.

	Central/ Nairobi	Coast	Eastern	North-Eastern	Nyanza	Rift Valley	Western	Total
Source of Demand								
Local Woodfuel Demand	2.46	1.94	3.11	.48	2.51	3.94	1.98	–
Woodfuel Demand Other Regions*	–	–	.94	.06	–	1.91	.30	–
Subtotal Woodfuel Demand	2.46	1.94	4.06	.54	2.51	5.85	2.28	19.64
Feedstock Demand	.18	.01	.03	–	–	.51	.04	.77
Total Demand	2.64	1.95	4.09	.54	2.51	6.36	2.32	20.41
Source of Supply								
Sustainable Supply	.99	1.62	3.06	.54	.38	4.17	.31	11.07
Supply from Stocks	1.65	.33	1.02	–	2.13	2.19	2.00	9.34
Total Supply	2.64	1.95	4.08	.54	2.51	6.36	2.31	20.41

oil consumption at 6.1 percent, and wood and charcoal at 3.8 percent and 5.9 percent, respectively. Future base-case wood requirements, taking account of projected end-use demands and conversion/distribution losses, are summarized in Table 3. The growing demand for wood is drawn from annual production yields and standing stocks on the various land types.

A number of changes in land-use patterns are expected to occur as a consequence of demographic trends and development policy. In particular, agricultural land devoted to food production must increase from about 2.3 million hectares at present to 3.7 million hectares by the year 2000, so that the national goal of self-sufficiency may be achieved (5). At the same time, land devoted primarily to export crops is projected to increase by 50 percent to about one million hectares by the year 2000, primarily from uncultivated high-potential land on large farms in Rift Valley province.

By combining all the various factors influencing supply and demand of woody biomass, the projections displayed in Table 4 are obtained. These figures, which are national aggregations of supply/demand analyses performed at the subregional level, indicate that there are insufficient wood resources to meet the requirement levels associated with "business-as-usual" policy assumptions.

THE COMING ENERGY CRISIS

Wood stock depletion is projected to accelerate as demand increasingly exceeds supply. As standing stocks are diminished, yields are further decreased and stock depletion is thereby further accelerated; it is projected to reach 21.6 million tons per year by 1995 (Figure 1).

The rate of stock depletion begins to abate only after 1995 as accessible stocks in some provinces become exhausted, leaving the local population without means of obtaining fuelwood. Standing stocks as a whole are expected to decline by about 30 percent over the 1980–2000 period. By 1990, available wood will fall short by one-third of meeting requirements, and by 2000, the shortfall will be twice that, if current trends continue. Of course, prevailing conditions and practices will alter the projected shortfall. This provides an indication of where new policy initiatives will have to be made.

While it is difficult to quantify the social, economic and ecological consequences of such a dramatic shortfall, multiple problems may emerge. The use of wood for social and other household and communal activities will probably have to be curtailed. Reduced cooking times, more infrequent meals, and changes in dietary patterns may negatively effect health. Fuel-switching responses such as the increased use of dung for cooking could increase bacterial intake and disease potential. Removal of animal waste and crop residues from the soil as a substitute for fuelwood may deplete the soil of nutrients (see Barnard, p. 259). Such removal also increases problems of physical bonding in the soil, thereby reducing agricultural productivity. With growing shortages, wood is likely to become a commodity in the cash economy, perhaps removing most cash-poor segments of the population from access to fuelwood. As farm and local supplies of fuelwood become exhausted, more household labor time will be expended in gathering supplies.

WOOD STRATEGY OPTIONS

The scenario outlined is not an acceptable future for Kenya. Strategic planning options for increasing the supply and moderating the demand for wood fuel need to be identified in order to develop a comprehensive fuelwood program. Five options for Kenyan wood-resource management are discussed below and are summarized in Table 5.

