FROM FARM GATE TO FOOD PLATE
Energy in post-harvest food systems in south Asia

Jyoti K. Parikh
Food and Agriculture Program, International Institute for Applied Systems Analysis, Laxenburg, Austria

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FOREWORD

A comprehensive food system extends much beyond farms themselves and includes food processing, food distribution, and cooking. In the modeling system developed by the Food and Agriculture Program of IIASA, the first two of these components are considered only indirectly by including processing margins. Therefore, a more detailed examination is called for. An IIASA Collaborative Paper by J. Parikh and S. Syed (of FAO) discusses these issues for 90 developing countries. However, a detailed examination of policy issues at the country level is also necessary. This is dealt with in this Research Report by Jyoti Parikh for four South Asian countries: India, Pakistan, Burma, and Sri Lanka. The food commodities account for a large share of transport in these countries, except for India, where they are second to coal transport. Fuel for cooking is one of the largest items in the energy budget of these four countries. The extent of energy used varies from country to country depending on income level, urbanization, cropping, and dietary patterns.

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Energy in post-harvest food systems in south Asia

Jyoti K. Parikh

This paper estimates energy consumed in the post-harvest food systems of India, Pakistan, Burma and Sri Lanka. The components of the post-harvest food system are: food processing, food transport and cooking. It is shown that they represent a significant share of national energy consumption and that variations among countries depend on variables such as urbanization, income, cropping patterns and whether a country is a food importer or food exporter. The policies to reduce energy consumption would involve measures for increased energy efficiencies, reduced food losses and careful consideration of markets *vs* food production areas for perishable commodities.

Keywords: Food systems; Domestic and industrial energy use; south Asia

The author is with the International Institute for Applied Systems Analysis (IIASA), A-2 361, Laxenburg, Austria.

This article derives much from the methodology devised by the author jointly with J. Hrabovszky and S. Syed of FAO. This FAO work was extended by using statistics from country reports to draw policy conclusions for the countries with funds from the Food-Energy-Nexus Programme of the United Nations University (UNU) and was presented at a conference on Food Energy Ecosystems in Brasilia in 1984. I am grateful to Professor Sachs and Dr Hrabovszky, formerly of FAO, for the critical comments on the earlier drafts of this manuscript and permissions of UNU and FAO to publish this work. Lilo Roggenland has patiently typed several drafts of this manuscript.

There exists a notable gap in research into energy consumed in the post-harvest food system in developing countries.[1] Unfortunately, any analysis requires data which are not readily available in conventional statistics and such accounting requires a considerable amount of caution. However, a beginning must be made because of the importance of the topic for policy purposes. Such an exercise should not only give zero-order estimates of the energy consumed in the post-harvest food system but also give insights into alternative food production and distribution patterns, identify where the gaps in information are, how sensitive the results are to various assumptions and to give some insights into the structure of the post-harvest food system and therefore, policy implications. The cautions and qualifications regarding difficulties in the primary data should be kept in mind when examining this study. There is an attempt to estimate energy consumption[2] based on the FAO's *Supply Utilization Accounts*[3] using international statistics, although policy conclusions for specific countries were not drawn in this unpublished report.

While each country in this study is different in its cropping and dietary patterns, levels of industrialization and specific agro-climatic conditions, each is a low-income country and the group has common traditions, lifestyles and a temperate climate. Thus, in spite of their differences, Burma, India, Pakistan and Sri Lanka are closer to each other than they are as a group to countries in the rest of the world.

The energy in post-harvest food systems is split into three components: post-harvest food processing industries; transport of food; household cooking.

Food storage could also, in principle, be part of this chain but our estimates show that energy spent on this is insignificant in most developing countries. While there have been some attempts to estimate the one or two components separately for some countries – energy in food processing or energy for cooking – no systematic effort has been made for the entire post-harvest food system.

