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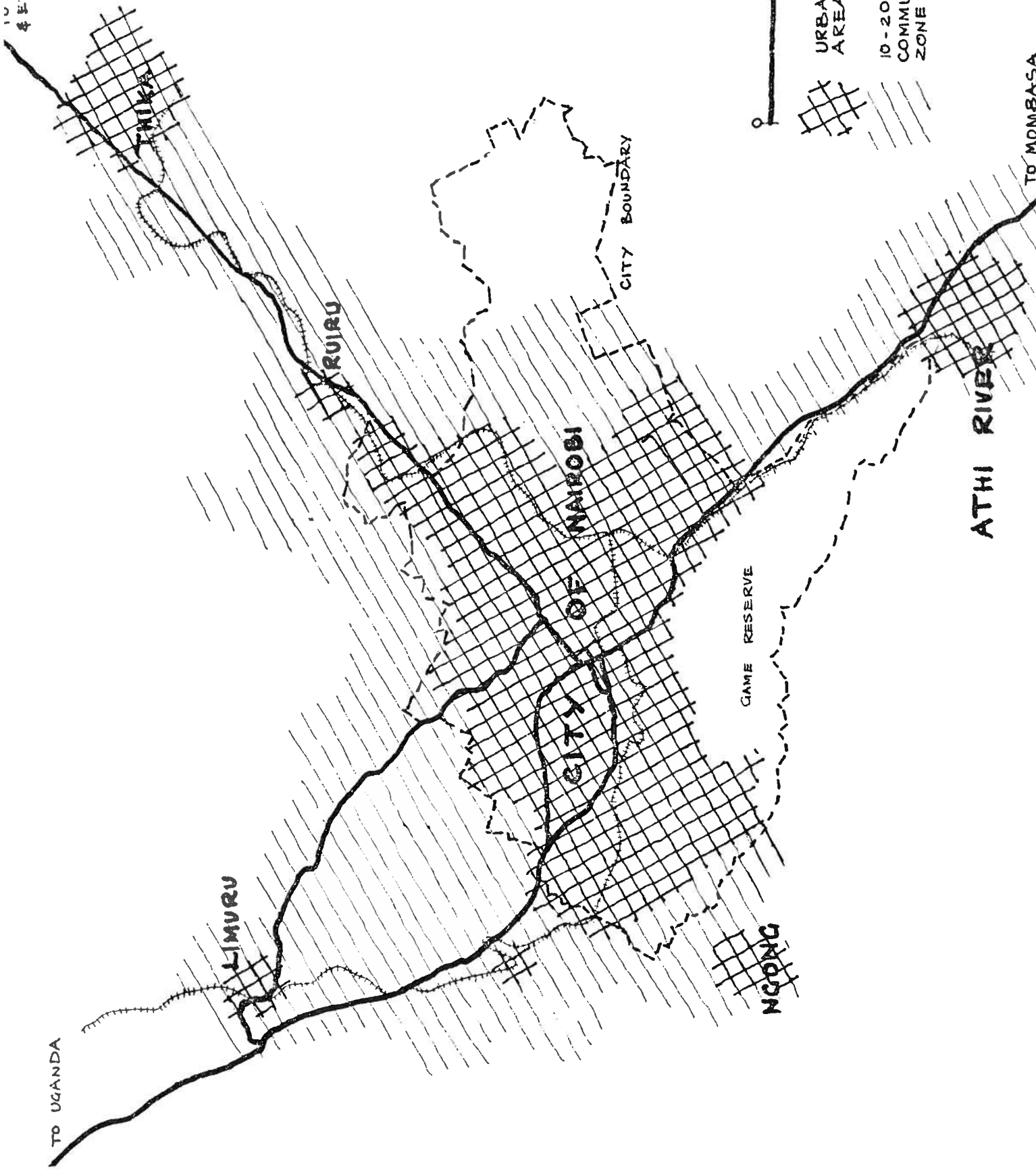
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10 MILES  
to ETHIOPIA

TO UGANDA



10 KM

URBAN  
AREA 1980

10-20%  
COMMUTER  
ZONE

ATHI RIVER

TO MOMBASA

# ENERGY FLOWS THROUGH NAIROBI

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Nairobi is one of the "newly emerging" metropolises of the Third World. It is a capital city that has been reaching out into the surrounding area for supplies of water, food, some cooking fuel, and labor, and is thus being transformed into a service region and a "commutershed."

Although the total population has not yet exceeded a million persons, it has been selected by the United Nations, many international nongovernmental organizations, and an increasing number of multinational corporations for regional headquarters. It is evident that, as a consequence of these external choices, Nairobi is becoming the most cosmopolitan human settlement in this part of the world, since in many ways it has passed Cairo. The reasons for this attractiveness will become apparent as we present more detail on the environment and the structure of the urban ecosystem.

The popularity of the metropolis accelerates its growth. The growth generates some critical new problems, the most serious of which are the supply of food, fuel, water, and shelter. Inland sites like Nairobi, for example, occasionally suffer from severe drought, whereupon the supply of perishable foods falls off first, then water supplies dependent upon streams and shallow wells are restricted, and finally the energy, especially wood-based and hydroelectric, becomes scarce and expensive. Nairobi experienced a moderately severe combination of such crises in the 1978-80 period. It is becoming increasingly vulnerable to drought over the decades to come, unless new measures are taken.

Meanwhile Kenya as a whole, and Nairobi in particular, must adjust to the steep rise in the price of petroleum. It has just been announced that the dollars needed for oil exceeded the dollars produced from the sale of coffee, which is by far the leading export. No money is left for development, nor do the OPEC countries seem willing to extend soft loans. The temporary response is to print money to pay bills, so inflation is accelerating. The Government does not know how to import the significance of the current financial crisis to the public. The metropolis is obviously the major energy consumer, so both it and the country are in the midst of a major crisis, yet no one feels the crisis or talks about it except a few people in the Treasury and the new Ministry of Energy.

Environmental conditions are worsening simultaneously. Crop failures and the die-off of cattle in the countryside cause people to crowd into the informal settlements on the edge of Nairobi. The parklands are threatened by tree poachers encouraged by the high price of charcoal. The recent level of population expansion occurring virtually everywhere in the society spurs the growth of the landless fraction in the society and multiplies the number forced to pick up and leave. Formerly rural people moved on into other rural areas, working as servants, laborers, field hands, and artisans, but now they drift down the roads and soon reach the metropolis. For the next human generation, and perhaps beyond, the pressures in the environment will result in an influx of people who will try to make a living in Nairobi.

This study will first consider the ecostructure of Nairobi, including the observable trends in 1980, whether they be growth, decline, or stasis. Then it is possible to take up the complete list of exports and imports, emphasizing the predictable demand for various forms of food and

fuel, and the shifts caused by changes in supply. Finally it will assess the adaptability or resiliency to the kinds of energy shock expected for the future. A number of policies can be inferred from the analysis which are expected to reduce the vulnerability of an urban community to outside forces. These policies should add up to a strategy that increases the viability of the community and its ability to minimize damage when extraordinary stresses are imposed.

