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IIASA Collaborative Paper
June 1986

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CP-86-21

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PREFACE

The extension of the food production system beyond the farmgate has been a matter of concern to the Food and Agriculture Program of IIASA. This post-harvest-food (PHF) system includes food processing, food transport, storage and cooking so as to reach the consumer in the final stage.

It is clear that self-sufficiency in food would require efforts and investments not only in the food production but also in the PHF system. What are the resource requirements, in particular energy requirements, of the PHF system, is a question that is addressed in this paper by J.Parikh and S.Syed for 90 developing countries of Africa, Asia, and Latin America. The results indicate that the energy required in the PHF system, depending on the national characteristics, is 2 to 4 times larger than the energy required to produce the food on the farm. There are other evidences which show that labor, investment and value added follow similar patterns. Recent experiences in tackling the famine in Africa also show that the PHF system could be a bottleneck.

It is hoped that cross-country variations shown here as well as the variables affecting these variations, e.g. income levels, urbanization, cropping patterns, dietary patterns, forest and fossil fuel availability and the like, will be of interest to all concerned with the food problem.

Ferenc Rabar
Food and Agriculture Program

ABSTRACT

This article reports on the methodology and results of the study on estimation of energy consumption in post-harvest-food system in developing countries. The components of the PHF system are: food processing, transportation, storage and cooking. The study has rather ambitious coverage for 70 processed commodities in 90 countries of Africa, Latin America, Far East and Near East. This was possible because of computer tapes available at FAO for a wide variety of data required for such an analysis. Of course, extensive checking was required for each country but much of the approximations remain, leading only to broad implications. Despite the difficulties with precise data, it seems reasonable to draw the following conclusions from the available information: The post-harvest-food system requires 2 to 4 times more energy than the energy on farms. Commercial energy is often used for food processing, such as milling, crushing, and food transport, and to some extent for cooking. The share of commercial energy in total energy used in the PHF system ranges between 22% in Africa to 80% in Near East. The levels of energy consumption in the PHF system depends on income levels and extent of urbanization and whether a country has locally available fossil fuels or forests. In addition, different components of the PHF system are sensitive to different parameters. For example, energy in food processing depends on cropping and dietary patterns, whether food is exported or imported, whereas food transport depends on the size of the countries and location of urban areas with respect to farms. These parameters are discussed here for the four world regions as well as for the 90 developing countries as a whole. Country-specific insights are given graphically due to lack of space to report all data individually.

ACKNOWLEDGEMENT

We are grateful to Dr. J. Hrabovszky, formerly senior advisor to the Agriculture Department, who initiated this study at FAO and is a co-author of the FAO document on this subject, and to G. Konda of FAO for computerizing the method of estimation. We are grateful to FAO for their permission to publish this work.

Lilo Roggenland has kindly typed this manuscript despite much other pressing work.

1. Introduction

A comprehensive food system is not restricted to farm level production alone but extends beyond the farm gate to include food processing, food transport, storage and cooking, referred to in this paper as post-harvest-food (PHF) system. The energy consumption as well as employment and value added by the PHF system is several times greater than the farm level activities. Analyses from several developed countries (Stout et al., 1979) indicate that the total food system uses around 17-20 percent of total energy use in the economies. Of this, usually around one-fifth to one-quarter is spent on production on the farm and the remainder goes into post-harvest operations. Given this substantial share of the PHF system in the total energy use, coming to around 13-15 percent of total energy use in developed countries, the question was raised: Are the patterns in the developing countries different? The arguments for less importance of the PHF system as compared to the farm system rested on the facts that a large share of the food in developing countries is consumed locally by the very same people who produce it and that it undergoes much less processing, packaging and cooling as compared to the situation in the developed countries.

The post-harvest food system is dispersed in various economic sectors of the economy and therefore standard national accounts and energy accounts do not provide directly available statistics. It is necessary to separate out from the energy accounts of a number of economic sectors the share that goes into the PHF system. Moreover, the differences that exist between the developing countries in this respect and the factors which cause these differences are also of great interest. Once such knowledge is available, it should be possible to improve energy use planning, develop technologies for subsectors, and achieve more optimal energy use in a manner appropriate to national needs.

Consequently, the objectives of this study are to bring together information from various sources within an internally consistent accounting framework, to identify the socio-economic variables that determine the structure of the PHF system, and to fill the gaps of knowledge about the energy used in the PHF system.

The choice of the countries for detailed treatment was based on the need to obtain information from large, developing countries (India, Brazil, Indonesia, Mexico, Pakistan, etc.) and, simultaneously, from a much larger group of small but typically representative countries (Cameroon, Kenya, Nicaragua, etc.) so as to capture their common characteristics.

In the second phase a simple accounting model was developed that could be applied to all the 90 developing countries in general, including the additional 66 countries required for the planned 90-country coverage and to standardize the sources and nature of the data required.

The third phase was to apply the model and analyze the results for 90 developing countries For the sake of consistency among countries, the study had to be done with international statistics, but care was taken to ensure that the rigidity introduced in handling such a large group should not compromise the earlier estimates made from country statistics. The present article reports a summary of this last phase for which a full description is available in Hrabovszky et al. (1984). The 90 countries covered here are the same as those chosen for the FAO study entitled "Agriculture: Toward 2000", for which energy used in food production systems had been estimated earlier.

While admitting that this effort will yield only a relatively rough first approximation, it should help to draw attention to the sensitive factors for a very important chain of the food system. Furthermore, such an approximation will identify additional information which needs to be collected and analyzed for improved energy planning and management for the food system, and by implication for rural energy systems and overall energy systems. This will call for more research, special surveys and better categorization of general statistics.

2. Conceptual Framework and Overall Methodology

2.1. Description of the System

A large number of operations take place after food commodities leave the farmgate and before they reach tho consumer's plate. They range from drying, milling, sorting, transporting, packaging, storing, sometimes again transporting and processing, marketing and finally cooking. They occur in different order for different commodities and the operations also differ according to dietary patterns, income levels, locations and so on. To simplify this picture, most of the activities are included in four main components defined in the present study:

- food processing
- food transport
- food storage
- household cooking

The methodology, to some extent, is already described in Parikh (1985) which reports on the results at detailed national level for four countries of South Asia. However, since the present study deals with 90 countries, the procedure had to be different and needs to be illustrated briefly again.

For some commodities, packaging and marketing are important components which are included in the food processing for convenience. Two of these variations are schematically illustrated in Figure 1, which shows that a portion of the commodities are directly kept by the rural consumers who may transport them through informal transport such a bullock carts, headloads, or even small trucks, involving no energy worth mentioning. The remaining food – the marketable surplus – will be carried formally by railways or trucks or by water transport, often over long distances. It may be stored at convenient points and again transported by smaller vehicles to the retailers for urban and town consumers. The order in which these operations take place, as shown in Figure 1 for two different variations, has little impact on energy accounting.

In this paper, the treatment of each component, regardless of its importance in other respects, is detailed only to the extent that it consumes energy.