The purpose of this paper is:

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- to give rough estimates of energy use for individual components, ie processing, transport or cooking, and for the shares of each in the total energy used in the post-harvest food system;
- to discover distribution of commercial and non-commercial energy[4] for each component;
- to identify priority areas where energy could be saved in view of the above estimates;
- to have general indicators, such as energy per capita, energy per tonne consumed;
- to compare the importance of energy in post-harvest food systems against other indicators, such as its share in total energy, commercial and non-commercial spent in the country, food transport and total transport, and compared to energy which went to producing the food based upon the above indicators;
- to draw policy conclusions based on the above analysis.

Methodology

Flows in the post-harvest food system

Here, we consider total energy spent in the post-harvest food system within each country. Food produced within the country is considered, ie excluding imported food, its processing and transport, but including exported food, its processing and transport. For example, wheat processing generally occurs in the consuming country but rice processing takes place in the producing (or exporting) country.

Accounting principles

These are the principles adopted to audit energy within the post-harvest food system. A large amount of non-commercial energy is used in food processing as well as cooking. These energy forms are used in such an inefficient manner that to add their primary energy contents with those of fossil fuels may imply a highly dominant role for non-commercial energy, which can be replaced by much smaller quantities of fossil fuels, if they were to be actually used. Therefore, a concept of oil substitution units which measure how much oil products (and not crude oil or its equivalent) would actually be required if non-commercial energy were to be substituted is considered while assuming certain end-use efficiencies for each energy form. The actual amount of oil products required for substitution of a given fuel is:

$$\frac{\text{Amount of energy used} \times \text{heat content per unit fuel} \times \text{end-use efficiency of fuel}}{\text{Heat content per unit of oil} \times \text{end-use efficiency of oil use}}$$

Oil substitution units are often used in energy accounting.[5] These units express the same concept as 'useful energy', but by multiplying relative efficiencies of the fuel with respect to oil, one gets a clear picture of fuel substitution by oil in physical units (tonnes of oil rather than GJ). Non-commercial energy is increasingly substituted by oil products in many countries because of the increase in urbanization and income and due to a decrease in the supply of non-commercial fuels. Moreover, accounting of non-commercial energy in primary energy terms or crude oil equivalent could be misleading for policy purposes due to the high inefficiencies in the use of non-commercial energy. For example, many developing countries seem to obtain more than 90% of their primary energy from non-commercial fuels. In reality, however, their contribu-

[1]B.A. Stout, C.A. Myers, A. Hurand and L.W. Faidley, *Energy for World Agriculture*, FAO Agriculture Series No 7, Food and Agriculture Organization of the United Nations, Rome, 1979.

[2]J. Hrabovszky, J. Parikh and S. Syed, *Energy in Post-harvest Food Systems of Developing Countries by Agriculture Department*, FAO, Rome, forthcoming.

[3]Food and Agriculture Organization, *Supply Utilization Accounts*, FAO, Rome, Italy.

[4]These include wood, agricultural waste and dung. Even if some of it may be sold and purchased in the market, it is not a commercial activity of a sustainable nature with inputs of investment and management. Some authors refer to these fuels as traditional fuels but then one has the dilemma of calling oil and gas 'non-traditional fuels'.

[5]The notion of useful energy is often used in the work of IIASA (see for example W.Häfele, *Energy in a Finite World*, Ballinger Press, New York, NY, 1981). The oil units approach is not to be confused with coal replacement units used in India, which are now somewhat out of date and multiply large numbers of actual oil used.

tion is less because one tonne of fuelwood used for cooking could be substituted by not 0.35 tonnes of oil but 93 kg of oil, because of the high efficiency with which kerosene is used.[6] Thus, the proposed units are used to encompass this process of fuel substitution.

Table 1 illustrates types of fuel, their heat contents, end-use efficiencies for cooking, tonnes of oil equivalent (conventional transformation) and oil replacement units used or adopted in this paper. This amounts to using useful energy as a basis for fuel conversion units rather than primary energy as is done conventionally. (However, this is converted back into physical units to provide tangible units for policy makers.) It may be pointed out here that animate energy is excluded because only actual physical resource requirements are considered. Having discussed the accounting principles used, we discuss how to account for energy in each component of the post-harvest food system.