### **Ecostructure**

Nairobi was first settled almost a century ago as a post for the extension of the British Empire. The immediately surrounding area was exceedingly attractive for European settlers because it was temperate the year round—the 1000-2000 meters of altitude moderating the equatorial location. Soon European-style extensive farming and plantation agriculture was established. Crop plants and horticultural stock was brought in from similar climates in New Zealand, Australia, the Mediterranean, and North America. Railroad builders moved over from India and built a line from Mombasa to Nairobi and beyond which allowed the agricultural products to flow into world trade.

**Boundaries.** A metropolis that is also the capital of an extensive country is a community with very fuzzy boundaries. Long ago it had spilled over the 684 sq. km. contained in the political unit called Nairobi Municipality. Spot surveys suggest that high-density, relatively rural settlements as much as an hour away on the bus may have ten to twenty-five percent of the males with part-time or full-time jobs in Nairobi. That means the principal source of cash in the neighborhood is obtained by commuting workers. Although the landscape is rural, and subsistence comes from the land, the improvements in livelihood are attributable to the degree of participation in urban activities.

At this stage it appears that the one-hour commute by bus, which takes one as much as 40 km. from the Centre, is a practical boundary. Maps 1 and 2 show our estimate of the spatial limits of the metropolis and its place within Kenya and the larger region as of 1980. The shading at the boundary reveals the uncertainty of assignment.

**Human Population.** The 1979 Census has yet to be published, but even when it is there will be considerable uncertainty in the effective population of Nairobi. An assessment of trends and the growth of settlement suggests that it will reveal:

Total Population (1980): 900,000-1,000,000

There is a tendency for males to come to the city ahead of the family, or to keep a family back in the *shambas*, so there are fifty percent more male immigrants to the city than females. The educational system strongly favors males in the towns and rural areas, so this pattern is likely to be retained in the rural-urban migration. At the present time probably 200,000 more males than females live in Nairobi.

Within Nairobi people segregate themselves, in their social lives as distinct from their economic activity, into subcommunities which subdivide as follows:

|                                            |             |
|--------------------------------------------|-------------|
| Africans (Kikuyu, Luo, Juhya, Kamba, etc.) | 750-850,000 |
| Asians (Hindu, Muslim, Arabs, etc.)        | 80-110,000  |
| Europeans (English, Germans, Swiss, etc.)  | 25-35,000   |

The North Americans are lumped together with the Europeans and make up 1,000-1,500 persons altogether. The spatial segregation in the metropolis is primarily for economic status, but the poorest neighborhoods are primarily differentiated according to tribe.

The fertility of the African population is extraordinarily high, one 1977-78 survey showing 8.1 births average per woman during her reproductive lifespan. Crude birth rates are not truly indicative because of the biased sex ratio and the warped age distribution. Despite a decade of

technical assistance in family planning with official encouragement, the fertility rate has reached the highest recorded in the world. Even the educated class have families of four to six children. At the same time the health facilities are relatively well organized, so infant mortality rates are dropping and maternal health is rising. The total number of "acceptors" attending family planning clinics in 1980 in Nairobi will probably not exceed 20,000 women. The natural growth rate is currently about 30,000 per year, while the net immigration is almost as great.

Therefore, counting the capture of densely settled rural population through extension of the boundaries of metropolitan Nairobi, the future growth is likely to be seven to eight percent per year for decades to come. The urban alternatives to Nairobi, especially Mombasa and Kisumu, which will attract more manufacturing, are expected to grow even faster, but from a smaller base.

The urban planners are reluctant to face up to such prospects, so they will tend to understate the current population and extrapolate urban growth rates which assume that poor people will remain in an increasingly overcrowded countryside (as compared to sources of livelihood) without having available any means for controlling migration. This bias exists throughout the Third World, but it is especially strong in Nairobi, so official projections must be treated with great caution. This means that per-capita measures of income and amenities, current and prospective, will be overstated. They are rendered meaningless here, as elsewhere, by the great disparities in income and privilege which are being addressed only now in the governmental planning.

**Fauna.** No numbers seem to be available for the various animal species living in Nairobi, so one must use observation and indirect evidence.

Pets are maintained by the middle classes, but they are not common. Therefore only a few thousand cats and dogs are supported in the households, and only a few hundred birds. A few hundred riding horses are maintained on the edge of the city.

The domesticated species maintained for economic purposes are goats, cattle, pigs, and chickens. Meat is an important part of the diet, even for poor people, but the predominant share is imported from grasslands far outside the metropolitan region. The kind of chickens available on the market come from a few highly rationalized poultry farms within the city, and some from rural farmers who also supply eggs.

**Flora.** The richness of plant life is the outstanding amenity of life in Nairobi. Trees from Australia have been particularly successful, but the orchard fruits, from citrus to papaya, have also been modestly impressive. The sophistication in horticulture is at a high level, so that nursery stock and flowers shipped by air freight are a significant export of Nairobi. The introduction and propagation of new species is easier here than elsewhere.

Market gardens concentrate primarily upon European vegetables—potatoes, cabbages, carrots, green beans, onion, tomatoes, lettuce—and very little upon the Arab or Indian gardening combinations. Maize, bananas, and dry beans will be found on some subsistence plots, but the bulk is imported. Seeds are adapted to local conditions and are available in convenient colored, illustrated packets backed up by Dutch horticultural experience in Africa. Pest controls are readily available because they are needed for the adjacent plantation agriculture.

Much of the underbrush is cut back by women who are foraging for cooking fuel, chopping up green saplings and fallen branches with a small *panga*. So far the Government has been successful in preserving vigorous new forest, even without barbed-wire fences. The increasing shortage of fuel is evident, but it has not yet reached a critical stage.

**Habitat.** Much of the region is a residential parkland with villas, cottages, and apartments for various classes of Government employees. Each plot is surrounded by a hedge hiding a few strands of viciously barbed wire or by a high fence. A high gate is invariably present, but it is sometimes left open. The dwellings are built to European standards, with the apartments often constructed of prefabricated components. The landscaping uses a great variety of ornamental plants, and is often maintained at a high level. About twenty percent live this way.

To the south, downstream from the central business district and not far from the industrial estates, the bulk of the population lives in shantytowns built with concrete block, wattle and daub, and sheet metal roofs. The commercial shops are small, and workshops are inter-mixed with them. Typical plots are 40-60 m<sup>2</sup>, and the one-to-two-room houses, free-standing or parti-wall terraces, occupy most of the land. The typical household size is five to eight persons; the smaller households take in roomers or boarders to use up the available space. Most often a grid arrangement has been superimposed upon the urban community, so that it does not possess the organic structure of a village. The whole place is teeming with life, most of it very young. It is noisy and boisterous from afternoon until late at night, much of it due to the home brew. However, improvements are very much in evidence.

Nairobi has a number of projects under way whereby the poor and the lower-middle-income strata can obtain relatively adequate housing within their means. Some of them utilize site-and-services, World Bank style, but an even larger share introduce core housing. Interestingly, in this society more than ninety percent is built by artisan contractors after the first stage, rather than as self-help. Thus the real housebuilding skill that needs to be acquired is that of supervising general contractor, and not block-making, masonry, or plumbing. Each group engaged in self-help projects and upgrading movements discovers this eventually, but now the insight is recognized at an earlier stage.

