PN-ABA-309
57095

ORNL-6468

OAK RIDGE
NATIONAL
LABORATORY

MARTIN MARIETTA

Energy Requirements for Rural Development

Donald W. Jones

OPERATED BY
MARTIN MARIETTA ENERGY SYSTEMS, INC.
FOR THE UNITED STATES
DEPARTMENT OF ENERGY

Printed in the United States of America. Available from
National Technical Information Service
U.S. Department of Commerce
5285 Port Royal Road, Springfield, Virginia 22161
NTIS price codes—Printed Copy: A04; Microfiche A01

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

ORNL-6468

ENERGY REQUIREMENTS FOR RURAL DEVELOPMENT

Donald W. Jones
Energy Division
Oak Ridge National Laboratory

Date Published: June 1988

Prepared for the
Office of Energy, Bureau for Science and Technology,
U.S.A.I.D.
under Contract No. B57-5728-P-ER-4257-01,
under Interagency Agreement DOE No. 1637-1637-A1
as part of the
Energy Policy Development and Conservation Project

Prepared by the
Oak Ridge National laboratory
Oak Ridge, Tennessee 37831
operated by
MARTIN MARIETTA ENERGY SYSTEMS, INC.
for the
U.S. DEPARTMENT OF ENERGY
under Contract No. DE-AC05-84OR21400

PREFACE

This study on the role of energy in the development of rural areas was originally conducted in the spring and summer of 1985. It was intended to serve as a background paper for the preparation of a program plan for the Office of Energy of the United States Agency for International Development. As such it begins with a brief overview of how rural development fits into national development, then offers a comprehensive framework for thinking about rural development in particular and the energy implications of the various components of rural development.

Agriculture naturally comes to mind when rural areas are mentioned, but industry is an important component of rural activity as well. Consequently both agricultural and nonagricultural energy use is discussed. Modernization of rural areas will change household, as well as production, energy use. However, household energy use is a veritable subject in its own right, with a large literature. Consequently, that topic is discussed in less detail than the production energy topics.

Numerical assessment of energy production and use in developing countries, particularly at scales below the nation, is difficult. Numbers of varying and often unknown quality are scattered throughout the literature. Quite often, ratios give the most incisive information, but the number for a numerator will appear in one fugitive report while a denominator appears--in several different versions, as often as not--in published articles or statistical sources. While this report is not intended to be a data book, it does attempt to assemble some numbers directly and indirectly related to rural energy use in developing countries so they will be accessible in one place.

Some three years have lapsed since this study was completed, and a number of interesting and important studies of rural energy use in developing countries have appeared. I have resisted the temptation to incorporate all the new material and offer the study largely as it was originally completed. The framework itself would not be altered significantly by the work of the past three years, and the numbers themselves primarily would be subject more to repetition than to replacement or revision.

TABLE OF CONTENTS

PREFACE iii

LIST OF TABLES iv

ABSTRACT vii

1. RURAL DEVELOPMENT IN NATIONAL ECONOMIC DEVELOPMENT 1

2. COMPONENTS OF RURAL DEVELOPMENT 5
   2.1 THE TRANSFORMATION OF FARMING 5
      2.1.1 Mechanization 5
      2.1.2 Irrigation 6
      2.1.3 Use of High-Yield Seed Varieties 6
      2.1.4 Use of Commercial Fertilizers 7
   2.2 RURAL INDUSTRIALIZATION 7
      2.2.1 Processing of Agricultural Products 8
      2.2.2 Other Rural Industrial Development 9
      2.2.3 Rural Commuting 10
   2.3 INFRASTRUCTURAL DEVELOPMENT 10