As far as exports and imports of food commodities are concerned, two different approaches are possible:

(a) consider the total energy spent for food consumed by the *people*: in this case food consumed within the country, including imported food, that is, transport of imported food and its processing done elsewhere, but excluding exported food and its processing and transport;

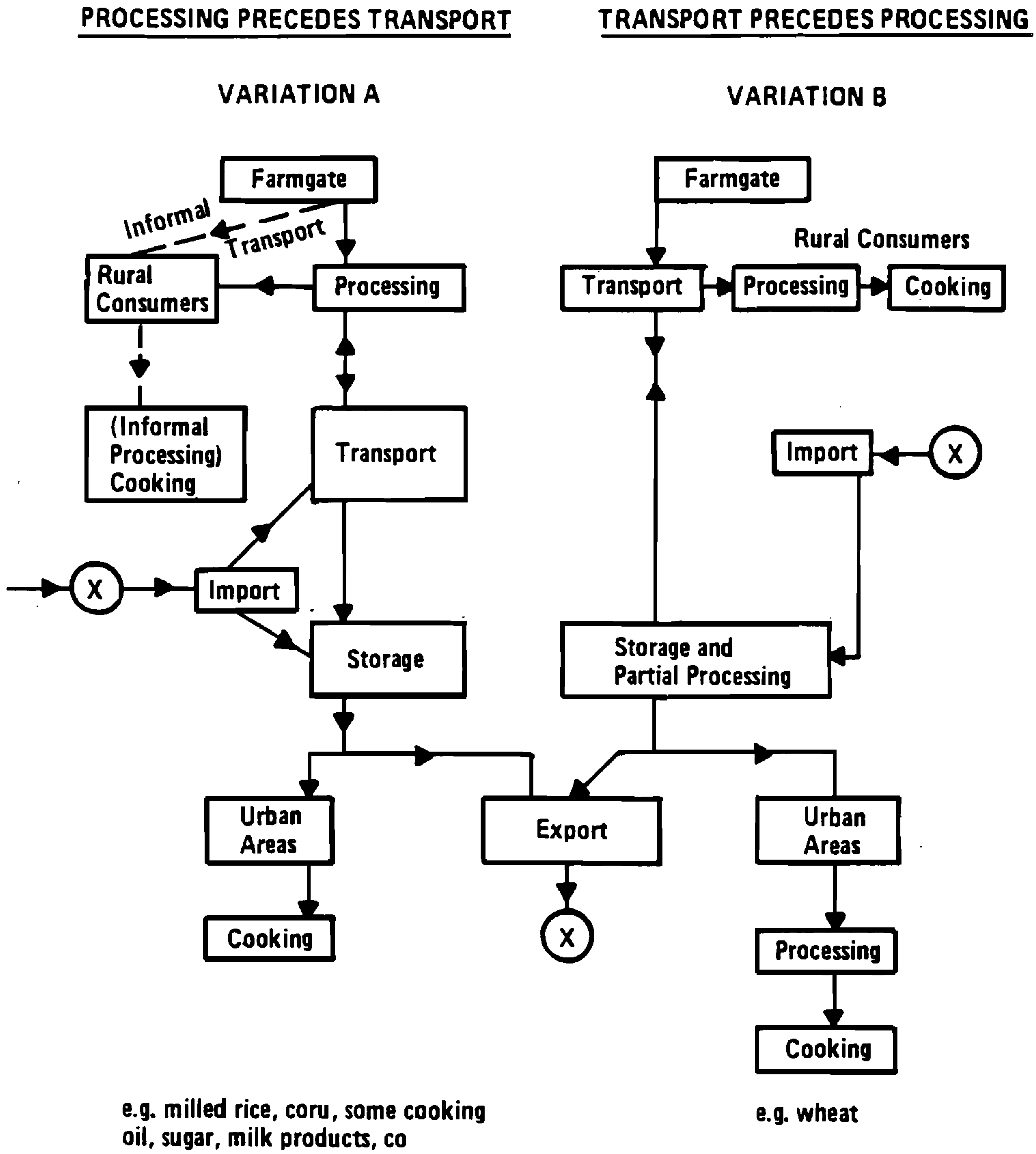
(b) consider total energy spent within the borders of the country: in this case food processed within the country is to be taken into account. This means the exclusion of the energy used abroad to process imported food but includes transport within the importer country and the energy spent on exported food.

We have chosen the second approach, rather than the first, because it is more relevant to decisions at a national level on energy allocations.

In order to arrive at broad orders of magnitude, a number of generalizations and estimates had to be made while dealing with 90 countries and 70 commodities. Some of the estimates had to be derived from limited and weak data, along with indirect estimations or inference. Even the data reported in literature varied widely. Therefore, when different sources were consulted, judgements had to be made in selecting them and consistency checks had to be applied.

2.2. Procedures Adopted for Energy Accounting

The following are the assumptions and procedures adopted:



Variation A: Processing of imported food is excluded and of exported food included, e.g. milling paddy.

Variation B: Processing of imported food included, and of exported food excluded, e.g. milling wheat

Figure 1. Schematic diagram of flows of two different types of food commodities

(a) the quantities of energy considered were estimated as "final energy use level" net of losses in conversion and transport:

(b) the energy considered was only direct energy (e.g. diesel oil used by machinery but not the energy embodied in the machinery). Energy consumed in the manufacture of bottles and cans, however, was included as this is a necessary ingredient of packaging and marketing and depends on technology choices;

(c) energy sources used were divided into commercial and non-commercial energy sources. Commercial sources included liquid fuels, gas, coal and electricity; non-commercial sources included wood and charcoal, bagasse, animal and other agricultural wastes;

(d) animate energy provided by humans and animals was not considered, partly because of several conceptual difficulties in adding animate biological energy to inanimate energy, also because of its restricted relevance for policy purposes;

(e) Once the different energy sources used were accounted in their own physical units, i.e. kilo-watt-hours (kWh), tons of wood, litres of kerosene, etc., they were converted into a common unit in useful energy terms taking into account the conventional efficiencies of each energy source. For this purpose the unit of account chosen was the ton of oil replacement or oil substitution units (TOR), rather than Joules, so as to relate the levels of energy consumption to actual supply necessary. This is explained in detail below.

2.2.1. Oil replacement units or oil substitution units

Estimating the use of energy in terms of primary energy content – without considering its utilization efficiency – is likely to give a wrong impression, especially when a substantial portion comes from non-commercial (n.c.e.) sources (J.

Parikh, 1986). It is therefore better to compare and estimate in terms of useful energy. To account for especially low efficiencies of non-commercial energy sources in useful energy terms and yet maintain physical units, the relative efficiencies were compared to kerosene use. These conversion units, known as oil substitution units are constructed to answer the question: how much kerosene would have been used, if this cooking had been done on kerosene stoves? Since the efficiencies of stoves using n.c.e. and kerosene stoves enter into the picture, the table has limited validity restricted to practices in fuel use in the developing countries. For example, if wood is used for cooking, the oil required is obtained by the following formula:

$$\frac{\text{amount of wood used} \times \text{heat value per unit of wood} \times \text{wood-efficiency}}{\text{efficiency of oil use} \times \text{heat value of oil}}$$

Table 1 below is constructed for a variety of non-commercial uses assuming average efficiencies as they are used in the households of the developing countries. Thus, the concept of useful energy uses absolute efficiency, and the oil replacement concept uses relative efficiencies (with respect to oil).[1]

Having discussed principles and procedures concerning energy accounting, we resume discussion on the four components of the post harvest food system.

2.3. Food Processing

Food processing is a necessary step prior to food consumption for several reasons:-

- *to make food edible:* Under this category come primary processing activities such as flour making, paddy husking, oil seed pressing, etc. In this case, all the primary food commodities have to be processed;

[1] It should be stressed that this notion is different from coal replacement units used in India, where all sectors, i.e. transport, industries, household, are assumed to have the same relative efficiencies and these efficiencies were those that prevailed two to three decades ago.