Nairobi has a number of advantages over most other parts of the world which they are now, when 5000 units or so into organized projects, learning how to exploit. For example, the cheapest building material is a quarried stone, brown in color, and quite homogeneous. With a hammer and chisel it can be shaped into a handsome earth-colored building stone that needs no maintenance whatsoever and can be resold at market value any time the house is taken down. The roof is corrugated iron, and the windows are steel frame and glass with some ornamental iron grillwork behind which provides security against entry. Doors are resplendent with varnished or oiled wood. The enclosed area is thirty to forty square meters, so often three units are raised on one 120-square-meter plot. Surprisingly, they are finding that when construction is finished they have an average of eight persons per plot, typically in the seven-to-ten range. Of course families are incomplete, so children will be arriving, and ten years from now, after the community has done much more development work, the household size is likely to fall into the eight-to-fifteen range.

Across the stream bed a plot of land of roughly the same size and characteristics was built up even faster than Dandora, the World Bank's site-and-services area. Professionals have not had time to investigate the details. This parallel development would provide the basis for an excellent thesis in architecture or planning. The hawkers in Dandora set up small rectangular "kiosks" next to the street, half for dry goods and beer, and the other half for vegetables. Some of the weedy areas have been converted into unfenced gardens, but so far too little time has been available to the housebuilders, and the drought has broken too recently. The World Bank has a clause in the contract which encourages the staff to promote gardens and trees, but they have been very busy and have not known how to begin. This would be a project for the social welfare staff (one person for every 250 houses), who are particularly busy during the moving in stage of the project.

It is interesting to note that the project's contractor-built toilets and showers, which are held to international standards, are poorer in quality than the self-help additions. The next stage will allow owners to build their own core around a water outlet.

A strong contrast is also available between these settlements and the preceding settlement, Mathare Valley, now approaching twenty years old, which is close to that part of the city that is maintained according to codes and by-laws. Mathare Valley is a community variously estimated to contain 80-120,000 people, renting from prior landowners who charge 50-80 shillings (\$7-11) per month for a rusting shanty. They are not permitted to improve the housing, nor are the landlords willing to pave the muddy lanes, introduce drainage, or provide community facilities. Mathare Valley has the reputation of seething with discontent; it is a political time

bomb. A large fraction of the families moving into the Dandora project came from Mathare Valley, but the places they left were immediately filled up.

**Community Facilities.** The conspicuous community facilities are the churches, parks, theaters, colleges, and university that cater to the top twenty per cent; they are clustered around the central district, and so belong as much to the nation as to the urban community. The design is tasteful, by anyone's standards, and the maintenance is at least good, and sometimes very good. The clinics, hospitals, and other health facilities are relatively well organized for a poor country, with Nairobi again serving the need of either the whole country or at least the Central Province.

An unusual feature of Nairobi is the relatively large number of private boarding schools, staff colleges, mission schools, community service centers, monasteries, convents, and retreats that have found sites somewhere on the periphery. Each of them is the outcome of a foreign aid project arranged between a donor group and the government. A large share of the donors would like to see something installed that is physical and will set an appropriately high standard. It should occupy a favorable site and photograph well, so that the donors are satisfied that the funds did not evaporate as short-term services. These facilities usually combine a handful of expatriate "do-gooders", at least an equal number of Kenyan collaborators and counterparts, service personnel, a local clientele, and often an outreach into the countryside, so as to create a specialized community with a limited set of common interests. The reason there are so many here is that the "do-gooders" element can live a comfortable, civilized life in Nairobi, and yet be working in "the heart of tribal Africa".

**Soils, Aquifers, and Base Rock.** Because the central highlands of Kenya were colonized by a technically advanced European society, all of the applications of soil science and geology known up to the 1950s have been routinely undertaken, and a number of specialized resource appraisals have been completed with technical assistance from international bodies and some Western countries since then. Thus Nairobi land is about as well studied as a typical urban site in the developed world. Only a few superficial observations will be included here that are relevant to the energy issues.

The soils are reddish, friable, and easily eroded, but are rated good to superior for agricultural purposes. They accept fertilizers very well.

The aquifers cannot compete with reservoir water brought in from the highlands. Thus wells are uncommon.

The base rock is a partially metamorphosed lava which contains all the desirable trace elements. Thus it provides an excellent base for continuing fertility, unlike many other tropical areas of the world. Therefore the geology seems likely to support the great intensification of land utilization that would be required for a huge multi-million metropolis.

**Public Utilities.** There are five grids that expedite distribution in Nairobi. Two transmit fluids, two are based upon electricity, and the other is a circulation system for traffic.

The water is potable and is delivered to the household for about half the city. The remainder shares a faucet or a standpipe. A system of underground sewers carries away wastewaters and sewage, and provision has been made to take away the excess runoff. Obviously this physical planning breaks down in the informal settlements, but not as badly as in most other low-income neighborhoods elsewhere in the world. The reservoir capacity was sufficient to allow almost normal use during the recent severe drought.

The electrical grid serves a region much larger than Nairobi, although Nairobi remains the area of most concentrated consumption. Approximately fifty-five to sixty percent of all the electrical power produced in Kenya is targeted for the capital city. The growth in consumption is irregular, due to power cuts, but it averages around seven to eight percent per year. Domestic demand seems to have been increasing at about that rate, commercial uses at about eight to nine percent per year, while the use for water heating and pumping has been declining. The sales to industry have been increasing at a rate of twelve to thirteen percent per year, so this is now the most promising sector in which to effect economies through conservation (Schipper

and Mbeche, February 1979).

The average cost of energy during normal times was U.S.\$ 0.034 per kWh in 1979 delivered to Nairobi. The actual charges were about ten percent higher due to cross-subsidies granted to less populated areas, including some rural electrification schemes (Gecan, 1979?).

The most current data about the telephone networks are those found in the 1980 Kenya telephone book. Analysis suggests:

Telephones (1980): 45-50,000

for the metropolitan area as a whole. The exchanges are not overloaded, so service is maintained at a level that would be satisfactory for Western Europe. Very likely the presence of United Nations agencies had a lot to do with the priority that has been given to telephone and telex services in Nairobi.

The streets and roads are maintained in tip-top condition for the prestige areas of the city. Very few of the vehicles moving about in the grid have collected the coat of red dust that is raised when driving along off the tarmac. The design of the intersections and the allocation of parking space all fits together into a system that generates significant congestion only for a quarter of an hour around five o'clock. Drainage is quite effective so the monsoon will seriously affect traffic only under extremely unusual circumstances.

**Offices/Factories.** Nairobi is a city that demonstrates better than any other how to use the modern office building as an instrument of development. There are instances of inappropriate monumental design that get in the way of the organizations expected to live and operate in them, but they are few and far apart. A well constructed organization will not have to overcome its built environment in order to function. If the personnel know how to be efficient, they can work quickly and effectively in Nairobi's multistory office buildings. The elevators work, the electrical connections do not short out, the toilets flush, the telephones are accommodating, the windows are washed, and the noise level is moderate. It seems miraculous that one does not have to pitch his voice to carry above the hum of an air conditioner, even though the Equator is only a few miles to the north.