Food processing

Food processing is one of the primary industries to be set up in a country when the nation begins to advance from a totally agrarian to an even slightly industrial economy. This is so because, irrespective of the level of the development or income, food processing in some form or another is required in any country at a level of about 0.3 t to 0.5 t per person per year. Most food commodities require some processing:

- to make food edible, for example dehusking rice, milling wheat, corn or oil seeds, crushing sugar cane or cassava;
- for food preservation for transporting to urban areas or for storage to extend its use over space and time;
- for making alternative derivatives and precooked food, such as cheese, potato chips, tomato ketchup, soup, chocolates and beverages. (It is in this area where the multinationals are active.)

Thus, a significant amount of value added and employment is generated in this sector. In the present study, energy for food processing is calculated making assumptions about the technologies by which it is processed.

Energy in food processing =

$$\sum_i (\text{food production})_i \times E_i^P \times S_i^P$$

where E_i^P = Energy required to process food commodity i.
S_i^P = Share of food commodity actually processed. $0 \leq S_i^P \leq 1$

[6] *Ibid.*

Table 1. Oil replacement units for fuels used for household cooking.

Fuel	Heat content (GJ/tonnes[a])	Assumed average efficency	Tonnes of oil equivalent	Tonnes of oil (kerosene) required for substitution
Green fuelwood	8.0	0.07	0.186	0.029
Fuelwood[b] (20, 30% moisture)	15.0	0.12	0.349	0.093
Fuelwood (0% moisture)	20.0	0.14	0.465	0.145
Straw	12.6	0.08	0.293	0.052
Dung cake	13.8	0.10	0.321	0.071
Agricultural waste	12.6	0.08	0.293	0.052
Jute stick	18.0	0.15	0.419	0.139
Bagasse (50% moisture)	7.4	0.10	0.172	0.038
Coal	24.0	0.15	0.558	0.186
Kerosene	43.0	0.45	1.000	1.000
Electricity (10^6 kWh)	10.5	0.70	0.244	0.380
Gas (m^3)	37.0	0.65	0.810	1.250

[a]The unit is the tonne unless mentioned otherwise in the first column.
[b]Unless known otherwise, this wood is assumed to represent average.
Source: J. Parikh, *Energy in the Post-Harvest Food System of Developing Countries*, FAO, Rome, 1984.

Energy norms for food processing

While considering energy for food processing, alternative practices for food processing need to be examined. In order to keep energy in focus, energy consumption is examined for major commodities, such as cereals, sugar and oil seeds. Energy norms per unit processed output are given in Table 2.

Cereals are the largest commodity to be processed for most countries and therefore disaggregated versions of technologies have to be considered and activities such as parboiling and drying of paddy and shelling pulses have to be taken into account. Rice mills separate rice and husks from paddy. Wheatflour where hard grains have to be ground in fine particles takes 2.5 times more energy than rice milling which only splits the husks and rice. Maize and coarse grains require nearly 25% more energy than wheatflour. However, some pulses and coarse cereals are not processed and eaten after soaking and boiling at home.

Assumptions concerning the processing of other commodities, such as oil, sugar, meat and milk, are indicated in the footnotes to Table 2. Most important are sugar and oil seed processing.

Energy in food transport

As the developing countries move from subsistence agriculture to

Table 2. Energy consumption norms for food processing (per processed unit).