Agroforestry, the combined farming of selected tree species and existing crops and livestock, has a number of potential advantages. First, an unexpectedly high fraction—about 40 percent—of total wood fuel demand was found to currently be supplied directly by trees located on agricultural land. Second, due to tool limitations, fuelwood gathering largely concentrates on wood that is small in diameter, a need that can be met by rotation agroforestry "energy trees." Third, agroforestry could potentially improve overall agricultural productivity; nitrogen-fixing trees could increase the fertility of the soil, while leaves and pods could supply food and fodder (6). Finally, the possibility emerges for farmers to earn additional income by sales of wood and charcoal.

The species identified for agroforestry in Kenya include, among others, *Acacia mangium, Alnus nepalensis, Calliandra calothyrsus, Grevillea robusta, Leucaena leucocephala*, and *Sesbania grandiflora* in high potential areas. Annual yields for fuelwood are estimated at about 4.5 tons per hectare (current wood production on farms is about 0.7 ton or 1 m^3 per hectare). The rotation period can range from two to five years, perhaps including coppicing or pollarding (selective branch cutting) or a system where wood is simply grown in an 18-month cycle as fuel sticks. Typical values of about four tons per hectare and three-year rotations have been assumed for the present analysis in high potential areas and 2.5 tons per hectare in medium potential areas.

Of vital importance in mounting a major agroforestry initiative will be the development of a training and extension program in agroforestry that is controlled and directed towards women. Of equal necessity will be sufficient supplies of material, particularly seeds, and the development of

Figure. National wood report demand and supply base case.

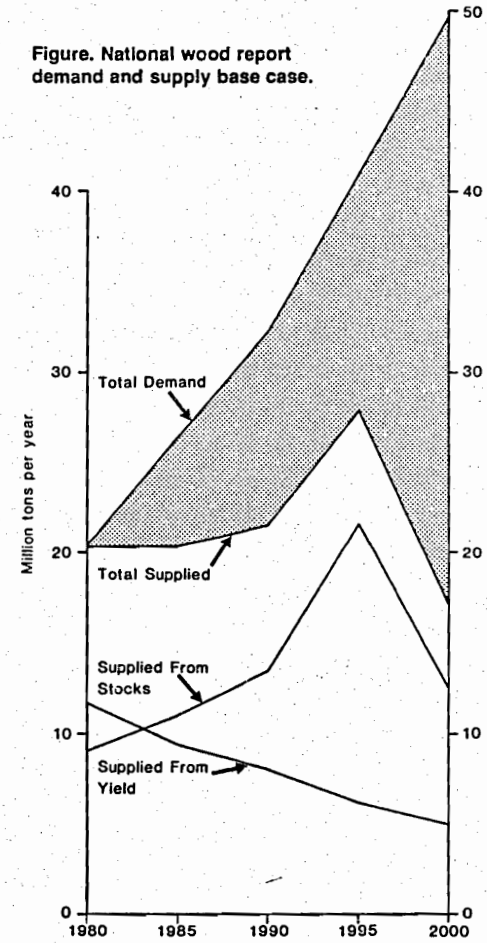

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Table 3. Wood requirements to meet Kenyan demand, in millions of tons.

	1980	1985	1990	1995	2000
Total	20.4	26.4	32.3	41.1	49.7
For Fuel	12.8	15.7	18.5	22.3	26.0
For Charcoal	6.8	9.7	12.5	17.0	21.5
For Construction and Feedstock to Industry	0.8	1.0	1.3	1.8	2.2

Table 4. National wood resource supply/demand relationship in Kenya, in millions of tons. (* = net annual production. Only accessible yields service demand. + = net reduction in accessible standing stocks service demand when demand exceeds accessible yields.)

	1980	1985	1990	1995	2000
Required	20.41	26.42	32.37	41.04	49.74
Supplied					
From Yields*	11.07	9.41	8.06	6.29	4.97
From Stocks +	9.34	10.94	13.51	21.62	12.16
Shortfall	–	6.07	10.80	13.13	32.61
Standing Stock	934.62	885.41	829.36	744.49	674.40

high-yield tree species. If all agricultural lands used agroforestry techniques, the ultimate potential by the end of the century would be some 28 million tons per year of sustained yields. By comparison, in the year 2000, rural households are expected to require about 18 million tons of fuelwood (out of a total national wood demand of 50 million tons).