A few architectural images have been created which are unusual enough to be remembered. The two structures in the Kenyatta Conference Centre are the jewel. The top of the brown-capped cylindrical tower is occupied by the UN's HABITAT headquarters staff. The immediate surroundings are very carefully landscaped for pleasant promenades and formal occasions. The surrounding government buildings have carefully differentiated facades, with a few of the spartan colonial stone block buildings carefully preserved to produce a sense of progressive development. The Hilton has put up a cylindrical tower that is a pale reflection of the Conference Centre, and it is surrounded by commercial office structures built by banks and insurance companies which show off in a staid British way, but nevertheless have bulk, floorspace, and lighting calculated so as to maximize revenue. Another quadrant of this busy hundred hectares contains two light brown stone-faced slabs-on-boxes nearly complete which have pleasant courtyards. They are in a matrix of diverse smaller structures. All are intended to house the embassies, consulates, and foreign governmental corporations (*e.g.*, Aeroflot, Sabena) and associated services such as bookstores and sports equipment. At the boundaries of this upthrusting urban core are the city hall and Provincial Commissioner's office buildings and the offices of the "parastatals"—coffee, tea, cattle, cooperatives, etc., all of them very presentable.

The factories are located on estates, and show influences of European design offices. Almost always an international organization was involved, whether as source of loan or grant money, or a license for the technology, or as a by-product of technical assistance. Thus factories are much more than minimal sheds. Other manufacturing is in lofts surrounding the central district, where the clues are the piles of clippings, shavings, and remnants going into the solid waste containers. Garments, leather products, and plastic articles are fabricated there. Many more small-scale artisans' shops are found in abandoned shipping districts and on the

fringes of informal settlements. These are stone block terraces of shops laid out according to the best colonial designs of the 1920s or sheet metal and concrete block sheds. Almost a hundred thousand workers are holding down industrial jobs in the Nairobi metropolitan area. The index of manufacturing has been growing fourteen to fifteen percent per year, but in 1979 the output of large-scale firms grew only 1.4 percent in the nation (about the same for Nairobi, which dominates this sector) and 9.2 percent for the informal sector, which is also very important in Nairobi. The slow growth is mostly ascribable to the drought and the power shortage.

**Machinery.** Virtually all of the stationary machinery depends upon the electrical grid for the source of its energy. In 1980 an estimated 300,000,000 kWh was consumed by industry in Nairobi, which is around 40% of the total consumed for all Kenya. In addition a number of water pumps are programmed to operate automatically off-peak; these use at least fifty million kilowatt hours in and around Nairobi.

Schipper and Mbeche (1979) have reviewed the highlights of industrial and commercial energy use in Kenya. The major installations using stationary machinery are (1) the East African Oil Refinery, (2) the pipeline from Mombasa, (3) cement, (4) steel products, (5) fertilizer, (6) glass, (7) food processing, (8) chemicals production, (9) the tall buildings, such as the Kenyatta Conference Centre, and (10) tire-manufacturing equipment, but they did not find any way of numbering installed motors or of estimating the aggregate demand for electrical energy. Our own estimates are based upon the 1979 issue of the *Statistical Abstracts*. The growth can also be deduced from them to be ten-to-twelve-percent annual increases in power requirements. In 1979-80 the actual power use flattened out because of the drought and the resulting power cuts, but it may well be resumed as soon as normal crops are harvested.

**Vehicles.** The population of motor vehicles in Kenya has been growing at the rate of ten to twelve percent per year, so we must expect that the half operating in and from Nairobi will be growing by perhaps twelve to fifteen percent per year—a much more significant population explosion than for people because it must level off much sooner. The current estimate is set at:

Motor Vehicles (1980): 140-160,000  
Passenger Cars: 50%  
Van, Pickup Trucks, etc.: 25%  
Trucks: 10%  
Buses: 3%  
Motorcycles: 5%  
Miscellaneous: 7%

Kenya seems to have stopped publishing data on the total population of registered vehicles in 1975. It does, however, continue to enumerate types and volume of imports. Since the imports match quite closely the proportions in the total population, and differential extinction (salvage) rates have small effect when growth rates of the total population are so rapid (the life expectancy of an automobile here is close to ten years), it is possible to update with some confidence. The average fuel use also remains quite stable at 3,000-3,200 litres per year per vehicle of petrol or light diesel fuel.

Each society evolves a close culturally-based adaptation to automotive vehicles. In Kenya it is called the *matatu*, a covered pickup truck with seats, a converted van, or a mini-bus, that operates as a jitney. No signs are carried, but a boy shouts out the route or destination and collects the fares. No limit is set on the number of passengers, so the seating capacity of twelve to fourteen is often stretched to twenty. At the downtown terminus a *matatu* is linked to a man who lines up riders. This service reduces the time they are in the terminus filling up with passengers. Almost exact parallels have evolved in the upland city of Bandung, quite independently. The fares are equal to the bus when paralleling city or country bus lines, and otherwise may increase. This is feasible because the bus system is only lightly subsidized. The *matatus* keep the buses at a reasonably satisfactory level of performance with respect to crowding and

frequency. The buses are, in general, better maintained than the *matatu*, and allow people to carry bigger packages, so they have a special niche as well.

**Automata (Control Systems).** The importance of control systems is that they can be used to manage the flows and the interactions in the community. By taking the trivial, routine decisions off the hands (or minds) of humans, they can pay attention to more important matters. The control system is designed to save only one kind of resource because the human being wants to decide on trade-offs between two or more scarce resources. Thus control systems will work well in isolated, or cleverly insulated, places in the community. Automata are pallid imitations of human or animal decisionmakers.

Nowadays automata thrive in a special environment provided by computers. If a computer account lasts more than a year it is presumed that some task is being performed which is worthwhile. Some people have come to depend upon the computer, just as they might depend upon a servant or a technician. In this manner an automator has come into being. It may be replicated and multiply in other sites; it may be erased in favor of a superior program, or it may evolve and assume a wider range of decisions until it collapses and some of its components take on a life of their own. The bioecological parallels are virtually infinite, but the human parallels are always limited. Nevertheless, automata are extraordinarily important at times when energy becomes scarce, because they can do their simple management and control tasks with minuscule amounts of energy—much less than is required by a human being. Thus in many different ways energy scarcity encourages the multiplication of automata and the expansion of computer capacity.

In Kenya about a hundred installations exist, according to a report that has been completed but not yet published. We estimate that sixty to seventy will be in the Nairobi metropolitan area. Some computers are dedicated to a single operation, most commonly maintaining the payroll of an organization. Others may be associated with industrial process control. In those instances one computer represents one viable control system—an automator—while elsewhere a computer will handle a number of similar accounts. A few general-purpose installations are staffed with people well enough trained to handle a wide variety of accounts. An environment for fostering a small community of automata is created. The Institute of Computing at the Chirano campus of the University of Nairobi offers one such site; the Data Centre and the Central Bureau of Statistics are others.

There are six firms selling physical equipment and offering service. They do a large share of the training of acolytes—the programmers. The University trains hundreds of others. Yet the greatest complaint that is heard is that there are not enough good programmers. One has the suspicion that many of the complainers have not set up systems for getting reliable data, and then blame the problems that result on poor programming.

To conclude, hundreds of people are making a living out of computing and their productivity is rising rapidly. Thirteen years ago there was no computer operating in Kenya, so the activity is very new. The number of computerized controls systems that are viable now is about two hundred and the growth rate is estimated at thirty percent per year.

**Organizations.** Although social, cultural, religious, and other organizations must be recorded, counts of their registrations are not separately published. The numbers of different governmental units can be estimated from the telephone book, they come to a minimum of 220. Churches, seventy-two of them, advertise services in the daily newspaper, but this is only a partial list because the two major mosques, the two Hindu temples, and the Sikh temple are not included (although the Hare Krishna Centre is in the list).