Processed commodity (tonnes)	Biofuels (kg)	Diesel operated (kg)	Small-scale electric (kWh)	Medium-scale electric (kWh)	Large-scale electric (kWh)	Kilograms of oil replacement[a]
Rice						
parboil[a]	292	32	305			
milling[b]		12	45	30	20	
Wheat						
flour		25	80	50	35	
baking	250	50	500	500	700	170
Maize						
course grains		30	100	50	42	80
Sugar						
concentrated					17	65
non-concentrated	2500					85
Fruit						
drying						11
juice concentrate						65
canned						122
Vegetables						
processed						15
canned						122
Meat						
slaughtered						55
canned						200
frozen						170
processed						170
Poultry and fish						
processed						80
canned						200
frozen						160
smoked						100
Milk						
skimmed }			205	165	99	45
evaporated }						250
condensed }						
butter						80
Oil seed						
hydrogenated vegetable oil						200
cotton seeds						326
copra		53	22	36		35

[a]This column was derived from literature sources accounting for all energy forms (coal, gas, electricity and oil) in heat units. These are used as reference norms. Parboiling is assumed to be included in cooking, often using the rice husks themselves. Therefore this amount is not included as processed. Bagasse for sugar has oil replacement units of 0.035. This means that the norm of 2.5 tonnes of bagasse per tonne of sugar is equivalent to 85 kilograms of oil replacement/tonne. All the oil seeds are assumed to have one norm of 35 kilograms of oil replacement/tonne of oil because no data of hydrogenated vegetable oil is available. Much fruit and vegetable drying as well as paddy drying is done in the open drying yards in the sun.

Source: J. Keddie and W. Cleghorn, 'The choice of technology in food processing', *Technology, Employment and Basic Needs in Food Processing in Developing Countries*, Pergamon, Oxford, UK, for the World Employment Programme, International Labour Office, Geneva, 1981; D.W. Delasanta and R.P. Morgan, 'The choice of sugarcane processing technique in Pakistan', *World Development*, Vol 8, 1980, pp 725–739; N. Preston, *Energy Consumption in Manufacturing*, Ballinger, Cambridge, MA, USA, 1976, pp 9–109, ch 3, pp 111–121, ch 6, pp 137–150.

intensified agriculture, they produce more marketable surplus which has to be transported to other regions, to other income groups and to urban areas. In India, for example, the average distance for food transport by the railways increased from 760 km in 1960 to 1181 km in 1977.[7] Moreover, the food is transported over larger average distances than the average distance for all commodities, which is 756 km. It is necessary to estimate the following:

1. amount of food transported;
2. average distance for which food is transported and total freight kilometers;
3. modes by which it is transported;
4. energy norms for each transport mode.

From these it is possible to work out the total energy consumed by each mode and the total energy by all transport modes.

The above points will be considered for total food consumed within the country only (ie in land transport). Air transport of food within the country is assumed to be negligible.

Out of this total amount consumed, that which is actually transported to large storages is estimated by considering consumption in urban areas. This consumption is estimated to be proportional to urban population multiplied by relatively higher propensity to consume with respect to rural areas which is assumed to be higher than rural areas by a factor of 1.2 because urban per capita income is higher than rural income.

$$\text{AT} = \underset{\text{in tonnes}}{\text{Amount transported}} = (\Sigma \text{ food consumed}_j) \times \left(\frac{PU}{P}\right) \times 1.2$$

j = commodities

where $\frac{PU}{P}$ = share of urban population in total population

1.2 = relative urban propensity for food consumption (ie 20% higher per capita than rural population)

Amount of transport in tonne-kilometres = AT (transported amount) $\times$ AD (average distance of transport)

Estimate of modes of inland transport

In case of India[8] and Pakistan, [9,10] the data for shares of road and railways are readily available. In Burma[11] and Sri Lanka[12,13] it was necessary to rely on the data for number of trucks, railway locomotives, wagons and crosscheck them with other information. The share of transport is based on the available rivers, waterways, traditions, direct and indirect references.