Replanted forests, the clear felling and replanting of portions of existing natural forests with species whose characteristics are favorable for a high productivity fuelwood supply base, could provide additional near-term wood resources. Effective management could promote a balance between cutting, replanting, thinning, and age distribution. Special attention might be required to maintain conditions appropriate to wildlife habitat requirements.

The principal species identified for replanting in Kenya are eucalyptus and wattle (*Eucalyptus* spp and *Acacia mearnsii*). Tracts of land planted in the first year will be harvested and regenerated at the end of the ten-year rotation cycle. Stocks are expected to grow to about 230 tons per hectare at maturity, with a steady yield averaging about 23 tons per hectare.

Despite the ten-year lead time required before the first year of clear felling, two aspects of forest replanting allow for earlier benefits. First, the initial clear felling of natural forest biomass will yield some 50 to 100 tons per hectare. Second, thinning during the course of the rotation cycle can yield about eight tons in addition to the steady yield of 23 tons per hectare in the seventh year, with total stocks growing to about 180 tons per hectare by the end of the tenth year.

A maximum potential of 400,000 hectares of natural forest conversion to eucalyptus, wattle or comparable species could be achieved by the year 2000. The wood resources derived from the clearing process alone would be in the neighborhood of one million tons per year in the late 1980s and nearly three million tons per year during the 1990s. Several multinational oil companies have already prepared plans for development of specific forest areas, although the Kenyan government does not wish to proceed in this direction at the moment.

Periurban plantations are located close to the urban population, thus minimizing the problems associated with logistics and cost of transport. Under managed conditions, using species such as eucalyptus, wattle, prosopis, and leucaena, periurban plantations would have wood production characteristics comparable to those of replanted forests. There is a maximum potential of about 200,000 hectares of periurban plantation by the year 2000. However, this approach will not have a large impact on wood supplies until the end of the century. Thereafter, a maximum sustained production of about four million tons could result. Since wood-fuel demand in cities is dominated by charcoal, the urban proximity of these sources suggest that consideration be given to charcoal production using more efficient kilns.

Industrial plantations, which dedicate agricultural land to fuelwood production, can service the processing fuel requirements of large industrial consumers. The sugar, tea, coffee, and tobacco industries, especially, use about 1.1 million tons of wood annually. By the year 2000 this demand is projected to grow to 3.3 million tons. Industrial forests could be composed of species selected for their wood-production characteristics on a site-specific basis. The estimated maximum potential for industrial forest plantations in Kenya is 50,000 hectares, or an ultimate annual yield of about 1.1 million tons. Currently, about 0.5 million tons are supplied from all such "woodlots."

Natural forest management may be a particularly attractive resource-enhancement option in that it uses an existing resource base and techniques that are well understood. Natural forests near centers of population can be managed and thinned for fuelwood to help meet the requirements of the local population. All the remaining natural forest areas of about 850,000 hectares are potentially available for improved management. Average existing yields in Kenyan natural forests are estimated at about 2.3 million tons annually. Only a small fraction of this woody biomass (between 10 percent and 20 percent) is accessible to the local population because of technological, labor, and distance constraints. Under managed conditions, annual yields could ultimately reach 4.7 million tons on a sustained basis. However, accessibility would have to be improved for this yield to be harvested and distributed.

Table 5. Wood project policy case national target implementations. (* = average annual yields from sustained harvesting of a uniform age, distribution of wood projects.)