The number and type of business establishments is well recorded for Kenya as a whole. The best estimate appears to be seventy percent of the non-agricultural establishments in Kenya or about 12,000 in 1978. The growth rate in the number of business names registered is about four to five percent, but a very large share of the total are dormant so this means very little other than that there is more rapid growth, very likely, than that of population in the city. Non-Asians, in particular, are encouraged to go into business.

The city is very well laid out and managed to propagate organizations. The telephones usually work and office space is in reasonable supply, with new blocks going up each year. The growth in floor space is in the ten-to-twenty-percent range annually from a visual inspection of the central district. Voluntary groups are under some restraint because they can be hauled into court for holding a public meeting without a permit, but the enforcement occurs only when such meetings have political overtones.

Organizations (1980): 15-20,000  
Growth Rate 10% per annum.

**Knowledge.** Most organizations in Nairobi, even the international agencies, do not accumulate knowledge efficiently. This is largely due to internecine politics and the petty corruption in the bureaucracy. The businesses collude with the politicians to exploit the public exchequer. Therefore the recorded, or transmitted, experience contains only a part of the truth, a fair amount of "cooked" data in both the public and the private sector.

The University is an institution that has been designated to collect knowledge from elsewhere in the world and disseminate it to the students and scholars. Its libraries are better shipped than most and the laboratories and museums are quite well organized. It teaches 6,000 students in facilities that would normally handle twice that number in America or in the Philippines where American formulas are still in force. The reason is that almost all students are living in dormitories on full scholarships. Moreover, an implicit belief in a meritocratic-elite-directed society is left over from colonial days. A teachers' college and a polytechnic add about 3,000 undergraduates. They are able to accept only about ten percent of the secondary school graduates. A few of the rejects find their way to institutions in the U.K. and the U.S.

British "qualifications" are still vigorously retained, so American-trained students start out in their first jobs at a strong disadvantage. But one of these, who became a tenured faculty member in a New Jersey university, came back to discover that people in his class who had gone to America had within ten years of returning risen to much higher posts than those trained in Nairobi or in the U.K. Also, the U.S.-trained seemed to have contributed as much as the others to the decline in corruption and the increased responsibility of the public service. The capital city is now much more able to learn from mistakes and successes than when the revered Jomo Kenyatta was still alive.

### Inputs and Outputs

Nairobi has a temperate climate, free of frost, and because of its 1500-1600-meter altitude below two ranges of mountains reaching 4000 and 5200 meters respectively, the mean maximum temperature is 22.5° (72.5°F) in July and 27.9° (82.2°F) in February at the peak. The humidity ranges between forty and sixty percent.

The mean hours of sunshine per day is given as:

|          |     |        |     |           |     |
|----------|-----|--------|-----|-----------|-----|
| January  | 9.5 | May    | 6.1 | September | 5.9 |
| February | 9.5 | June   | 5.7 | October   | 7.1 |
| March    | 8.3 | July   | 4.2 | November  | 7.0 |
| April    | 7.2 | August | 4.1 | December  | 8.7 |

The mean rainfall in the metropolitan area ranges from 900-1050 mm. annually (30-34 in.). Most of its water is held in reservoirs upstream on various tributaries of the Nairobi and Athi rivers.

Thus far no data have been found for the flow of mail, telephone calls, telex, or other sources of information. Nairobi maintains only one television channel, and the medium has not generated a great deal of enthusiasm. There are direct connections with a communications satellite, so calls to the rest of the world are quick and convenient. Plans exist for adding a second by the end of the year.

For immigrants there are no indicators of the internal visits made by Kenyans to their capital city. The data on tourism is for the nation as a whole (Nairobi has about forty percent of the hotel beds, but the rates of use are highly variable.)

Again, there are no indicators of the amount and type of food imported into the metropolis. Because body size is relatively large for the Third World, the average intake is estimated at 2700-2800 Cal/day. The staples are

Maize meal (predominantly white)  
Bread (British style)  
Meat (beef, chicken, pork, mutton)  
Potatoes  
Cabbage  
Greens  
Milk  
Bananas

To an important extent these can be varied according to price and availability, but there are certain substitutions which can be accepted only under desperate conditions. For example, the white maize meal ran short near the end of 1979 because growers had shifted from maize to coffee and a drought reduced yields of the maize that was planted. Imported maize meal was yellow, which is rejected by many people. Clinics observed children suffering from malnutrition; students at the Polytechnic were offended, so they rioted, destroyed school equipment, and then went home. Meat also appears to be very nearly a necessity, even for very poor people, but the price has recently been escalating. Feed for animals is not imported into the city; only the animals or the cleaned carcasses are introduced.

Fuel energy is imported either as electric power from a distant hydroelectric site or as crude petroleum. Frequently a range of products from refining in nearby countries is also purchased, and even more is sold.

for Kenya:

Petroleum (1980): 1900  $\pm$  50 million liters (Kenya)  
Crude (1980): 3500 million litres

Thus, in normal times (and 1980 is not yet normal), Uganda would absorb 500-550 million liters and Tanzania 0-200 million liters, with the total export ranging between 1400-1900 million liters exported.

Much of the fuel oil goes into electricity (130 was added in 1978 to the capacity) but some of the power was exported out of the region. These complex relationships are best expressed in Figure 1: Because the metropolitan area is a very open system, the producers and distributors do not keep accounts that enable anyone to determine clearly what is imported, consumed, and exported from the area. It is important to realize that Nairobi imports large quantities of crude oil, much of which is exported in the form of products and power, although Nairobi also imports hydroelectric power. These relationships affect the decision making when prices rise or sufficient supplies are unavailable.

The manufactures imported by Kenya ending up in Nairobi are primarily from the U.K., Germany, Japan, U.S., and Italy, in that order. The exported manufactures go primarily to the rest of Kenya and to Uganda. The most energy-intensive of Nairobi exports are cement, iron products, flour and meal, textiles, and clay and glass products.

The export of waste heat from Nairobi seems to be well distributed. Industrial fuel use is balanced by nearby green open space. Metal roofs do not retain solar energy. Therefore it is anticipated that the "heat island" normally created by a metropolis, which allows it to get rid of the imported and absorbed energy, would be detectable only under conditions of dead calm, when warm air is not carried away by the breezes. The cooling water for power plant and