Energy consumption norms by each mode

Table 3 illustrates the energy consumption norms for different modes of transport. Country differences might be due to several factors some of which are illustrated below:

Energy consumed in food transport = $EFTR$ = $AT \times AD \;{}_m\Sigma\, (E_m \times S_m)$

[7] *Report of the National Transport Policy Committee*, Planning Commission, Government of India, New Delhi, 1980.
[8] *Report of the Working Group on Energy Policy*, Planning Commission, Government of India, New Delhi, 1979.
[9] Government of Pakistan, *Working Papers for the Development Perspective*, Vol 2, Sectoral Chapters, Planning Commission, 1975–80.
[10] *Statistik des Auslandes, Länderkurzbericht Pakistan*, W.Kohlhammer GmbH, Stuttgart und Mainz, FR Germany, 1981.
[11] *Statistik des Auslandes, Länderkurzbericht Burma*, W. Kohlhammer GmbH, Stuttgart und Mainz, FR Germany, 1981.
[12] *Transport Statistics in Sri Lanka (1974–81)*, National Planning Division of the Ministry of Finance and Planning, Colombo, Sri Lanka.
[13] G.B.A. Fernando, *et al*, *Sri Lanka Energy Sector Study, March 1981*, Asian Development Bank Regional Energy Survey, Manila, Philippines.

Table 3. Energy consumption norms for different modes of transport per 1000 tonne-kilometres.

	Energy sources (units)	Energy consumption norms taken	Kilograms of oil replacement
Rail	Electric (kWh)	35	
	Diesel (kg)	12	12
	Steam coal (kg)	100	
Road	Diesel for average conditions (kg)	70	70
Water (barges or ships)	Fuel oil or diesel	10	10

Source: J. Parikh, *Modelling Energy Demand for Policy Analysis*, Planning Commission, Government of India, New Delhi, 1981.

where E_m = energy consumed for 1000 tonne-kilometres by mode m
S_m = share of each mode in total transport.

Energy for household cooking

Energy for cooking is the largest component not only of the post-harvest food system but also of the energy consumption by the entire economy, especially in the countries of the Far East.[14,15] We rely on the approach of looking from the supply side of fuels for cooking supported by rural energy surveys rather than working from the demand side, ie amount of cooked food × cooking energy norms.[16] The difficulties in using the demand approach are described elsewhere.[17]

The data on commercial energy supply, ie kerosene, LPG, coal and natural gas, are available from which amounts used for other purposes, such as kerosene for lighting or LPG for industrial purposes, are substantial. For woodfuels, surveys by the FAO are used.[18] Agricultural waste and animal dung are respectively estimated from available crop residues from the crop-production data and number of cattle and buffaloes from the *FAO Production Yearbook*.[19]

Results

Energy for food processing

Energy for food processing in India, Pakistan, Burma and Sri Lanka is given in Table 4 along with the structural details. Total energy spent in 1980 was 2658, 508, 82 and 18 thousand tonnes of oil (kerosene) replacement respectively. In per capita terms, this is 3.96, 6.01, 2.39 and 1.25 kilograms of oil replacement respectively. In terms of energy per tonne of processed food, this is 20.3, 24.8, 10.8 and 10.5 kilograms of oil replacement respectively. Pakistan is relatively urbanized, has a high per capita income and is a rice exporter (the rice is dehusked domestically) and therefore has the highest energy consumption for

[14]J.K. Parikh, *Energy Systems and Development Constraints, Demand and Supply of Energy for Developing Regions*, Oxford University Press, Delhi, 1980.
[15]D.O. Hall, G.W. Barnard, and P.A. Moss, *Biomass for Energy in the Developing Countries*, Pergamon Press, Oxford, 1982.
[16]*Ibid*.
[17]J. Parikh, 'Household Energy assessment: integration of approaches and additional factors', *Biomass*, Vol 7, 1985, pp 73–84.
[18]P. Wardle and F. Pontecorvi, *Special Enquiry on Fuelwood and Charcoal*, FAO Report WP/1726, FAO, Rome, 1981.
[19]FAO, *Production Yearbook*, Vol 36, Rome, 1982.

Table 4. Energy for food processing.