Strategy	Cumulative Areas 1990 (1000 Hectares)	Cumulative Areas 2000 (1000 Hectares)	Actual Yield 2000 (Million Tons/Year)	Ultimate Sustainable Yields* (Million Tons/Year)
Agroforestry	983	2,660	10.63	10.64
Replanted Forest	81	306	5.38	6.58
Periurban Plantations	51	165	3.82	3.44
Managed Near Forest	116	260	.63	1.56
Managed Far Forest	180	180	.64	1.08
Industrial Plantations	14	39	.82	.84
Totals	1,425	3,610	21.92	24.14

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TOWARD A SUSTAINABLE RESOURCE BASE

Having analyzed the dimensions of the wood problem in Kenya and identified various supply options, we begin to see the outlines of a long-range policy program. Here we look at a possible scenario for bringing about sustainable wood-energy use by the end of the century. Such a policy scenario provides guidelines and goals for near-term national energy planning.

As wood resource enhancement strategies are pursued, complementary policies to promote technically feasible and cost-effective improvements in the efficiency of end-use equipment are needed. Charcoal, woodburning, and open-fire stoves dominate domestic end-use technologies in Kenya. Considerable reductions in wood fuel consumption could occur if a suitable stove-design project were implemented.

The policy scenario assumes a program of dissemination of new stoves and management techniques in the rural sector, with the objective of reaching 40 percent of households using wood by 2000. A somewhat higher penetration in urban households and the commercial sector is targeted, reaching 50 percent of those using wood stoves by the year 2000.

The best prospect for enhanced efficiency probably lies in construction of masonry kilns in conjunction with dense plantation-type wood cultivation. These can achieve efficiencies of up to twice that of existing earthen kilns and could account for a substantial fraction of charcoal production if concentrated plantation cultivation becomes a major source of charcoal feedstock. Such efforts would need to be far more organized and centralized than current informal methods of charcoal production.

With improved wood-burning stoves in place, local wood shortfalls will be decreased. On a national basis the wood shortfall would be reduced to 23.7 million tons by the year 2000, from 32.6 million tons in the base case.

The principal impacts of the combined wood-demand and supply-policy targets are summarized in Table 6. The expected national shortfall for the year 2000 was reduced from 32.61 to only 2.28 million tons per year. The improvement is traced to an increase in wood supplies of about 17 million tons per year and a decrease in demand of about 13 million tons per year. An expected shortfall of 10.8 million tons is reduced to 9.6 by demand policies, and is further reduced to 6.96 by supplementing these with the resource enhancement policies. While the near-term improvement could be substantial under wood policy assumptions, the remaining shortages present an additional policy challenge. Fuel-switching strategies, such as increased rural electrification, and dispersed renewable energy systems could usefully complement the priority for near-term actions identified above.

As also seen from Table 6, stock depletion would be substantially reduced by the combination of demand and supply policies. Wood-stock density on cultivated lands that could otherwise face cumulative

Table 6. Policy case wood resource supply demand relationship in Kenya, in millions of tons.

	1990		2000	
	Base Case	Policy Case	Base Case	Policy Case
Requirements	32.37	26.23	49.74	36.35
Supplied	21.57	19.26	17.13	34.07
From Yields	8.06	12.91	4.97	29.74
From Stocks	13.51	6.35	12.16	4.33
Shortfall	10.80	6.97	32.61	2.28
Standing Stocks	829.36	839.45	674.40	799.92

Table 7. Cost assumptions in Kenyan shillings (Ksh) for policy measures. Note that capital costs are spread over the rotation period. Distribution costs assume 4 Ksh per m^3 for loading, 3 for unloading, and 1 Ksh per m^3 per km for transportation (1.4 m^3 = 1 ton), and the exchange rate is 13.4 Ksh per U.S. $.

End-Use Measures	Capital Cost (per device)	Lifetime (years)
Efficient *jiko*	50	4
Improved open stove	5	4
Enclosed stove	150	4

Wood Conversions	Capital Cost [per ton/year of capacity)	Production Cost (per ton output)
Improved charcoal kilns	310	20

Resources	Capital Cost (per ha/yr)	Operation & Maintenance (per ha/yr)	Harvesting (per m^3)	Distribution (per m^3)
Agroforestry	10	10	22	10
Replanted forest	100	100	22	100
Periurban forest	100	100	20	20
Industrial forest	100	100	20	10
Managed forest	–	25	20	110 (remote) 40 (near)

reduction of 75 percent would decline by only 50 percent. Most significantly, the process of stock restoration would be well under way by the end of the century.