Table 1. Oil equivalent and replacement units for fuels for household cooking

	10^9 Joules	Assumed efficiency in cooking	Metric ton oil equivalent*	Tons of oil replacement
Coal and Charcoal	29.3	0.18	0.69	0.276
Fuelwood solid 20-30% MC	15.0	0.15	0.35	0.105
Bagasse	15.1	0.10	0.35	0.077
Dung Cakes	13.8	0.10	0.32	0.071
Sawdust	11.3	0.10	0.27	0.060
Agri-waste	12.6	0.08	0.29	0.051
Kerosene	46.5	0.45	1.09	1.09
LPG	49.4	0.65	1.14	1.69
Natural Gas	48.6	0.65	1.14	1.69

The above table was based on the following:
1 ton oil equivalent = 10,180 $\times 10^3$ kcal*
1 calorie = 4.1868 Joules
Fuelwood: 1 M^3 = 725 kg
Charcoal: 1 M^3 = 167 kg
1 ton coal equivalent = 7000 $\times 10^3$ kcal
*Source: Yearbook of World Energy Statistics (1979) and Hrabovszky et al. (1984)

- *to preserve food:* so as to store perishable food for longer periods, either for transporting it elsewhere or for consuming it at a later stage – thereby extending its use over space and time.

- *to make alternative derivatives:* partly for consumer preferences, partly for using all by-products, and partly for preservation purposes. More than one derivative may be extracted from primary commodities, such as cheese, butter, evaporated milk and the like. Secondary processing activities, such as baking bread, making noodles, and the like also come under this category. The importance of these activities depends on income levels, consumers' preference, the volume of the commodity and the distance it is to be transported.

A particular plant may use various sources, such as electricity, gas, or others simultaneously to process a particular commodity. These are all expressed in terms of oil equivalent units. Thus, the method for deriving the estimates consisted of the following steps: (a) Starting from FAO Supply Utilization Accounts (1980), which give amounts of processed commodities for each country for 70 commodities, the share of the food commodity volume processed outside households is estimated; (b) the volume of each of the commodities processed is then multiplied by its respective average energy requirement coefficients; (c) for each commodity the estimated energy use volume is next converted into oil replacement units as described earlier; (d) the energy used by the 70 commodities is then aggregated into eight major groups. For example, for milk nearly eight derivatives are included. A number of technical reports are studied and experts consulted, before selecting energy consumption norms for each commodity.

$$EPROC = \sum_{i=1}^{70} (PC)_i \times (EFP)_i \tag{1}$$

where EPROC is energy for food processing in TOR, $(PC)_i$ is volume of the processed commodity in tons, $(EFP)_i$ is the energy consumption required to process one unit of commodity.

Most food processing activities utilize commercial energy, i.e. coal, oil, gas or electricity, except sugar cane processing or paddy drying, where bagasse[2] or rice husks may be burned to provide all or most of the required energy. These biofuels are accounted separately and added only at the end using oil substitution units. Commodities processed prior to export have been included (fruit juice) as well as imported commodities processed after importing (wheat). The energy consumption norms are given in Table 2.

2.4. Food Transport

As indicated in Figure 1, the transport of the same food takes place several times and quite often by different modes. These range from bullock carts and bicycles to railways and trucks. However, we consider only transport of long

[2] Waste from sugar cane processing

Table 2. Energy consumption norms for food processing

		Litres oil/ ton of processed product
Cereals:	Rice milled	5.00
	Wheat flour	12.50
	Rye flour	12.50
	Maize flour	12.50
	Sorghum flour	12.50
	Millet flour	12.50
	Other cereal flour	12.50
	Cassava flour	5.10
	Pulses flour	12.50
Vegetable oils:	Soya oil	290.00
	Groundnut oil	290.00
	Sunflower oil	218.00
	Rapeseed oil	218.00
	Safflower oil	360.00
	Sesame oil	360.00
	Mustard oil	360.00
	Cotton oil	360.00
	Maize oil	360.00
	Ricebran oil	360.00
	Coconut oil	30.00
	Palm oil	218.00
	Olive oil	218.00
Fruits and Vegetables:	Tomato juice	31.60
	Tomato paste	59.00
	Tomato peeled	33.00
	Vegetable proc.	112.00
	Vegetable frozen	153.00
	Orange juice	10.28
	Orange juice conc.	54.00
	Grapefruit juice	10.28
	Citrus juice	10.28
	Pineapple canned	112.00
	Pineapple juice	10.28
	Other fruit juice	10.28
	Fruit processed	102.20
	Wine	126.00
Livestock and milk products:	Meat slaughtered	33.50
	Meat processed	115.00
	Meat canned	350.00
	Pig slaughtered	33.50
	Bacon	228.00
	Sausage	125.00
	Pork processed	115.00
	Lard	33.00
	Poultry	49.00
	Poultry canned	110.00
	Milk past.	12.40
	Milk ster.	40.00
	Butter	109.00

	Cheese	113.00	
	Skim milk	40.00	
	Evaporated milk	260.00	
	Canned milk	260.00	
	Powdered milk	500.00	
Fish:	Fish frozen	102.00	
	Frozen fillet	331.00	
	Fresh Fillet	204.00	
	Fish canned	500.00	
	Smoked fish	0.00	or 3 tons of wood
Sugar:	Sugar centr.	3.00	or 2.5 ton of bagasse
	Sugar non-centr.		2.5 ton of bagasse
Other:	Bakery bread	60.00	or 0.25 tons of wood
	Bakery cakes	170.00	or 0.70 tons of wood
	Tea	500.00	or 5 tons of wood
	Coffee cas.	0.00	
	Paddy dry	5.70	or 0.05 tons of rice husks
	Paddy parboiled	18.00	or 0.15 tons of rice husks
	Dry parb. paddy	17.00	or 0.14 tons of rice husks
Alcoholic bev.:		530.00	

Source: Hrabovszky et al. (1984)

distances.

A method of estimation is developed based on various assumptions including the following:

1. Estimation of volume transported
2. Estimation of average distances
3. Estimation of modes of transport
4. Multiplication by energy coefficients to obtain energy used in food transport.

Figures for total and per caput consumption of these commodities were taken from FAO Supply Utilization Account (1982). Data on non-agricultural populations are from the FAO Production Yearbook (1983). Data on exports are from FAO Trade Statistics (1983).

The calculated volume of food transported is then multiplied by the average distances traveled to convert them into ton-km transported by each sub-mode. Some countries do include in their published national statistics direct or indirect information on the average distance and also on each type of goods transported by different modes. Although food commodities may not travel the same distance as other commodities, such an approximation is essential due to lack of data. However, in the absence of such information, the extent of average distance was assumed based on the following information:

- the distance between the main food producing regions and consuming regions;
- the distance from the port of entry of imported food to the main consuming centres of imported food;
- the distance of port of exit for export from the main centres growing those exported commodities;
- the total length of the road and railway network;
- the area of the country.

The third step identifies modes of transport and their shares in the total national network. Road, railway and water are assumed to be the major modes of food transport (Parikh, 1981). Road and railway are further classified into:

ROAD	Good road
	Bad road
RAILWAY	Electric
	Diesel
	Steam

The shares of the road network can be termed as good road and the shares of total railway network is electrified, or diesel powered are inferred from using national and international data sources such as by the World Road Federation (1982) and International Railway Statistics (1982) and or by making suitable assumptions from the data of similar countries. The percentage of bad road and steam-powered railway is considered residual. The total energy consumption by all the sub-modes could be

$$\text{ETRAN} = \underset{\text{ton-km}}{\text{TTV} \times \text{AD} \times} \left[\underset{\text{road transport}}{\text{SRD} \times [\text{SGR} \times \text{ERDG} + (1-\text{SGR}) \times \text{ERDB}]} \right. \qquad (2)$$

$$\left. + \underset{\text{railway transport}}{\text{SRW} \times [\text{SRWC} \times \text{ERWC} + \text{SRWD} \times \text{ERWD} + \text{SRWE} \times \text{ERWE}]} + \underset{\text{water transport}}{\text{SWR} \times \text{EWR}} \right]$$

where TTV is total transported volume in 1000 tons; AD is average distance in km; SRD is share of road; SGR is share of good roads in total road transport; SRD, SRW and SWR are shares of road, railways, and water transport in total transport; SRWC, SRWD and SRWE are shares of coal diesel and electricity respectively in railway transport, where energy consumed by each mode per ton-km is denoted ERWC, ERWD and ERWE respectively; ERDG, ERDB and EWR is energy consumed on good and bad roads and for water transport per ton-km respectively.