Indicators	Unit	India	Pakistan	Burma	Sri Lanka
Amounts processed	10^6t	131.0	20.5	7.6	1.7
Energy consumed (tonnes oil replacement)[a]	10^3	2658.0	508.0	82.1	18.1
Energy per tonne	Kilograms of	20.29	29.78	10.86	10.52
Energy per capita	oil replacement	3.96	6.01	2.39	1.26
Share of commercial energy	%	63.0	82.3	59.6	89.8
Shares of commodities[a]	%				
cereals		44/74	35/55	61/74	59/65
sugar		40/–	37/–	18/–	10/–
oil		3/5	2/3	7/8	17/19
fruits and vegetables		–	–	1/1	–
meat, fish, poultry		1/2	6/10	11/13	6/7
milk and products		11/19	20/32	4/5	7/8

[a]A tonne of oil replacement = 1000 kilograms of oil replacement.
[b]The shares of commodities are given in energy consumption for food processing. The first number is the share of the commodity in total energy and the second the share in commercial energy. Total energy includes non-commercial energy, in particular bagasse and rice husk.

Table 5. Energy for inland food transport.

Indicators	Unit	India	Pakistan	Burma	Sri Lanka
Volumes transported	10^6t	56.22	12.71	4.13	1.24
Per capita food transported	kg	84	150	120	85
Average distance	km	900	350	350	120
Transport in tonne-kilometres	10^6t km	50600	4450	1446	149
Tonne-kilometres per capita		75.4	52.7	42.0	10.2
Modal share	%				
rail		65	44	10	3
road		32	51	80	87
water		3	5	10	10
Energy consumed	10^3 toe	1543	154	84	9
Energy per tonne	KOR[a]	27.4	14.5	20.4	7.5
Energy per 1000 tonne-kilometres	KOR[a]	30.5	41.3	58.1	62.1
Energy per capita	KOR[a]	2.30	2.18	2.44	0.64

[a]Kilograms of oil replacement.

food processing. Sri Lanka imports large shares of food (processed abroad) and therefore has low energy consumption.

The share of commercial energy in energy for food processing, which is obtained by excluding energy for sugar, works out to be 60%, 63%, 82% and 90% for India, Pakistan, Burma and Sri Lanka respectively. Shares of different commodities in energy consumption indicate dietary and cropping patterns. In India and Pakistan, the cereals and sugar claim nearly the same shares followed by milk and milk products in third place. In Burma and Sri Lanka, cereals claim a considerably large share (80%) and sugar, oil products and fish play important roles.

Thus, the energy in food processing depends on the following factors: urbanization and income; dietary and cropping patterns (especially sugar); whether the country is a food importer or food exporter.

Energy for food transport

The results obtained by following the procedure mentioned in the earlier section are reported in Table 5.

In terms of amounts transported, food is almost the first among the largest commodities to be transported, except in India, where coal is the first largest commodity transported, followed by food (two decades ago, it was number six). In Burma, nearly 80% of the total transport seems to be for food commodities alone, partly because Burma is a food exporter and has a low level of industrial activities. Up to a point, the importance of food transport is increasing with urbanization and income. Per capita food transported in the four countries is 84, 150, 120 and 85 kg for India, Pakistan, Burma and Sri Lanka respectively. Thus, the amount of food transported seems to depend on decentralization of agricultural areas with respect to populated areas.

Modal shares of the railways, the roads and water transport, of course, are very significant because road transport requires nearly four to six times more energy per tonne-kilometre than railways or water. Thus, in spite of smaller transport per capita, Burma and Sri Lanka have high energy consumption per capita due to the low share of railways.

On combining the three factors, ie amounts transported, average distance and modal shares of transport, the energy consumption works out to be 1543, 184, 84 and 9 thousand tonnes of oil replacement for the four countries respectively.

Resulting average energy per 1000 tonne-kilometres, which depends on the overall efficiency of the transport system works out to be 30.5, 41.3, 58.1 and 62.1 kilograms of oil repacement/1000 tonne-kilometres showing the highest values for countries where railways have the lowest share.