COST AND BENEFITS

It is of interest to quantify the tradeoffs in costs and benefits that a program such as described above would entail for Kenyan society. Here, we shall rely on market-price estimates of program costs and proxy estimates of "external" benefits to arrive at an approximate measure of the cost-effectiveness of a major fuelwood initiative along the lines outlined.

The cost assumptions are summarized in Table 7: these expenditures would equal about three billion Kenyan shillings (U.S. $220 million) by 1990 and 17.5 billion Ksh ($1.3 billion) by the year 2000. These substantial outlays must be compared to the benefits derived from promoting sustainable wood use.

The major benefit to be gained is the closing of the gap between wood requirements and supply, thus avoiding the substitution of inferior fuels with uncertain environmental repercussions, greater use of high-quality fuels with related exacerbation of foreign exchange pressures, and the disruption of the rural economy.

The scorecard on the cost trade-offs is shown in Table 8. The net program benefits are measured in billions of Ksh per year. By 1990, cumulative net economic benefits would be almost eight times cumulative costs, and by 2000 the net benefits reach about 10 times costs per year. While these estimates can be considerably refined, the overall cost-effectiveness of a wood-fuel management program is evident.

Efforts such as those embodied in the policy scenario can establish a stable and sustainable wood-resource base in Kenya as it enters the next century. Realization of a program of this scope would be an outstanding achievement that would moderate and eventually overcome Kenya's most pressing energy-resource and ecological problems. Success depends on the establishment of an adequate and efficient institutional framework. Close cooperation between relevant government ministries, departments and nongovernmental organizations will be required. Even so, program elements will take time to have their full effects realized. As the planning and institutional apparatus evolves, it will be necessary to identity and evaluate additional options in order to reduce near-term problems. These might include a mix of the more promising renewable energy opportunities—solar applications (e.g., for drying and other thermal requirements), biogas production from crop and animal wastes, producer-gas production (for transport, small-scale electricity production, and other uses), decentralized power sources (wind, small-scale hydro)—and perhaps expanded coal imports. Each of these concepts must be assessed for application to the specific conditions and requirements in Kenya. A wood program can, however, provide a policy focus through which the nation can begin to take command of its energy destiny.

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Table 8. Cost trade-offs for full program in billions of 1980 Kenyan shillings. (13.4 Ksh = 1 U.S. $.)

Cumulative to	Costs	Benefits
1990	2.9	22.3
2000	17.5	169.3

References and Notes

1. Research findings are summarized in P. O'Keefe, P. Raskin and S. Bernow, *Energy Planning in Kenya: Problems and Opportunities*, (Scandinavian Institute of African Studies, Uppsala, 1984) and nine specialized companion volumes on environmental issues, supply and demand data and energy modeling techniques, all forthcoming. A report with the same title was submitted to the Kenyan Ministry of Energy, 1982 and adopted as a cornerstone of Kenyan energy policy.
2. The energy unit employed here is the petajoule (PJ) = 10^{15} joules. 1PJ is the equivalent of about 0.16 million barrels of oil, 0.034 million tons of coal, or 280 million kWh.
3. In converting to physical units, the energy content of wood (air-dried to 15 percent moisture content) is taken at 16.0 10^9J/ton, while that of charcoal is 33.1 10^9J/ton.
4. P. Raskin and D. White, *LEAP, LDC Energy Alternatives Planning Model.* (Energy Systems Research Group, Boston, 1982).
5. C. Barnes and P. O'Keefe, (Eds) Landuse in Kenya (Rural Africana, special edition, fall, 1983).
6. For example, see P. Felkner, *State of the Art: Acacia abbidu as a Complementary Permanent Intercrop with Annual Crops*, (U.S. Agency for International Development, Washington, D.C., 1978).

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