2.5. Food Storage

Preliminary investigations in individual countries suggested that very little energy was required for food storage. For example, 800 TOE in Bangladesh, 35 TOE in Tanzania, 35,000 TOE in Brazil. Food is stored in houses, warehouses, silos, and the like, requiring few lights and occasionally stationary equipment for turning over, loading and dispatching food. Cold storage of course, requires energy but that is of little significance in most developing countries. However, the energy for heating and chilling, for storing and preserving food had already been taken into account earlier in the food processing activities such as freezing, canning, etc. The energy for refrigeration consumed in households, shops and cold storage is assumed to be negligible in our analysis. Thus, food storage, although an important step in the PHF system, is neglected for energy-use calculations.

2.6. Household Cooking

This is the largest and, unfortunately, the least documented component in the literature. Household cooking in rural areas and in poor households of urban areas of developing countries is often done by non-commercial energy sources, i.e.

gathered fuels such as wood, twigs, agricultural waste and animal dung, especially by low income groups (see Parikh and Krömer, 1985). Data for their amounts, heat contents and efficiencies are obtained using a few surveys, available measurements and indirect methods and had to be cross-checked with other information as much as possible.

2.6.1. Estimation of non-commercial energy

Insights obtained from rural energy surveys of individual countries (see Hall, 1982; de Montalembert and Clement, 1983; Wardle and Pontecorvi, 1981) helped us to evaluate how much of such fuels were being consumed for household cooking and how much for other purposes (manure, construction and fodder). However, for handling 90 countries simultaneously, a method of estimating energy used in household cooking had to be developed which could be applied to all the countries. Total availability of fuelwood (and charcoal) are taken from the FAO Forestry Yearbook.

Crop residues: the total availability of agricultural residues is estimated by multiplying the total production of the crop commodities whose residues are used as fuel by the per unit residue availability coefficient. The assumed coefficients for the different commodities are given in Table 3. Of course, there are wide variations between different varieties of paddy or oil seeds, etc., but to simplify the analysis only an average value was taken for all countries for a given crop.

Animal dung is estimated by considering dung coefficients per animal (World Bank, 1979) which are 1, 0.75, 0.3, 0.15 and 0.005 for cattle, horses, pigs, sheep and goats, and poultry, respectively. In all the three fuels, the potential availability is kept as an upper limit. The lower limit could be zero, if no tradition exists or if other fuels adequately meet the cooking needs. Thus, the surveys and other information was used to estimate the actual use within these upper limits.

Table 3. Crop residue coefficients for crop commodities

Commodity	Coefficient per ton of main product
Paddy	1.22
Wheat	1.00
Maize	2.00
Sorghum	2.00
Barley	1.00
Sugar cane	0.30
Rye	1.00
Millet	2.00
Oats	1.00
Tobacco	0.80
Groundnuts	0.30
Sunflower	2.00
Cotton	3.00
Cotton seeds	0.25
Soya bean	1.00
Jute	1.50
Cassava	0.40
Coconut oil	3.40
Coffee, berries	1.00
Cocoa beans	1.50

2.6.2. Estimation of commercial energy

Even commercial energy for cooking in urban areas and affluent rural households, such as kerosene, liquid petroleum gas (LPG), natural gas and, occasionally, electricity could not be estimated directly.

Data for commercial energy sources are obtained from the Yearbook of World Energy Statistics (1980) as well as national statistical publications. It is assumed that those used for cooking are kerosene, LPG, natural gas and coal. The use of electricity for cooking are assumed to be negligible.

In order to estimate the shares of these sources for household cooking information was collected from national data sources of several countries, wherever available. Typically, natural gas used in households amounted to less than 5 percent of total consumption; most of it went for power, industries and fertilizers. In the case of LPG, the share of households was around 40 - 80 percent. All household consumption of LPG and natural gas was assumed to be exclusively for cooking, but in the case of coal, part of it was attributed to heating. Accordingly, among the countries using coal for household purposes, we separated the countries that require household heating. Depending on the severity of their climate and the percentage of the population affected, a certain quota (ranging from 8 - 40 percent) was deducted for heating and the residue attributed to food preparation.

Kerosene: Depending upon the extent of electrification, kerosene is used for lighting and to some degree for cooking. The share for cooking was estimated by subtracting the volume required for lighting from total household consumption. A number of rural energy surveys confirm that the quantity of kerosene required per person annually for lighting is about 4kg. Consequently to obtain a country's total requirement of kerosene for lighting it suffices to multiply the population without electricity by 4kg. In some countries the household use of kerosene was reported to be less than 4kg per person. In such cases, kerosene was entirely allocated to lighting.

The energy required for cooking is given by

$$ECOOK = \sum_{k} (HF)_k \times S_k \times ECR_k \tag{3}$$

where S is the share of the total available fuel used for cooking; HF_k is available household fuels of type k (commercial and non-commercial); and ECR_k is energy content according to oil substitution units given in Table 1.

Although the results of many village surveys carried out by FAO and those quoted by Hall et al. (1982) were consulted for checking purposes, they were not directly carried over into the analysis. Many consistency checks were applied and the figures were tested along with national energy balances, when available.

In some cases, the selected commodity baskets were multiplied by the fuel required per unit to cook them, to check energy use from the demand side rather than supply. Finally, the share of household energy was checked against the country's overall consumption to see if it was compatible with that country's energy balances, income, population and similar indicators.

In spite of these checks, some anomalies remain. For example, the consumption of bio-fuels in many of the African countries seems very high and may include other uses, for example, rural industries. On the other hand, the figures for kerosene for cooking in some of the oil-producing countries, and Sri Lanka and Ghana appear to be very high and it is suspected that kerosene assigned to household cooking may be deviated toward trucks, kerosene-operated refrigerators and other devices.

It is evident that the total energy-use in the PHF system (EPHF) is given by

$$EPHF = EPROC + ETRAN + ECOOK \quad (4)$$

where EPROC is energy required for processing; ETRAN is energy required for transport; and ECOOK is energy required for cooking.

3. Results of the Energy-Accounting Model for the PHF System

In the present chapter, the results of the energy-accounting model for the year 1980 are discussed. Unfortunately, it is not possible to include printouts of country-wise tables indicating all the numerical results. Therefore, only regional aggregates are given supplemented by some observations of interest from individual countries. As this gives an incomplete picture, country-level results are included in histrograms indicating orders of magnitudes and patterns. Even here, only 50 major countries are indicated while referring to the full paper by Hrabovszky et al. (1984) for further details. The outliers are discussed specially to illustrate why they differ from the rest of the countries.

3.1. General Information

In addition to the inputs required for individual sub-sectors, there is a common pool of data used in the study as given in Table 4 These relate to population, urbanization, total energy consumed within the country, area and forest area. Although they are taken from standard sources as indicated in the footnotes, they are given here to serve as ready references for the readers who may wish to apply cross checks or to construct and verify certain indicators of their own choices.