Transport energy per capita, which is a mixed indicator of the size of the country, urbanization, transport efficiency and food self sufficiency works out to be similar (2.3 kilograms of oil replacement) for all countries except Sri Lanka which is a heavy food importer and is the smallest. Thus, in the end, India compensates for its large size with better transport efficiencies.

Thus, energy for food transport depends upon: urbanization and income; size of the country and average distances; transport efficiencies and modes of transport.

Energy for cooking

A wide variety of statistics has to be counter checked to test the consistency and reliability of the estimates for energy used in cooking. These are rural energy surveys, energy availability considerations judging from the forest areas, agricultural residue production and animal population, while also keeping the demands on these resources from other sectors and for other purposes, such as timber, fodder and manure. The share of commercial energy in total energy for household cooking is as little as 12%, 24%, 6.8% and 26% in the four countries (Table 6). More than 50% of commercial energy comes from kerosene, except for Burma, where gas provides a major share. In the case of non-commercial energy, its major share comes from wood which has 60%, 43%, 79% and 77% shares respectively. Per capita energy for cooking is 33.6, 27.3, 64.3 and 46.7 kilograms of oil replacement respectively. Thus, it seems that the per capita energy use for cooking depends on the abundance of non-commercial energy in each country, due to the coping strategies people adopt.

Sri Lanka, in spite of its oil imports, seems to spend far more on commercial energy, in particular kerosene.

Energy in total post-harvest food system and identification of key factors

Total energy in the post-harvest food system and its structure is indicated in Table 7. Since absolute magnitudes are small by international standards, it is necessary to put this in perspective in relation to other national indicators for the respective countries.

Table 6. Energy for cooking.

Indicators	Unit	India	Pakistan	Burma	Sri Lanka
Commercial energy used for cooking (tonnes of oil replacement)	10^3	2742	552	15	179
kerosene	%	60	51	4	97
LPG plus natural gas	%	13	37	83	2
coal	%	27	12	13	1
Non-commercial energy (tonnes of oil replacement)	10^3	19816	1757	2195	499
wood	%	60.1	43.0	79.4	76.7
agricultural waste	%	14.5	23.1	13.5	10.8
animal dung	%	25.3	33.9	7.1	12.4
Total energy (million tonnes of oil replacement)		22558	2309	2211	678
Energy per capita (kilograms of oil replacement)		33.6	27.3	64.3	46.7
Share of commercial energy	%	12.1	23.9	6.88	26.4

Table 7. Energy in the post-harvest food system.

	India	Pakistan	Burma	Sri Lanka
Food-processing	2658	508	82	18
commercial (%)	(59.6)	(63.0)	(82.3)	(89.8)
Transport	1543	184	84	9
Cooking	22558	2309	2211	678
commercial (%)	(12.1)	(23.9)	(6.8)	(26.4)
Total energy in post-harvest food system (10^3 tonnes of oil replacement)	26759	3001	2377	705
Share of commercial energy (%)	(21.9)	(35.1)	(6.6)	(29.0)
Per capita total energy (kilograms of oil replacement)	40.0	35.5	69.1	48.6
Share in national total energy (%)	(23.1)	(21.2)	(61.2)	(38.7)
Shares in total energy				
Food processing (%)	9.9	17.0	3.5	2.6
Transport (%)	5.8	6.1	3.5	1.3
Cooking (%)	84.3	76.9	93.0	96.1
Shares in commercial energy				
Food processing (%)	27.1	30.2	43.0	8.0
Transport (%)	26.3	17.4	53.5	4.4
Cooking (%)	46.6	52.4	3.5	87.7
Energy in agriculture (10^3 tonnes of oil replacement)	6835	1406	157	183
Energy in agrofood sector (10^3 tonnes of oil replacement)	33594	4407	2534	888
Ratio of post-harvest food to energy in agriculture	3.91	2.13	15.1	3.85