3. ENERGY IMPLICATIONS OF RURAL DEVELOPMENT 13
   3.1 MACROECONOMIC IMPLICATIONS 13
   3.2 ENERGY USE IMPLICATIONS OF THE COMPONENTS OF AGRICULTURAL MODERNIZATION 17
      3.2.1 Mechanization 17
      3.2.2 Irrigation 23
      3.2.3 Commercial Fertilizer Use 26
      3.2.4 High Yield Variety Seed Use 28
      3.2.5 Infrastructural Development 28
   3.3 RURAL INDUSTRIALIZATION 30
      3.3.1 Employment Shares 30
      3.3.2 Energy Use in Agroprocessing Industries 32
   3.4 HOUSEHOLD ENERGY USE 39

4. SUMMARY 41

REFERENCES 45

LIST OF TABLES

Table		
1	Agricultural and Related Energy Use, Selected Countries	14
2	Energy Use in Mechanized Agriculture, South and Southeast Asian Countries, 1975	18
3	Irrigation Requirements--Selected Sites Along the Senegal River Valley	24
4	Pumped Irrigation Energy Requirements in Subsaharan Africa: Energy Requirements to Increase Arable Land By 5% Through Irrigation	25
5	Manufacturing Shares (%) in Rural Nonfarm Employment, Selected Countries	31
6	Industry Distribution of Employment in Rural Manufacturing for Selected Countries (%)	32
7	Shares of Agroindustry in Manufacturing Sectors in Selected Developing Countries	33
8	Energy Requirements in Selected Rural Industries, Thailand, 1980	35
9	Energy Use in Agroindustry Plants, Kenya, 1972-1980	36
10	Projected Energy Use in Biogas Rice Mill, Nepal, 1982[a]	37
11	Energy Use in Soybean Processing, Haiti, 1984	37

ABSTRACT

In traditional agriculture, fuel use is almost nonexistent. As nation develops and its agricultural sector develops and mechanizes, other sectors grow at relatively more rapid rates, reducing agriculture's share of national income. As a result, more developed and mechanized agricultural sectors claim roughly the same, or even smaller, shares of national energy consumption.

Farm mechanization, irrigation, commercial fertilizer use and the introduction of high yielding variety seeds are the major elements of farm modernization which increase energy use. The actual quantities of energy used in each of these activities are quite country- and even location-specific. Fuel cost shares of farm equipment operation have been estimated to be between 25% and 45% of total equipment operating cost, although conditions of fuel availability, spare parts and maintenance appear to be as important to successful mechanization as low fuel prices. Farm mechanization is highly dependent on road infrastructure. The release of former farm residents to urban locations, where they require delivery of their food, accompanies farm mechanization. A rough estimate of the magnitude of the associated increased fuel use is 10% of the embodied energy in the food moved.

Most opportunities for gravity flow irrigation and natural flooding appear to have been undertaken already, so modest additions to irrigated acreage will rely on pumping. Energy use in pumping is quite location- and crop-specific and is greatly affected by pump and delivery system maintenance. Fuel cost shares in pumped irrigation are roughly the same as in agricultural equipment operation.

Commercial fertilizer production is highly energy intensive, particularly for nitrogen fertilizers which are in heavy demand in tropical regions. Transportation demands by both feedstocks and outputs are great.

Agriculture accounts for only between 50% and 75% of rural labor forces in developing countries. Manufacturing accounts for 25% to 50% of rural nonfarm labor, and agricultural processing -- including textile and wood activities -- accounts for a large share of these. Evidence from these activities is scattered, and macroeconomic implications are difficult to draw from what exists, but some comparative statements can be made. Food processing in Kenya in 1979 accounted for 28% of industrial electricity consumption and 20.5% of industrial fuel consumption, or 13.2% of total electricity consumption and 18.7% of industrial and commercial fuel consumption. In the same year, Kenyan textile production consumed roughly half of what food processing consumed. No rural-urban disaggregations can be made on these consumption shares however. In Thailand in 1980, cassava chipping and pelletizing used 4.1% of national industrial oil consumption, and cassava flour milling used an additional 1.64%.