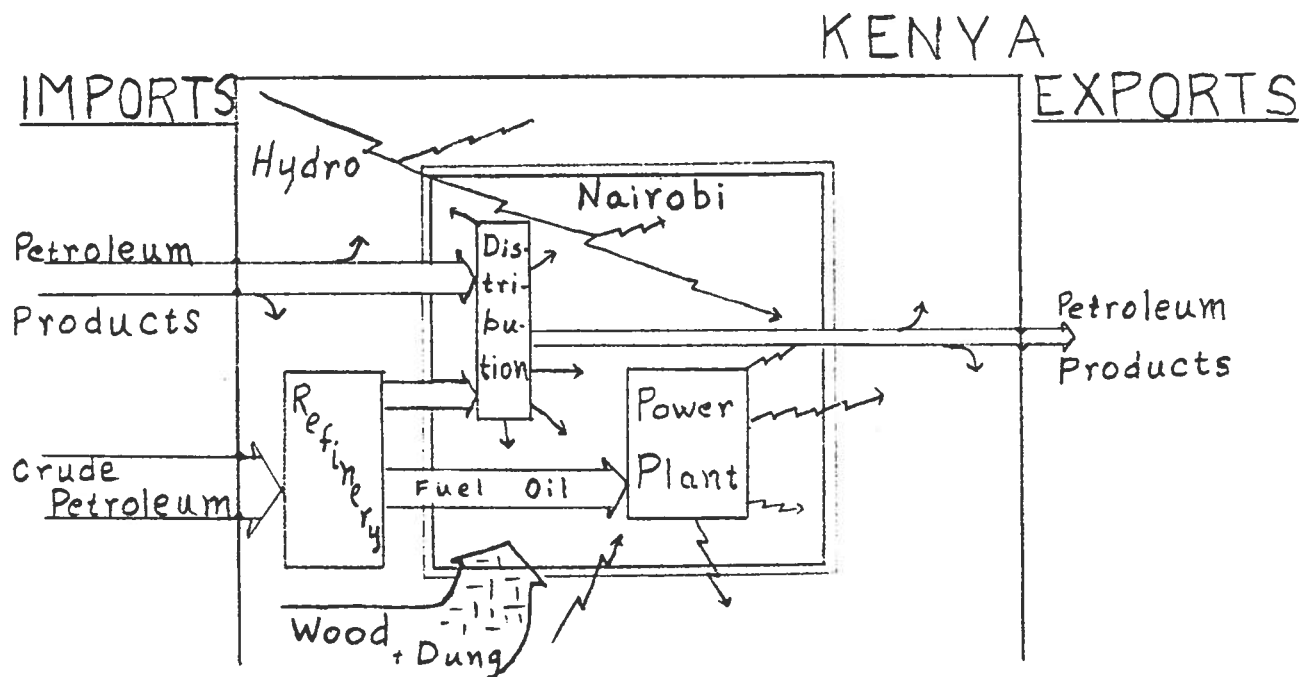


Figure 1.

Complex Energy Flows Through Nairobi

refinery will have a higher temperature while in the stream, but the difference becomes trivial when diluted by a reservoir below. The waste heat is not an important element in the environment of Nairobi, nor are chimneys a significant feature in the cityscape.

### Impacts of Prospective World Energy Crises

Nairobi has had experience in adapting to two fifty-percent price increases for energy since 1973, when the oil price was suddenly raised 300-400%. Therefore it is relatively easy to project what might happen if the world were subjected to another similar increase. At a time when the price of petroleum appears to have peaked, and has even declined by about five percent, it seems strange to talk about price rises. But Kenya can appreciate the likelihood as somewhat more real than elsewhere in the world because of some recent experience. In 1978 its primary oil supplier was Iran, but Iran could not fulfill its contracts, starting in 1979, so Kenya had to look around for other sources on short notice. If another major supplier drops out of the world market, the stage will have been set for manipulating a new price rise. It would be heavily at the expense of Third World countries.

In Kenya the government is now quick to transmit a price rise to the consumer; it has learned from past experience that its financial reserves could be wiped out very quickly if it does not do so. Therefore one can expect overnight increases in the cost of cement, iron sheet, iron bars, brick and tile, and other energy-using manufactures, even if produced by Government corporations, by as much as twenty-five percent. Since fuel is now about thirty percent of the cost of operating a *matatu*, the minimum ticket would go up from sh. 1.40 to sh. 1.60. The effect upon automobile traffic would not be very great, because the recent rulings upon the number and size of autos to be imported has raised the value of an automobile to such a high level that the amortization and capital costs predominate. The predilection of the Government would be to put a greater share of the burden upon petrol and lesser increments upon diesel fuel and kerosene. But the refinery would be fortunate to obtain the crude oil it has contracted for, so it must sell the products that can be obtained from it. The current policy of subsidizing diesel oil because buses and trucks serve most of the people is likely to create a shortage of diesel oil within a few years. If nobody uses the gasoline produced simultaneously with the diesel fuel it evaporates; thus energy would be wasted with concurrent harm to the local environment. Sri Lanka, an economy almost as large as Kenya, has already been greatly embarrassed by refinery imbalances. Concepts of social justice cannot change the product mix from a catalytic cracking unit in a refinery more than a few per cent without assuring a scandalous waste of energy.

The rise in the price of kerosene and propane, the domestic fuels, would add to the demand for charcoal, using up stocks, and triggering a temporary price rise of as much as sixty to seventy percent. That, in turn, would be a strong incentive for poaching trees. The draw-down on biomass reserves, which is already causing great concern, would be accelerated.

This complement of consequences sounds seriously disruptive, but Nairobi has outlived more serious situations in recent times caused by the recent drought. The result of the major price rise is a transfusion of the lifeblood of a growing economy to the petroleum producers, and a noticeable closing of horizons and shrinkage of opportunity for the young people entering the economically active society. Ecologically, when energy supply diminishes the number of niches available decreases and the territories and ranges of many individuals physically shrink, while the remainder have little hope of expanding.

What would happen if a relatively likely "worst case" were to befall the world—the loss of Arabian Gulf petroleum from world trade for a year or more? This amounts to a fifty-percent cut in supplies, and it would take effect when most importing countries have managed to accumulate enough stocks to last a hundred days of normal consumption. Since Kenya currently obtains most of its oil from the Gulf, it would first have to hope that the multinational firms, which Kenyan politicians have often publicly castigated, will succeed in their intention to equalize the remaining flows of petroleum so that all importers suffer equal cuts. One

immediate concern is the effect upon the share for Uganda. What is the fair way of calculating cuts on the supplies of products?

How might energy be rationed in Kenya? What devices do the people with clout use to get more than their share? The administration is relatively new and uneven, so it could not manage a full-scale rationing system. Very likely the Minister of Energy would bring the bad news to the President. The advisors on economic planning would point out that it takes more labor to distribute half the fuel to as many customers as before, and it requires more management as well. Some essential services, such as food transport, water pumping, hospitals, and police cannot safely be cut by half. Therefore other consumers, such as manufacturing and households, would need to take sixty-percent cuts. The economic advisers would suggest a very sharp price rise to reduce the intensity of demand. If customers did not wish to consume their allocation at, say, twice the price, they could offer it for sale on the "parallel market". In that way people with family crises, or concerned about a potential crop loss, could find fuel to meet an emergency. (When Nepal was faced with an equivalent situation due to landslides on the road connecting with India it was agreed that a Land Rover carrying cigarettes and machine parts to a provincial town should get precious fuel, the excise taxes being about as important as the parts.)

Industries that use large amounts of energy (cement, steel, tile, glass) would very likely shut down until they were sure of a production run of a month or more. Very soon thereafter most construction would grind to a halt. The single men would return home to the village or farm when they could find transport. Tens of thousands of families would need help when the breadwinner lost his pay packet, and only a few have social insurance of any kind. This is a dangerous situation, so small, almost random, events could cause political conflagrations and destructive violence. It is virtually impossible to explain the transmission of shock and stress in a metropolitan economy. The wise politician would use his precious stocks of fuel to get over the worst of the situations. In general the well-organized unions or cliques are able to get something for themselves out of those reserves. The Government might have to call out troops to keep order in Mathare Valley and in the neighborhood of the closed plants.