3.2. Energy in Post-Harvest Processing Industries

3.2.1. Food Volumes Processed

If accounted in unprocessed forms, the volumes add up to 1,262 mt (of which 614 mt is sugarcane alone). As illustrated in Table 5, in 1980, in Africa, Latin America, the Near East and the Far East, the food volumes processed commercially, in terms of output products excluding home processing was 54, 196, 56 and 281 million tons (mt), respectively. As for the 90-country sample as a whole, 587 mt of commodities were processed. As shown in Table 5, in per capita terms, this

Table 4. General indicators for the four regions and total

Indicators†	Units	Africa	Latin America	Near East	Far East	90 Countries Total or Average
(1) Total Population	M	360	349	202	1270	2181
(2) Share of Non-Agric.Pop.	%	32	64	46	36	41
(3) Area	$10^3 km^2$	2150	2005	1100	865	6180
(4) Total energy used with non-comm.energy	MTOR	70	302	103	295	770
(5) Total comm. energy used	MTOR	39	264	98	223	624

† All indicators are calculated for each country and then added or averaged for the world regions.
MTOR = millions of tons of oil replacement
M = Million = 10^6
Source: FAO Production Yearbook (1981) and Yearbook of World Energy Statistics (1980)

amounted to 0.15 tons in Africa, 0.56 tons in Latin America and 0.28 tons in the Near East and 0.22 tons in the Far East, with an average of 0.27 tons per person. This clearly shows the importance of the dietary patterns.

The shares of cereals in the total volume processed are the largest, because grain constitutes their staple food, and most of the grain crops need to be processed. The shares of cereals are 65 percent for Africa, 35 percent for Latin America, 69 percent for the Near East and 77 percent for the Far East.

There are some country-specific features in addition to the above factors. For example, shares of sugar in Mauritius is 90 percent and Cuba is 78 percent; Colombia, Mexico and Argentina have high shares in livestock and some African countries, Brazil and Sri Lanka have high shares in cassava, coffee and tea respectively. Alcoholic beverages are very important for Latin America and Africa compared to the Near East and the Far East, and this may be due to cultural or religious differences.

Table 5. Energy for food processing and shares of different commodities

Indicators†	Units	Africa	Latin America	Near East	Far East	90 Countries Total or Average
(1) Total volumes processed	10^6t	54	196	56	281	587
(2) Commercial energy consumed	M	1.8	7.4	2.0	5.9	17.1
(3) Total energy consumed	M	3.4	19.7	2.5	17.2	42.8
(4) Share of non-commercial	%	46	62	21	66	60
(5) Per capita	KGOR	9.4	56.6	12.3	13.5	19.6
(6) Per ton of food processed	KGOR	62.3	100.8	44.8	61.2	73.0
(7) Share of each commodity in commercial/ total energy						
(8) Cereals	%	26/17	11/5	30/27	25/10	20/10
(9) Sugar	%	5/42	1/62	22/35	0/63	35/60
(10) Vegetable oils	%	27/15	8/3	12/10	27/9	17/7
(11) Fruits & veg.	%	2/1	1/1	2/2	1/0	1/1
(13) Livestock & milk products	%	9/5	47/18	24/19	16/5	30/10
(14) Fish	%	0/15	0/0	0/0	2/1	1/1
(15) Alcoh.bev.	%	29/16	30/11	9/7	28/10	27/11
(16) Other	%	1/1	1/1	0.0	0.0	1/0

†The total or average for each geographic region does not include all the countries of the region but only those indicated in the list in Annex 1.
All indicators are calculated for each country and then added or averaged for the world regions.
KGOR = kilograms of oil replacement
M = Million = 10^6
Source: Hrabovszky et al. (1984)

The importance of livestock and milk products depends upon the degree of urbanization and income levels. For example, in Latin America and the Middle East, it ranks second, whereas in the other two regions under study it ranks third.

3.2.2. Energy Consumption in Food Processing

The ranking of commodities in energy consumption need not follow the same pattern as the volumes processed because of the different energy consumption involved for each commodity. Non-commercial energy is mainly used in sugarcane (bagasse). Some rice husk and their by-products are also burned for heat necessary for drying. The rest of the processing, such as milling, freezing and canning, is done with commercial energy.

In Table 5, commercial and non-commercial energy are discussed separately. It indicates that in 1980 in Africa, 1.8 million TOR commercial energy was spent; in Latin America 7.4 million TOR; in the Near East 2 million and in the Far East 6 million. Although the differences among countries in energy in per ton processed output (about 29 KGOR/ton average) are very small, the differences in per caput consumption are large – being four times higher in Latin America than in Africa and Far East. This happens because in Africa and Far East much of the food consumed does not even enter the processing system (but the amounts which do enter it consume similar amounts of energy per ton processed).

The shares of individual commodities in the total energy consumed in the PHF system are interesting in that livestock and milk products are often in first or second position, except for Africa where such processed foods are consumed in smaller quantities, more being eaten in unprocessed form. Strangely enough, and except for the Middle East, energy for producing alcoholic beverages is the next highest – or the first – for Africa, and exceeds energy consumption by cereals which are essential to basic nutrition. This is simply because beverages require twenty times more energy per ton as a result of the high quantity needed for bottling and bottles.

The exceptions are the Philippines, Korea, Cyprus, Argentina, Congo, Gabon, Venezuela, where the share of alcoholic beverages is large compared with the regional average, whereas in Malaysia, Nigeria, Gambia, Sierra Leone, Paraguay and Sudan, the share of vegetable oil is large.

Figure 2 illustrates how dietary and cropping patterns and income levels determine the magnitude of the per capita energy for food processing.

Low Income or Food Importers or Cassava Consumers	Grain Consumers	Medium Sugar Producers or Middle and High Income			High Income or Large Sugar Producers
Algeria	Ivory Coast	Peru	Bolivia	Brazil	Mauritius
Angola	Kenya	Paraguay	El Salvador	Malaysia	Argentina
Ethiopia	Morocco	Venezuela	Ecuador		Columbia
Ghana	Mozambique	Cyprus	Guatemala		Cuba
Madagascar	Senegal	Korea, Rep.	Thailand		Jamaica
Mali	Chile	Philippines			Panama
Niger	Egypt				Trinidad & Tobago
Tanzania	Iran				Mexico
Uganda	Sudan				
Upper Volta	Turkey				
Iraq	India				
Bangladesh	Pakistan				
Burma					
Sri Lanka					
Indonesia					
Saudi Arabia					
Syria					
0–10	11–20	21–30	31–40	41–50	>50

KGOR/Capita

Figure 2. Total energy in food processing

When non-commercial energy is included the share of sugar is the largest – consuming as much as 35 to 63 percent of total energy use at the regional level and also for most individual countries growing sugarcane. This means a decrease in the shares of other commodities. For Africa, Latin America, the Near East and the Far East, the per caput total energy consumption rises to 9.4, 56.5, 12.4 and 19.6 KGOR/Cap and energy per ton processed rises to 62, 101, 45 and 61 KGOR/ton respectively. The share of non-commercial energy in total energy for food processing is 46, 62, 21, and 66 percent respectively.

For the 90 countries, the total energy spent is 43 MTOR and commercial energy 17 MTOR, giving per caput 20 and 8 KGOR respectively. This amounts to 73 and 29 KGOR per ton processed.

3.3. Patterns of Transport and Energy for Food Transport

Food commodities constitute the largest item in all transport in most developing countries. As mentioned earlier, the volumes of food transported have been estimated from available data on urban population, the average distances and modes of transports. These three elements make up the patterns of transport presented below, together with the corresponding estimates of energy consumption.

3.3.1. Patterns of transport – volumes, distances and modes

A summary related to these patterns is given in Table 6 for each of the regions studied. The volumes transported for Africa, Latin America, the Near East, and the Far East, are 44, 156, 53 and 424 million tons, respectively. The average distances are respectively, 374, 500, 372 and 460 km. The shares of road:rail:water for Africa, Latin America and the Near East are not very different from each other except in the Far East where they are 42:52:6, bringing the 90 country average to 63:31:7. This is because India., Pakistan and Korea have high shares of railways. The shares of water transport are significant only in countries for the Far East. At a country level the share is either zero or 10 percent if there is a central river or coastal shipping. Correspondingly, the shares of road and rail decrease. The shares of good road and bad road also vary little between regions.