Shares of the components in the post-harvest food system

Per capita energy consumption in the post-harvest food system is 40 kilograms of oil replacement in India, 35 in Pakistan, 69 in Burma and 49 in Sri Lanka. Burma has a significantly higher rate because it is a non-commercial energy user. Burma may appear sometimes anomalous because of its large area and the exports of rice and due to the fact the farms are far from Rangoon, leading to long journeys to the major markets. Moreover, Burma differs from other countries because of a high use of wood for cooking (due to its abundance) which leads to a low share of commercial energy. The share of commercial energy seem to be proportional to the energy availability and to relatively low pricing for commercial energy. They are 22% for India, 35% for Pakistan 6.6% for Burma and 29% for Sri Lanka. Among the shares of energy used for food processing, food transport and cooking, the latter predominates.

The share of the post-harvest food system in the national total is 23% for India, 21% for Pakistan, 61% for Burma and 39% for Sri Lanka. These shares are expected to be lower when industrialization increases and more energy is used for other purposes. The high shares of the post-harvest food system in Burma and Sri Lanka indicate lower industrial activities. In comparison with energy consumed in agriculture,[20] the energy for post-harvest food is greater by a factor of 3.9, 2.4, 15.1 and 3.8 for India, Pakistan, Burma and Sri Lanka respectively.

The total energy in agro-food sector works out to be 33.6, 4.4, 2.5 and 0.9 million tonnes of oil replacement respectively, where the sum of energy consumed in agriculture and the energy for post-harvest food is referred to as energy in agro-food sector.

[20]Energy used in agriculture is taken from the study *Agriculture Towards 2000* (AT2000) (FAO, Rome, 1978) which unfortunately 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.

Conclusion

Despite the difficulties in availability of precise data and differences between the countries, a few conclusions stand out. Energy consumption during processing, food transport and cooking is dependent on urbanization and income and several other factors indicated below.

Energy in the post-harvest food system, even if consideration is given to the inefficiencies of the use of non-commercial energy sources, claims a sizeable (20% to 60%) share of national total energy consumption. This energy is several times (two to four times, in general, except Burma) more than the energy required for producing food. It is estimated that in 1980, the post-harvest food system in India, Pakistan, Burma and Sri Lanka required 27.7, 3.0, 2.4 and 0.7 million tonnes of oil replacement respectively, of which the shares of commercial energy were 22%, 35%, 7% and 29%.

Energy required for food processing and food transport has to come largely from commercial energy. For example, the shares of commercial energy in the food processing components of the four countries were 63%, 82%, 60% and 90% respectively, with the remaining due to bagasse and rice husk.

The energy for food processing depends upon dietary and cropping patterns, whether food is imported or exported and of course, urbanization and income levels which are the common factors for all the three components. In the countries selected, the share of energy consumed by cereals was the highest (more than 35%), followed by sugar, milk products and oil.

The energy for food transport on the other hand, depends on the size of the country, transport efficiencies, ie modes of transport and transport infrastructure, food self sufficiency and again urbanization and income. It should be noted that in most of these countries, food is one of the largest commodities (second after coal in India) to be transported, for example it accounts for more than 70% of all transport in Burma. Moreover, the transport distances for food are increasing with time.

Cooking energy consumption varies with dietary practices, fuel efficiencies, stoves, cooking practices, pans, scale and a number of other factors. Therefore, a different approach of cross checking it with rural energy surveys and availability of fuel supply is adopted here. The share of energy for cooking, which is the largest of all components (roughly 75%), as well as per capita consumption (30 kilograms of oil replacement per capita) in the four countries, depends upon the availability of energy, ie availability of biomass or oil and gas, lack of which seems to be a controlling factor for reducing the waste and promotes coping strategies.

Finally, all the countries need to think about the centralization *vs* decentralization of cropping patterns to reduce transport of food and fuels and to take appropriate energy-saving measures for all three components of the post-harvest food system. Reducing food losses in the post-harvest food system can have substantial influence on the energy consumption per output. While considering policies relating to food self-sufficiency, the investment, imports and energy consumption in the post-harvest food system and in the food production system as a whole need to be considered.