After two or three months the second- and third-order reactions will have worked themselves out. The city will have dropped back to a level it had been operating at about ten years previously. Frustrations will have dulled somewhat as expectations drop. The quick opportunists will start making up for the immobilized fatalists, so some substitutes for petroleum and energy-rich manufactures will begin appearing on the market. A tentative balance is achievable, particularly because almost everyone in the city knows personally how to live at a subsistence level, or has at least absorbed much of that tradition from stories told by parents and relatives. At subsistence the need was perhaps only ten percent of the quantity of imported energy as is consumed now. The recent population growth, and the resulting subdivision of farms, is the principal reason more energy would be needed than two decades ago. Fertilizer is needed now, and in some places energy is required to pump water, to get the higher yields per unit area.

The ultimate worry is that the world will return to Malthusian times. The most likely combination of events is a repeated failure of the monsoon. Both China and India, and some of the smaller countries in their vicinity, have the stocks and reservoirs to ride out one failure without permanent injury, but another failure the second year would force them into the world market, where the prospective stocks are insufficient. These events are important for Nairobi because it is getting too large to be supported from the surplus from the Kenyan countryside. Nairobi can be fed only when the crops are good; during the lean years it must rely on the foreign exchange earned from coffee, tea, sisal, cattle, and tourism to purchase maize, wheat, and cooking oil on the world market. However, in Malthusian times, their prices are likely to triple, or thereabouts, current prices. If the monsoon fails, the conditions for Kenya's crops will also be changed to either flood or drought, so Nairobi has a strong chance of finding itself in trouble.

Nutritionists believe that little permanent damage is done if the caloric intake does not fall below seventy-five to eighty percent of the normal intake over the course of a year. The principal effect is a reduction in physical activity and a loss of body fat. When a community is cut down to seventy percent of normal for a season or more incremental mortality is observed among infants, mothers, and old people. Their observations set the outer limits for food rationing. Therefore, while the large cities remain less than twenty percent of the total population of Kenya, and farmers have not converted completely to export crops, a sharing of the shortage between city and countryside should allow everyone to survive. At the present rates of population growth that strategy will work no longer perhaps than ten to fifteen years. Immunity from world food rises is possible, but it will take very intensive work on population controls and in agricultural development simultaneously. As observed earlier, no significant results have yet been obtained in family planning, so the threat remains one which cannot be averted by known policies available to the Kenyan government. More knowledge, experience, and effort are required.

What has been projected here are reasoned responses to some foreseeable energy-related crises. It was assumed that good policies would be adopted and implemented promptly with prior levels of effectiveness. There is of course, no assurance that this will happen. If major errors in response are made, the people will suffer.

In conclusion it should be pointed out that the setbacks and the costs visualized here are significantly less than those borne in the event of war or revolution. Political errors are still more costly than the foreseeable discontinuities in the flow of energy in the case of Nairobi. With nations around Kenya undergoing one or another political misfortune, or many, it is important to establish a realistic set of welfare priorities.

### **Potentials for Conservation**

It is quite possible that the world will safely emerge from the period of OPEC monopoly practices and that the breakdowns in supply will have been minor. A new stage in which many suppliers of petroleum, coal, synthetic fuels, and alcohol are linked to many consumers should be reasonably stable against discontinuity. That does not diminish the need for cities to transfer their dependence upon fossil fuels to renewable sources. Considering the time it takes for new technologies to be developed and installed, the forty to sixty years available for the transition in the Third World as allowed by visible supplies of fossil fuels will cause a pinch in countries with rapidly growing populations and rigid traditions. What are the appropriate long-range policies for Nairobi?

For the practiced observer, the future for Nairobi rests upon efficient use of solar energy in the form of biomass. This would not require huge amounts of capital, as against the procedures open to European cities or desert cities, such as Cairo. The task is to find successive stages, each one of which is economical at the time it is installed.

At the moment attention is focused upon crop waste. A plant is going up to convert coffee waste into charcoal; another seems possible for sisal waste. If a plant for converting cane juice into ethanol is undertaken in the Mombasa area, then part of the bagasse will be available for the cogeneration of electric power or for charcoal.

Nearer to Nairobi is the wood. Natural forests must be replanted with fast-growing species. The traditional charcoal is much less efficient than it could be. The potentials for the charcoal route have been very ably described by Prof. J. D. Kokwaro (Department of Botany, Nairobi) in his unpublished paper "Indigenous and Introduced Common Firewood and Charcoal Plants of Kenya" given to the Royal Swedish Academy of Sciences, May 1979. His recommendations for the near term are very carefully reasoned.

An alternative technology, recently evolving in the forests around the Pacific Ocean, is complementary to it and adds some extra efficiencies. It would start with a portable wood chipper that can use twigs and branches otherwise lost. The chips can be converted into dense

briquettes with the aid of another simple hand-operated piece of equipment which converts the chips into dense briquettes, conveniently sized. The briquettes save on transport and distribution costs.

Once chip briquettes are established upon "free" waste, it should become evident that more of the original energy can be retained via the chipping and briquetting route, or chips to medium-scale carbonization plants for the production of methanol from synthesis gas intermediates, than can be obtained by improvements upon traditional charcoal-making practices. A doubling in thermal efficiency seems achievable, but this assertion would need to be supported by detailed on-site investigations.

Further increases in efficiency can be obtained on both ends of the chipping/briquetting process. Fast-growing species on poor soil (the nitrogen-fixing *Leucaena* and some *Acacia* species are most promising) can add to the overall wood supply, and urban trees can be systematically harvested. On the consumer side, household stoves can be built to extract the most useful heat from wood. They are likely to be three to four times as expensive as charcoal burners, so the advantages must be apparent. (For example, they can be set side by side in a market place to heat a big pot of water. Then an equal money value of fuel is employed. A graph would show the speed with which the respective fires heated the water. It would also show the temperature reached when the fuel was used up.) African artisans for efficient stoves are already being moved from one country to another by nongovernmental technical assistance groups.

The path from wood to liquid fuels substituting for petroleum is already known technologically, although the most efficient designs have not yet been determined. It would start from tree farms and go through methanol to a reforming into petrol, kerosene, or diesel fuel. When the effective price of hydrocarbon fuels is double the present level it appears that the society can move over to a dependence upon photosynthesis. At that time water will become a crucial resource, and strenuous efforts will be made to recycle water and obtain the most photosynthesis per unit of rainfall. However, for the next two decades water will be rather cheap.

The high price of fuel, and prospects of rising costs, suggest a number of efforts to redesign the city and its industries to conserve fuels. This is an activity pushed by the Ministry of Energy and sparked from the outside by Lee Schipper of Lawrence Berkeley Laboratory, Oyuko Mbeche from the University of Nairobi, and Robert Nathans and G. McGranahan from the Stonybrook Campus of the State University of New York. The work is in information-gathering and proposal stage and still more than a year from the first stages of implementation. The Common Market countries have designated Italy to act on energy in Kenya, and Italy has in turn designated a Dr. F. Cecchi, representing a consulting firm, to handle their responsibility. The Peace Corps and the Beijer Institute are also interested in organizing community conservation of energy. There will be a multiplicity of projects over the next few years, and an increasing number generated by Kenyans involved in industry, transport, and commerce.