Total energy in transport appears to depend on the following factors:

- population or population density
- share of urban population
- average distance
- total area
- food exports

3.3.2. Energy Consumption for Food Transport

As shown in Table 6 energy consumption for food transported in 1980 is estimated to be 1 million TOR in Africa; 5 million TOR in Latin America; 1 million TOR in the Near East and 4 million TOR in the Far East.

In terms of per caput energy consumption, this means 3 KGOR per person in Africa, 15 KGOR in Latin America, 6 KGOR in the Far East and 3 KGOR in the Near East. However, in terms of per ton of food transported this means 26, 33, 24 and 21 KGOR of the respective regions.

The shares of road, rail and water in the energy consumption are approximately 95:4:1 except for the Far East where it is 78:21:1. This changed pattern as compared to share of modes in volume transported arises because it takes 4 to 5 times more energy to transport one ton-km by road compared to rail transport. Thus, already high shares of road in the total volumes become even higher when energy consumption shares are compared.

The factors mentioned above explaining the divergences from the average

Table 6. Patterns of food transport and energy consumption

Indicators†	Units	Africa	Latin America	Near East	Far East	90 Countries Total or Average
(1) Amounts transported	10^6t	44	156	53	171	424
(2) Ton-km	10^9tkm	16.3	78.1	19.8	81.7	195.8
(3) Share of rail in total transport	%	18	13	20	52	30.5
(4) Share of road in total transport	%	78	78	74	42	62.8
(5) Share of good roads in road transport	%	34	47	54	47	46.7
(6) Total energy spent	MTOR	1.1	5.2	1.2	3.5	11.7
(7) Share of energy spent in road transport	%	95	95	93	78	89
(8) Per capita	KGOR	3.1	14.8	6.2	2.8	5.1
(9) Per ton transported	KGOR	25.5	33.2	23.5	20.5	26.1

† All indicators are calculated for each country and then added or averaged for the world regions.

(1) Amounts transported are derived by multiplying share of non-agriculture population. Total amounts of 70 commodities are considered for each country.

(2) Obtained by multiplying (1) with average distances.

(3)+(4) Share of rail and road, when not available in country statistics is inferred from the indicators such as total track kilometers, railway wagons, road-km, number of trucks etc. The remainder in each is done by water transport, i.e. by coastal and river transport.

(5) The share of good roads in total road transport, if not available, is inferred by looking at the shares of asphalt or paved roads in total road-km. The remainder is assumed to be transported on bad roads.

(6) Total energy spent is obtained by

$$(2) \times \left[\frac{(3)}{100} \times .02 + \frac{(4)}{100} \times \left[\frac{(5)}{100} \times .075 + \left[\frac{100-(5)}{100}\right] \times .094\right] + \left[\frac{100-(4)-(3)}{100}\right] \times .01\right]$$

where the first, second and third terms represent rail, road and water transport. The multipliers for each mode of transport are the energy norms.

(7) Energy spent on road transport divided by the total energy given in (6)

(8) Energy for transport per capita = (6) / population

(9) Energy per ton transported = (6)/(1)

become even more visible at individual country level. Indeed, while per caput energy consumption varies more with parameters such as export – or import – urbanization and income levels, energy consumption per ton is more sensitive to average distances (size of country and location of urban centre with respect to farm areas) and modes of transport. Therefore, it does not vary as much from region to region.

These observations could be confirmed even more by outliers such as India, Libya, Sudan, Mexico, Argentina, Tanzania, Angola with large average distances and a number of small countries with small distances of 40 to 150km. For example, Argentina, an exporter which requires 63 KGOR per caput energy but only 49 KGOR per ton. On the other hand, Saudi Arabia, an importer requires 8 KGOR per caput but 28 KGOR per ton. In both cases, the per caput figures differ more widely than per ton figures. The variations in per ton figures are mainly due to differences in average distances (and occasionally to differences in modes of transport). For example, the average distance of transport in Argentina is approximately twice that of Saudi Arabia.

3.4. Energy for Cooking

Cooking is the largest sub-sector of the PHF system. As shown in Table 7, shares of non-commercial energy in total energy used for cooking are 85 percent for Africa, 42 percent for Latin America, 21 percent for the Near East and 78 percent for the Far East. The shares of wood in non-commercial supplies in terms of million TOR are close to 95 percent or more, except in the Near East. For the same regions, the total use of energy for cooking is 30, 39, 17 and 72 million TOR respectively, with per caput energy consumption of 82, 113, 84 and 57 KGOR respectively. The shares of cooking non-commercial energy in national use of non-commercial energy for all purposes are for Africa 81 percent, for Latin America 44 percent, for the Near East 72 percent and for the Far East 77 percent. The remaining non-commercial energy is used for food processing, rural industries and household heating.

The shares of commercial energy for cooking out of total commercial energy amount to 11 percent for Africa, 9 percent for Latin America, 14 percent for the Near East and 7 percent for the Far East. The shares for cooking, out of overall energy sources, amount to 42, 13, 16 and 24 percent respectively, for the four

Table 7. Energy for cooking

Indicators†	Units	Africa	Latin America	Near East	Far East	90 Countries Total or Average
(1) Total energy used in cooking	MTOR	29.6	39.4	16.9	71.8	157.8
(2) Share of commercial in total energy	%	15.0	58.3	78.6	21.8	35.8
(3) Share of wood in non-commercial	%	97.5	98.1	85.7	88.5	92.2
(4) Share of each resource used for cooking						
a. kerosene	%	67.0	92.8	95.5	72.1	82.8
b. wood	%	85.2	71.8	75.6	91.8	85.1
c. agr.waste	%	10.2	3.5	12.1	21.9	14.0
d. dung	%	8.8	0.7	11.4	27.0	14.5
(5) Per capita cooking energy	KGOR	82.4	113.0	83.6	56.6	72.4
(6) Share of total cooking energy in total energy use	%	11.4	8.7	13.6	7.1	9.0
(7) Share of wood in non-commercial energy use	%	42	13	16	24	21

† All indicators are calculated for each country and then added or averaged for the world regions.

(1) Includes cmmercial and non-commercial energy and given in million tons of oil replacement units (MTOR)

(4) Share of cooking use in total use of each energy resource, i.e. the rest of kerosene is used for lighting and other purposes. The rest of fuel wood used for rural industries. The rest of agricultural waste for fodder, construction and other purposes. The rest of dung for manure and other purposes.

(5) Total natural gas + coal + LPG + kerosene used for cooking / national use of all commercial energy

(6)= (1)/(5) from Table 4. This is accounted in useful energy terms which give low weights to non-commercial energy uses. If accounted in primary energy terms, the share may increase by a factor of two or so.

regions.

The extent of energy use for cooking depends on:

- energy availability, represented by indicators such as forest area or fossil energy production;
- income level and urbanization

- dietary and cropping patterns
- amount of food exports (or imports)

Figure 3 shows per capita use of energy used for cooking including non-commercial energy. It demonstrates clearly how income levels, energy availability and food exports determine the magnitudes.

3.5. The Total PHF System

Having examined the individual sub-sectors we now turn to the overall PHF system. It is evident that the major factors affecting the magnitude of energy consumption, shares of commercial energy and relative importance of individual sub-sectors are usually among the following:

- population and its share of urban population
- per caput income
- dietary patterns, grain, cassava and cropping patterns (meat eaters or sugar cane growers);
- size of the country or magnitudes of the average distances
- food and energy importers or exporters
- energy availability (wood or oil).