1. RURAL DEVELOPMENT IN NATIONAL ECONOMIC DEVELOPMENT

Much of the effort in economic development since World War II has been devoted to heavy industrialization and to the urban sectors of developing countries. Agriculture has received considerable attention as well, but despite the prominence of the green revolution in several countries, developments in agriculture do not appear to have the prestige conferred on large new factories and urban construction projects. Indeed, Lipton has claimed that a pervasive urban bias has existed in most developing countries during the postwar period and that it has retarded, and in some cases even crippled agricultural development, in turn retarding overall national economic development.[1] The thesis, like most in the field, has not gone unchallenged.[2] Whether or not further examination supports the claim of bias, the debate underscores the importance of the development of agriculture in national economic development. Intellectual opinion has alternated between recommending dynamic sectoral imbalances for hastening development[3] and a balanced development of agriculture and industry.[4] For a while, a number of countries experimented practically with import substitution. The concept of export-led growth intellectually superceded import substitution, and some spectacularly successful countries gave that new idea apparent empirical support that the import substitutors never gave to the proponents of that development strategy. Even export-led growth has received second thoughts and is being balanced with the idea that healthy domestic markets are also important for vigorous and sustainable growth.[5] Current judgement favors the simultaneous development of the urban/industrial sector and the rural/agricultural sector, as well as balanced development of domestic and export markets, on the theoretically- and empirically-informed belief that the two pairs of sectors are too intertwined for either to progress without improvement in the other. In fact, the sectoral distinctions are becoming blurred as rural industrialization is undertaken or recognized as having existed for

---

[1]Michael Lipton, Why Poor People Stay Poor: Urban Bias in World Development (Cambridge: Harvard University Press, 1977).

[2]See for example, the papers in John Harriss and Mick Moore (eds), Development and the Rural-Urban Divide (London: Cass, 1984).

[3]For example, Albert O. Hirschman, The Strategy of Economic Development (New Haven: Yale University Press, 1958).

[4]W. Arthur Lewis, The Theory of Economic Growth (London: George Allen & Unwin, 1955), p. 283.

[5]Irma Adelman, "Beyond Export-Led Growth," World Development 12, No. 9 (1984), pp 437-949. See the comments on Adelman's thesis: H. W. Singer, "Success Stories of the 1970s: Some Correlations," World Development 12, No. 9 (1984), pp 951-952; and Tibor Scitovsky, "Comment on Adelman," World Development 12, No. 9 (1984), pp. 953-954.

some time; additionally, it is becoming recognized that some urban residents are farmers or rurally employed nonfarm workers.

Between 40% and 90% of the populations of developing countries live in rural areas, and agriculture produces between 20% and 60% of national income. One-quarter to nearly one-half of the labor forces in rural areas of developing countries are not in farming but rather are in rural services and manufacturing that rely heavily upon agricultural products. The rural sector provides population to cities as a country urbanizes and in earlier phases of urbanization and industrialization also provides a large market for the outputs of new domestic industry. Agriculture is the major source of domestic capital accumulation for urban industrialization in nascent periods of development, and the major part of foreign exchange earnings generally is derived from agricultural exports. The rural sector, and agriculture in particular, looms too large in the economies of developing countries to be ignored.

Sustenance of an urbanized, industrial labor force depends on the ability of domestic agriculture to increase per worker outputs. Such an increase has been achieved in the past only with the introduction of new techniques, inputs and organizational forms into traditional agriculture. Agriculture, in turn, relies on cities and urban systems for the advances in knowledge that generate the new inputs and techniques, for the production of the new inputs, and for interregional movement of agricultural products to new markets.[6]

Agriculture is not a major energy consumer in industrialized countries, primarily because agricultural shares in national incomes are small. Agricultural energy shares in developed economies range from 1% to 3%, while agricultural shares in GDP range from 3% to 6%. In developing countries, agriculture is a minor consumer of energy, ranging from 2% to 7% of total national consumption, while agriculture's share of GDP ranges from 20% to 60%, with even higher labor force shares. This percentage of energy consumption is primarily due to the character of agriculture, which for the most part, uses human and animal power sources for actual farming operations.