Each will require energy information in order to consider alternatives. What Nairobi needs is a site where the abstracts, recent journals, and most pertinent reports are on hand, while those that are needed urgently can be ordered via communicating satellite. This "energy information centre" needs professional information science training to get it started properly. It would provide the link that allows Nairobi to pick from the best of the external information available. In a matter of two weeks in Nairobi it was possible to identify projects on which tens of millions of dollars were due to be spent upon obsolete technologies which would be a waste of capital, but there was no body of information that could be called upon to test the arguments pro and con. In the future it will be hundreds of millions of dollars (or Kenyan pounds at \$2.85 apiece) that will be at stake.

It appears now that this centre should be under the wing of the new Ministry of Energy and close to the Office of the Minister. Information is one of the major influences upon events that the Ministry can have. It seems natural for Kenyans to consult it for guidance on energy issues. But documentation and information presentation are the responsibilities of other agen-

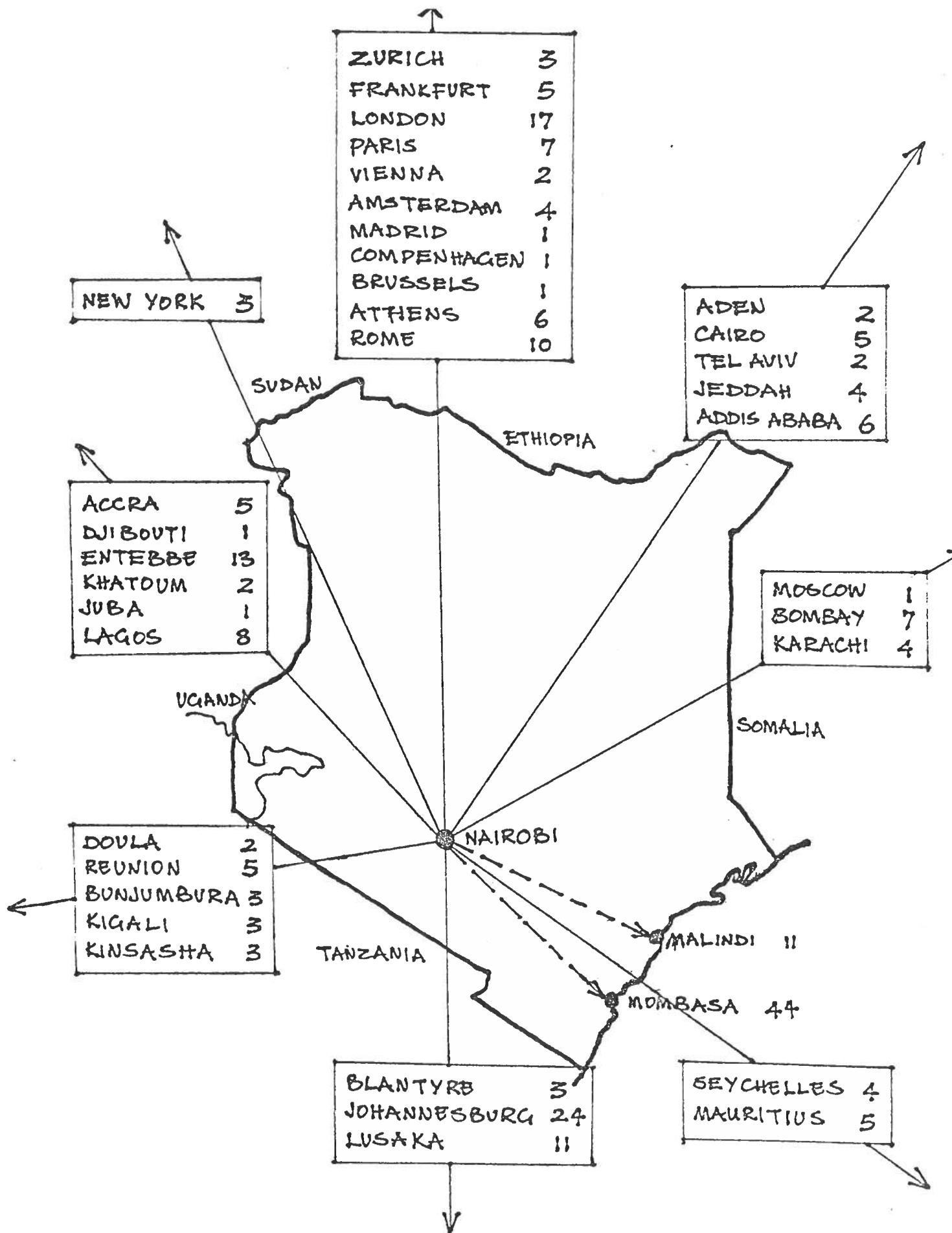
cies and services who will fight to retain their control. The Ministry of Energy is handicapped by being new and having to battle for a place in the bureaucratic division of labor. Whatever happens, energy information must be located in the inner square kilometer of Nairobi, preferably in the diplomatic or international quadrant.

Very likely the index of success will be energy per unit of output (as measured by GDP), but from the point of view of human settlements it will be the ability to sustain increasing numbers at an adequate level of living, despite external threats. The dimensions associated with the future Nairobi, based upon present knowledge, are presented in Table 1. They apply to conditions to be achieved two decades or more hence.

Establishing a consumption standard for energy, food, and scarce materials at a minimum adequate level of living would require some major sociopolitical advances. The differentiation of social status, for example, including promotions in rank, should no longer be associated with a private car, higher yet a car with chauffeur, or with large villas for dwellings. Symbols must be invented to take the place of consumption; a knighthood, or a university chair, for example, need not cost any extra energy, although such an award should provide personal security, and some assurances that projects undertaken to improve efficiency will be carried through. Since developed societies are not as rational as this, the sociopolitical advances proposed are not borrowings from elsewhere but true innovations. They lead a steady state in the consumption of energy at the same time that welfare and control over destiny are enhanced.

**Table 1**  
***Energy in the Future Resource-Conserving Community***  
***With Adequate Levels of Living***

|                             | <i>Per Resident</i>                              | <i>Organizations Needed</i>                                                                                                                                                                                                    |
|-----------------------------|--------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Food/Feed                   | 5,000-10,000 Cal/day                             | <ol style="list-style-type: none"> <li>1. Urban gardening coops</li> <li>2. Surplus food preservation coops</li> <li>3. Sewage conversion into fish or chicken food</li> <li>4. Food processors of snacks</li> </ol>           |
| Transport                   | 50-150 vehicles<br>per 1,000 residents           | <ol style="list-style-type: none"> <li>1. Ride-sharing commuter groups</li> <li>2. Pathway networks designed for bikes, mopeds, 3-wheelers</li> <li>3. Telework arrangements</li> <li>4. Alcohol production systems</li> </ol> |
| Domestic                    | 10-50 m <sup>2</sup> /cap<br>2,000-5,000 cal/day | <ol style="list-style-type: none"> <li>1. Clustered housing</li> <li>2. Neighborhood water recycling for baths, laundry, etc.</li> <li>3. Wood briquette delivery service for cooking</li> </ol>                               |
| Utilities/<br>Manufacturing | 0.1 kW capacity<br>3,000-10,000 cal/day          | <ol style="list-style-type: none"> <li>1. Solar power with pumped storage</li> <li>2. Computing/telecommunications systems</li> <li>3. Energy farms</li> </ol>                                                                 |



NUMBER OF WEEKLY FLIGHTS FROM NAIROBI