3.5.1. Energy Consumed in the PHF System

As shown in Table 8 total energy consumed in the PHF system in 1980 in Africa, Latin America, the Near East and the Far East works out to be 34, 64, 21 and 93 million TOR respectively. In per caput terms this is 95, 184, 102 and 73 KGOR for total energy and 20, 102, 182 and 20 KGOR respectively, for commercial energy alone. It is evident that for commercial energy the income effects are more important than for total energy including non-commercial. It should be pointed out that the total energy figures in terms of primary energy would be much larger –

Figure 3. Per capita commercial energy use in cooking

Less Forests Energy Importers	Middle Income, Moderate Energy Availability		High Income or Energy Availability		
0–70	**71–90**	**91–110**	**111–130**	**131–150**	**>150**
Ethiopia	Angola	Algeria	Brazil	Argentina	Trinidad & Tobago
Ghana	Mozambique	Kenya	Chile	Guatemala	Venezuela
Ivory Coast	Uganda	Nigeria	Mexico		Iran
Madagascar	Upper Volta	Bolivia	Panama		
Mauritius	Cuba	Columbia	Korea, Rep.		
Morocco	Peru	Ecuador			
Niger	Cyprus	Paraguay			
Senegal	Syria	Iraq			
Sierra Leone	Malaysia	Saudi Arabia*			
El Salvador	Thailand	Sudan			
Jamaica		Indonesia			
Egypt					
Turkey					
Bangladesh					
Burma					
Sri Lanka					
India					
Pakistan					
Philippines					

KGOR/Capita

*Saudi Arabia is an exception with high income and energy availability perhaps two to four times – if the conventional oil equivalent concept had been used, rather than the oil replacement one, which considers the low efficiencies of non-commercial energy.

Table 8. Energy use in the PHF system and its comparison with energy in food production and in national total

Indicators†	Units	Africa	Latin America	Near East	Far East	90 Countries Total or Average
(1) Total energy use in the PHF system	MTOR	34.1	64.3	20.6	92.6	211.7
(2) Per capita total energy in PHF	KGOR	94.9	184.3	102.2	72.9	97.1
(3) Share of comm. energy in (1)	%	21.6	55.3	79.9	27.1	39.9
(4) Shares of each component in commercial [(1)x(3)/100]:	%					
a. Food processing		24.7	20.8	11.9	23.5	20.2
b. Transport		14.2	13.9	7.0	10.9	11.7
c. Cooking		61.1	65.3	81.1	65.6	68.1
(5) Shares of each component in total energy (1):	%					
a. Food processing		9.9	30.6	12.1	18.6	20.2
b. Transport		3.3	8.1	6.0	3.8	5.2
c. Cooking		85.9	61.3	81.9	77.6	74.6
(6) Commercial energy used in:	%					
a. Food production system		1.6	10.6	4.8	14.3	31.3
b. PHF system		7.4	35.6	16.5	25.1	84.5
c. Agrofood system		9.0	46.2	21.3	39.4	115.8
(7) Share of PHF in regional total	%	48.7	21.3	20.0	31.4	27.5
(8) Share of agrofood in regional comm.energy	%	22.9	17.5	21.8	17.7	18.2

† All indicators are calculated for each country and then added or averaged for the world regions.

(1) Sum of the energy used in three components, i.e. food processing + food transport and cooking.

(8) Agro-food system = PHF + food production. Energy in food production is carried over for each country from AT2000 study which is not strictly comparable with this study as it pertains to the year 1976. Thus, it is assumed that it did not change during 1976-80; therefore, this figure underestimates the share of the agrofood system.

Low Income Less Forested Energy Importers		Low Income with Forests		Sugar Producers or Energy Exporters or High Income	
Mali	Ghana	Ethiopia	Ivory Coast	Algeria	Mauritius
Morocco	Madagascar	Sierra Leone	Uganda	Angola	Argentina
Egypt	Senegal	Burma	Upper Volta	Kenya	Brazil
India	Sri Lanka		Syria	Mozambique	Chile
Pakistan			Turkey	Nigeria	Columbia
Somalia			Philippines	Bolivia	Cuba
Bangladesh				Ecuador	Guatemala
				Paraguay	Mexico
				Peru	Venezuela
				Iraq	Iran
				Saudi Arabia	
				Sudan	
				Indonesia	
				Korea, Rep.	
				Malaysia	
				Thailand	
1–60	**61–70**	**71–80**	**81–100**	**101–150**	**>150**

KGOR/Capita

Figure 4. Per capita total energy in PHF system (with non-commercial)

Low Energy Low Income Energy Importers		Food Importing Energy Exporters or Food Exporting Energy Importers		High Income or Energy Producers		
Ethiopia Madagascar Mali Mozambique Niger Uganda Upper Volta Bangladesh Burma	Angola Ghana Ivory Coast Kenya Senegal Sri Lanka India Pakistan Philippines	Nigeria El Salvador Guatemala Paraguay Sudan Thailand	Mauritius Indonesia	Morocco Bolovia Brazil Columbia Cuba Ecuador Panama Peru Egypt Turkey Malaysia	Jamaica Saudi Arabia	Argentina Chile Mexico Trinidad & Tobago Venezuela Cyprus Iran Iraq Korea, Rep. Algeria Syria
0–10	11–20	21–30	31–40	41–80	81–90	>90 KGOR/Capita

Figure 5. Per capita commercial energy in PHF system

Results of individual countries can be seen in Figures 4 and 5. It is interesting to see that the distribution of countries is quite different between the two Figures because Figure 4 has only the commercial energy and the other has the total energy. Apart from the income effects which are already obvious at the regional level, the effects of energy, i.e. forest or fossil fuels, availability is also significant. These countries differ from their regional average by a large margin. For example, per caput energy consumption levels in sugar producing countries, such as Mauritius, Cuba, and Brazil, are 385, 475 and 275 KGOR respectively. Those with consumption above 100 KGOR are large energy exporters or high income countries. Lack or abundance of forest areas also determines the relative position within the range specified above. On including non-commercial energy in Figure 5, a few additional factors come into play in addition to the above. For example, at the lower total energy and up to 80 KGOR if they have forests. Moreover, at the higher end we find sugar producers which were not present in Figure 4.

3.5.2. Relative Shares of Food Processing, Transport and Cooking

The relative shares of the PHF system, i.e. processing, transport and cooking for Africa are 10:3:87 for total energy and 25:14:61 if only commercial energy is considered. Since non-commercial energy is mainly used for cooking, the latter share decreases when only commercial energy is included. This is not the case in Latin America, where sugarcane is grown using extremely energy-intensive techniques but where bagasse provides much of the energy for processing. There, the respective shares including non-commercial are 31:8:61 and for only commercial energy they are 21:14:65. Thus, the share of processing is reduced when only commercial energy is considered because it is mainly done with bagasse but it is still high. In the Near East, where non-commercial energy plays a small role, the shares of the sub-sectors remain approximately the same, that is 12:6:82 and 12:7:81, whether or not non-commercial energy is included. In the Far East, the shares of the sub-sectors change from 18:4:78 to 23:11:66 when only commercial energy is considered. Here are some general observations of interest:

(a) Cooking is the most important sub-sector for all regions *in spite* of the fact that non-commercial energy sources are included, not in the sense of primary energy but in the sense of useful energy.

(b) The maginitude of the determinant factors are per caput income levels, energy resource availability, extent of imports and exports.

(c) For the PHF system the variations in per caput consumption in total energy are smaller than in commercial energy because the latter shows fuel substitution effects and income effects more prominently.

3.5.3. Relation of the PHF System to National Energy Consumption

The interesting question is how important is the PHF system for the national economy. In line with our approach of keeping non-commercial and commercial energy clearly apart, we will discuss each one of them separately.