Reference to the small agricultural shares in industrialized countries' energy consumption indicates that the mechanization of agriculture in developing countries is unlikely to increase agriculture's share of energy consumption. Because of the simultaneous changes in energy consumption technology elsewhere in the economy, the larger absolute quantities of energy consumed by agriculture will remain a small share of total energy consumption. Linear extrapolations of energy requirements per agricultural worker or per unit of output for the purpose of projecting a future agricultural energy consumption share are improper because the proportions of both workers in and income from

---

[6]See Dennis A. Rondinelli and Kenneth Ruddle, Urbanization and Rural Development: A Spatial Policy for Equitable Growth (New York: Praeger, 1978), especially Chapter 3 on the role of urban systems in rural development.

agriculture will fall with development. However, the fact that agriculture claims low shares of national energy consumption at both low and high levels of development does not necessarily imply that agricultural development will cause no macroeconomic energy problems on the path between those two points. For example, Jones and Samuels (1988) calculate that using pumped irrigation to increase arable land by only 5% can require from 5% to 15% of a small developing country's 1980 commercial energy consumption, large enough shares to disrupt local energy supply systems.

Rural development entails more than purely agricultural development. Rural industrialization and the manufacture of agricultural inputs such as machinery and fertilizer are concomitants and supports for the development of agriculture and have their own energy requirements. Food production for domestic urban populations requires more extensive transportation than does traditional production, particularly when such transportation uses modern fuels. Last, but by no means the least, as personal incomes in rural areas increase, modern fuels will replace less convenient traditional fuels -- usually biomass fuels -- in domestic use, possibly increasing per capita energy use. Given the large rural populations, this potential change in household use is large, and migration to urban areas will only change the location of household energy demands, not their total quantity.

2. COMPONENTS OF RURAL DEVELOPMENT

This section sketches out a number of events involved in the economic development of the rural regions of a country and indicates some of the major interactions among them. They are divided into three major categories: transformation of farming, rural industrialization, and infrastructural development.

2.1 THE TRANSFORMATION OF FARMING

In traditional agriculture, activities on the farm are generally powered by human or animal labor, involving little or no actual fuel use. Highly sophisticated irrigation systems have existed in some countries for centuries, but their flexibility has been limited by accompanying animate power sources. As long as relatively low-yielding seed varieties were used in traditional agriculture, soil nutrient replenishment could be accomplished adequately with locally available biomass, primarily animal dung, human feces, and crop residues. Labor demands varied substantially over the crop season, peaking at planting and for some crops replanting times and at harvest time; effective yields could be reduced by leaving some crop in the fields because sufficient labor was not available. The transformation of agriculture extends beyond the farm and entails changes in four major activities actually on the farm: (1) mechanization of power sources, (2) introduction or modernization of irrigation, (3) introduction of new, higher yielding seed varieties for some crops, and (4) the use of commercial fertilizers. These changes in agricultural production technology are treated below.

2.1.1. Mechanization

Mechanization offers power-intensive operations such as plowing and control-intensive operations such as weeding and interculture.[7] Mechanization of power-intensive operations appears profitable even where wages are low, but mechanization of control-intensive activities appears more restricted to high-wage areas. It is common for mechanized power-intensive operations to coexist with animal- or human-powered control activities, depending upon factor prices.[8]

---

[7]Prabhu L. Pingali and Hans P. Binswanger, "Population Density and Farming Systems--The Changing Locus of Innovations and Technical Change," Discussion Paper No. ARU 24 (Agriculture and Rural Development Department, World Bank, Washington, October 1984), p. 20.

[8]Hans P. Binswanger, Vernon W. Ruttan, and others, Induced Innovation: Technology, Institutions, and Development (Baltimore: John Hopkins University Press, 1978) and, for discussions and analyses of the role of factor prices in the adoption of new agricultural technology, see James Roumasset, and Ganesh Thapa, "Explaining Tractorization in Nepal; An Alternative to the 'Consequences Approach'," Journal of Development Economics, vol. 12, (1984) pp. 377-395.