It is obvious that a large share of non-commercial energy consumed as a whole goes in the PHF system mainly for cooking and food processing. For Africa, Latin America, the Near East and the Far East 86, 77, 82 and 92 percent respectively goes into the PHF system, the remainder into the rural industries and heating. However, there are wide variations in the shares of national commercial energy going into the PHF system. At this point, one has to compare how large is the rest of the country's energy systems or its economy. For subsistence level economies, such as Haiti, Burma, Nepal, the share of total commercial energy used in the PHFS exceeds 25 percent, but for more industrialized countries like India, Brazil, Venezuela, it is less than 11 percent because there is a large industrial production base requiring energy outside the PHF system. However, when incomes increase even further, the share again increases somewhat because more urbanization leads to more processing and transport. The shares then rise to 18 percent as in Argentina, Mexico and Iran. The shares become much larger when non-commercial energy is included.

3.5.4. The PHF System vs Agricultural Production System

Here, the comparison of the results obtained for the PHF system is made with results published in 1981 in "Agriculture: Towards 2000" (AT2000), the FAO study which does not use the same methodology used here. For example, the AT2000 study includes only commercial energy and took 1975 for a base year. Our study has 1980 for a base year. However, except for manure and human and animal power, the agricultural production (Agri-Prod) system uses only commercial energy anyway. Moreover, the energy in the Agri-Prod system in the AT2000 study was worked out by taking into account direct energy for irrigation, mechanization, for manufacturing irrigation equipment, tractors, harvestors and the like, but not fertilizer plant machinery. In the PHF system, on the other hand, the only indirect energy taken into account goes into making cans and bottles. The comparisons shown in Table 4.10 and Annex 10 gives only broad dimensions. The sum of the Agri-Prod and PHF systems is referred to as Agro-Food sector.

In Africa, Latin America, the Near East and the Far East, the commercial energy spent in the PHF system is larger than in the Agri-Prod system by factors of 4.7, 3.4, 3.4 and 1.7 respectively, giving the ratio of 2.7 for all 90 countries. If non-commercial energy spent in the PHF system is included, this increases further to 6.8 for 90 countries. For the Agro-Food sector as a whole, 9, 46, 21 and 39 million TOR respectively, giving a total of 116 million TOR of non-commercial energy is also to be added to the PHF system. In per caput terms commercial energy use in the total Agro-Food system is 25, 132, 106 and 31 KGOR of commercial energy for the same regions respectively, giving a 90 country average of 53 KGOR or 110 KGOR if non-commercial energy is included.

4. Conclusions and Policy Implications

The study could only aim at a first approximation of the magnitudes of energy use in the PHF system in developing countries. Even so, there are clear indications that the share of the PHF system in developing countries actually claims a bigger share of the total energy use than in the developed countries. The regionally aggregated shares of the PHFS in total commercial energy use range from 11 to 19 percent and, once non-commercial sources are also added, they rise to between 20 and 49 percent. These figures are expressed in effective energy utilized; if expressed in terms of primary energy (in TOE), the share of the energy used in the PHFS rises to 43 percent for the 90 countries as compared to 27.5 percent for the TOR account. Why is this share so large? First of all, both food processing and food transport represent a large share of the industrial transport sector in developing countries where industrialization and urbanization levels are low. Furthermore, cooking in households is one of the dominant energy use not only in the total energy used; it is a major item even for commercial energy use, especially in the middle and high income developing countries and in those producing fossil fuels. This is because developing countries have large population living in a relatively simple life-style and often at subsistence level, where cooking dominates.

Among the components of the PHF system, food processing and transport subsectors rely much more heavily on commercial energy sources, with the exception of sugarcane processing where bagasse serves as fuel. In cooking, non-commercial sources dominate, especially at lower levels of economic development and, among them wood is the most important. In terms of effective energy used for the 90 countries, the shares of processing percentage, transport percentage and household cooking percentage are 20.2, 13.0, 66.8 for commercial energy and 30.2, 5.1, 74.7 for total energy including non-commercial energy.

What factors determine the levels and nature of energy-use in the PHF system? Let us examine their role in each of the sub-sectors and the total PHF system.

Food Processing: This depends on dietary patterns. Whether the countries are food exporters or importers also matters a great deal. Cereals claim the largest share in the area of processing, but in those situations where sugar and alcoholic beverages are an important part of total processing, they do become dominant. Income levels and urbanization play an important role.

Food Transport: The three major influences on energy used for food transport come from the urban population's share in the total, the modes of transport used and the distances transported, the latter being a function of the size of the country and the location of urban populations in relation to agricultural surplus areas. Major energy saving opportunities exist in those situations where rail and water transport can replace road transport and where alternative patterns of agricultural development exist. Location of processing plants need careful analysis of the distribution of demand and supply centers and the flow of food commodities.

Household Cooking: Here, the dominant factors are income levels, urbanization and domestic availability of fuel sources, that is, fuelwood or fossil fuel sources. In household cooking also substitution opportunities are wide, and therefore the energy accounting in terms of effectively applied heat is important. The ratio between efficiencies of commercial and non-commercial energy sources is large and pinpoints the need for keeping these in mind when planning substitutions.

Total PHF System: As the analysis has shown, wide variations exist between the relative weights of PHFS use of energy in total energy use, in the relative weights of the individual components within the PHF system as well as in the roles played by different sources of fuels. Per caput consumption of effective applied energy in the PHFS rises quite rapidly with rising incomes and so does the share of commercial sources within it. At the same time the low development level of the economy, especially of its industrial and transport sector and its service sectors, results in a relatively high share of energy use in PHFS at low levels of income. Some of these income influences are closely connected with degrees of urbanization.

It is also worthwhile exploring ways to rationalize the PHF system and its components. For example, by reducing transport distances, improving collection systems for food processing, and using better controlled food processing techniques. For the households, the main opportunities lie in improved stoves, more energy-conscious cooking methods and dietary choices. In some situations where non-commercial fuels are scarce, careful analyses will be necessary for optimal choices between raising the efficiency of non-commercial sources or substitute them, or more often, supplement them with commercial ones.

The wide differences between country and country also underline the need to plan energy use in the PHFS, and to plan it on the one side as part of rural energy planning and on the other side as overall macro-economic and energy planning. Effective planning calls for greatly improved data availability regarding both actual energy use and its efficiency. It seems that much more survey and analytical research work is required so that the energy aspects of the PHFS become a well-integrated component of energy planning. This study has been only a first step in this direction.

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FAO, 1981. "Agriculture Towards 2000" - (AT2000) Unfortunately this study is not carried out with the same definitions and the same conventions used in this study. For example, the AT2000 study includes only commercial energy and relates to the year 1975 instead of 1980. Therefore, the comparison shown in Table 7 gives only broad dimensions.

ANNEX

List of countries included in different regions

Africa	Latin America	Near East	Far East
Algeria	Argentina	Afghanistan	Bangladesh
Angola	Bolivia	Cyprus	Burma
Burundy	Brazil	Egypt	Sri Lanka
Camerun	Chile	Iran	India
C.Afr.Empire	Columbia	Iraq	Indonesia
Chad	Costa Rica	Jordan	Kampuchea
Congo	Cuba	Lebanon	Korea D.P.Rep.
Benin	Domin.Rep.	Libya	Korea Rep.
Ethiopia	Ecuador	Saudi Arabia	Lao
Gabon	El Salvador	Sudan	Malaysia
Gambia	Guatemala	Syria	Nepal
Ghana	Guyana	Turkey	Pakistan
Guinea	Haiti	Yemen Ar.Rep.	Philippines
Ivory Coast	Honduras	Yemen P.D.Rep.	Thailand
Kenya	Jamaica		Viet Nam
Liberia	Mexico		
Madagascar	Nicaragua		
Malawi	Panama		
Mali	Paraguai		
Mauritania	Peru		
Mauritius	Surinam		
Morocco	Trinidad Tob.		
Mozambique	Uruguay		
Niger	Venezuela		
Nigeria			
Rhodesia			
Rwanda			
Senegal			
Sierra Leone			
Somalia			
Tanzania			
Togo			
Tunisia			
Uganda			
Upper Volta			
Zaire			
Zambia			