Labor demand peaks during planting and harvesting periods can be reduced with appropriate mechanization. Concern has been expressed that extensive mechanization of agriculture will reduce employment opportunities. In the short run, such concerns will have more force, but the release of agricultural labor can eventually be absorbed by expansion in other activities, either rural or urban industry. Reduction of bullock employment for power can release livestock for dairy activity or in the absence of sufficient demand for dairy products can increase the acreage devoted to nonfodder crops.[9] In the event that draft animals are fed primarily from crop residues, the acreage increase with draft animal reduction will be less, but more crop residues will be released for use as fertilizer and fuel, compensating the reduction in animal dung at least partly.

The practicality of mechanization depends upon, among other conditions, the size of holdings, implement sizes, and the possibilities of sustaining equipment cooperatives.

2.1.2 Irrigation

Irrigation can be used to modulate the timing of water flow to fields, to simply increase the quantities of water delivered, or both. Rearranging the timing and improving the reliability of water flow can permit double and triple cropping where only single or double cropping is possible otherwise. In arid areas, it usually is desirable to increase water quantities as well as improve timing and reliability, but larger scale irrigation efforts are more successful at higher population densities.[10] Where irrigation has existed for some time, relying on human or animal power sources for lifting water, mechanization of pumping can save immense quantities of labor time.

Irrigation is part of a package -- mechanization, irrigation, and use of commercial fertilizers; one change encourages, or even requires, several others. The proportions in the package vary from place to place, largely because of differences in factor prices, which is a generalization of the principle that larger scale irrigation efforts are more successful at higher population densities (higher rent-wage ratios).

2.1.3 Use of High-Yield Seed Varieties

The high-yield varieties (HYVs) of wheat and rice associated with the name of the Green Revolution in South and Southeast Asia in the 1960s underlay the growth in agricultural productivity in Japan and Taiwan in

---

[9]This is the case only in areas where livestock parasites and diseases are not prevalent.

[10]Pingali and Binswanger (1984), p. 13; and Martin E. Adams and John Howell, "Developing the Traditional Sector in the Sudan," Economic Development and Cultural Change, vol. 27, (1979), p. 516.

the early part of the twentieth century.[11] The seeds are responsive to fertilizer, and HYV use and fertilizer use may be viewed as a package. Whether HYV use and mechanization should be seen as a complementary technological package is an open question, however.[12] Intuitively, it would appear that increased yields would increase the demand for labor at least during harvesting, giving an incentive to mechanization. However, the empirical record does not support such a simple explanation, suggesting instead that mechanization of HYV operations is governed to a large extent by relative factor prices.

In addition to the complementarity of HYVs and fertilizer, in many environments the HYVs are more susceptible to insects and pests, so pesticides may be part of the package.

2.1.4. Use of Commercial Fertilizers

High-yielding varieties of seeds need not be adopted for farmers to shift from traditional farm fertilizers to commercial fertilizers. Agriculture in many developing countries has a high demand for nutrient replenishment, especially but not only nitrogen, as a means to increase yields in areas where the intensity of cropping has increased. It is not clear from empirical evidence whether use of commercial fertilizers straightforwardly increases the demand for irrigation and mechanization or whether the latter decisions are separably dependent on relative factor prices.

2.2 RURAL INDUSTRIALIZATION

Actual farming occupies only 50% to 75% of the rural labor force, with the remainder largely in services and manufacturing.[13] From the macroeconomic point of view, economic development of rural areas moves much production activity out of the household into factories where it can be conducted on larger and more efficient scales and often with newer technologies. At the individual or family level, rural industrialization is a principal source of off-farm employment for part-time farmers and their family members, and it has been important in reducing rural poverty

---

[11]Yujiro Hayami in association with Masakatsu Akino, Masahiko Shintani, and Saburo Yamad, A Century of Agricultural Growth in Japan (Minneapolis: University of Minnesota Press, 1975), pp. 64-65; and Vernon W. Ruttan and Hans P. Binswanger, "Induced Innovation and the Green Revolution," In Hans P. Binswanger, Vernon W. Ruttan and others, Induced Innovation: Technology, Institutions, and Development (Baltimore: Johns Hopkins University Press, 1978), pp. 359-360.

[12]Ruttan and Binswanger (1978), pp. 361-362, note 8.

[13]Dennis Anderson and Mark W. Leiserson, "Rural Nonfarm Employment in Developing Countries," Economic Development and Cultural Change, vol. 28, No. 2 (1980), pp. 227-248.

and personal income inequality.[14] This section discusses three topics in rural industrialization: processing of agricultural products ("agroprocessing"); other rural industrial development, including industrial dispersion policies; and rural commuting.

2.2.1 Processing of Agricultural Products

Before the onset of urbanization, little preparation of food products for transportation to distant markets was necessary, and most preparation of food crops was conducted within the household. A high proportion of rural labor time is currently spent is postharvest operations such as shelling, cleaning, and grinding of crops for local consumption. Despite the time consuming nature of these activities, traditional processing contributes little value added to food crops. Presently, even processing of food crops destined for urban markets is often minimal, restricted to drying and shelling or husking, depending upon the crop. However, as urbanization proceeds and income levels rise, the demand for processing can be expected to increase, as it did in the presently developed countries. Industrialization and mechanization of these activities can release a considerable amount of rural labor for other activities, although like mechanization of field operations, employment problems may be exacerbated temporarily.[15]

Textile and wood products manufacture also can be classified as agroprocessing industries. The prominence of these industries in the national economy commonly increases in early periods of economic development, although textile production, in particular, may be modernized earlier in urban areas than in rural as urban mills supplant rural weaving.[16] However, Anderson and Leiserson cite shares of

---

[14]For evidence from Taiwan, which admittedly is an exceptional case, see Dennis L. Chinn, "Rural Poverty and the Structure of Farm Household Income in Developing Countries: Evidence from Taiwan," Economic Development and Cultural Change, vol. 27, (1979), pp. 283-301; and A. R. C. Low, "The Effect of Off-Farm Employment on Farm Incomes and Production: Taiwan Contrasted with Southern Africa," Economic Development and Cultural Change, vol. 29, (1981), pp. 741-747 offers a contrast between southern African countries and Taiwan.

[15]Kenneth R. M. Anthony, Bruce F. Johnston, William O. Jones, and Victor C. Uchendu, Agricultural Change in Tropical Africa (Ithaca: Cornell University Press, 1979), pp. 61-67.

[16]Morris D. Morris, The Emergence of an Industrial Labor Force in India; A Study of the Bombay Cotton Mills 1854-1947 (Berkeley: University of California Press, 1963); Kang Chao, with the assistance of Jessica C. Y. Chao, The Development of Cotton Textile Production in China (Cambridge: East Asian Research Center, Harvard University, 1977), pp. 106-142; and Ruth B. Dixon, Rural Women at Work: Strategies for Development in South Asia (Baltimore: Johns Hopkins University Press, 1978), p. 88.

"textiles, wearing apparel and leather" as ranging from 13% to 53% of rural manufacturing employment in five developing countries.[17] So despite the progress of urban-rural competition in the industry, it is an active employer in rural areas. Putting-out systems are prevalent in a number of lines of production in rural areas, representing a half-way position between traditional home production and more modern factory.[18]

2.2.2 Other Rural Industrial Development

Anderson and Leiserson's data indicate that from 23% to 45% of employment in rural manufacturing is in "metal, machinery, and fabrication" or "other" classifications. Agricultural implement manufacture is a prime candidate for rural location. Experience has shown that modifications of imported machinery, originally designed for different environmental or even social conditions, are very important for adaptation to developing country conditions and that these modifications are best made under conditions of close coordination between the farmers using the machinery and the engineers and machinists making the modifications.

Some governments may impose specific location policies which promote spatial dispersion of manufacturing to rural areas: licensing of new private plant locations, planned dispersion of government owned facilities in backward areas, and selective tax credits or subsidies. India and Taiwan, in particular, have used these tools, with varying degrees of success. India's deconcentration does not appear to have been marked,[19] but Taiwan's rural industrialization has been exceptional, in nonagricultural industries as well as agriculture-related industries.[20]

---

[17]Anderson and Leiserson (1980), Table A.3, p. 246.

[18]Dixon (1978), pp. 63-69, discusses food processing in rural towns in India, and see Hubert Schmitz, Manufacturing in the Backyard: Case Studies on Accumulation and Employment in Small-scale Brazilian Industry (London: Frances Pinter, 1982), pp. 105-113, for discussion on rural subcontracting in hammock making in Brazil.

[19]A. Uday Sekhar, Industrial Location Policy: The Indian Experience. World Bank Staff Working Paper No. 620. (Washington 1983), pp. 77-85.

[20]Samuel P. S. Ho, "Decentralized Industrialization and Rural Development: Evidence from Taiwan," Economic Development and Cultural Change, vol. 28, (1978), pp. 77-96; Gustav Ranis, "Industrial Development," In Walter Galenson (ed.), Economic Growth and Structural Change in Taiwan: The Postwar Experience of the Republic of China (Ithaca: Cornell University Press, 1979), pp. 222-223, Table 3.8; p. 224. For information on other countries' regional dispersion efforts, see Rondinelli and Ruddle (1978), pp. 12-13, 50-51.

2.2.3 Rural Commuting

As the economy develops, many farmers take part-time jobs, and other family members who would have worked in farming take off-farm factory work in nearby towns or cities. In some countries, Taiwan being the prime example with its excellent rural transportation network, a substantial number of rural residents actually commute daily to factory employment in towns or smaller cities.[21] Such circumstances can offer producers the administrative and agglomeration benefits of urban location as well as the opportunity to draw on a potentially large rural labor supply.

2.3 INFRASTRUCTURAL DEVELOPMENT

The direct ingredients of agricultural and general rural development have been described in Sections 2.1 and 2.2. However, as many writers have noted, without supporting infrastructural development, the fertilizer, irrigation, and new tractors and seeds almost certainly will be of little benefit.

Without transportation infrastructure in farm regions, farm output cannot get to markets or farmgate prices are gutted by transportation costs. Either way, farmer's abilities to purchase inputs and to produce for wider markets are reduced if not eliminated entirely.[22]

Once the products get to initial sales points off the farm, there must be marketing institutions which put the suppliers in touch with potential buyers, and the buyers must be assured of the qualities and quantities they think they are purchasing. Marketing institutions need not include marketing boards, which as often as not transfer income from both consumers and farmers to government administrators,[23] but could well include commodity futures markets.

---

[21]Ranis (1979), p. 225.

[22]See John M. Antle, "Infrastructure and Aggregate Agricultural Productivity: International Evidence," Economic Development and Cultural Change, vol. 31, No. 3 (1983), pp. 609-619; and John M. Antle, "Human Capital, Infrastructure, and the Productivity of Indian Rice Farmers," Journal of Development Economics, vol. 14, (1984), pp. 163-181, for discussion of the factor productivity effects of transportation infrastructure, as well as educational and research support, for an international cross section and in Indian rice farming.

[23]Frank Ellis, "Relative Agricultural Prices and the Urban Bias Model: A Comparative Analysis of Tanzania and Fiji," In John Harriss and Mick Moore (eds), Development and the Rural-Urban Divide (London: Cass, 1984), pp. 32-40, for an example of Tanzania in the 1970s.

Taking a step back from the point of marketing, credit and local agricultural research and extension are important. Without credit, farmers cannot purchase modern inputs and without research and extension, mechanical, chemical and biological technologies that are borrowed from outside the country cannot be properly adapted to local conditions.[24]

Rural electrification is a major component of rural development. In many countries, the primary consumer of rural electricity is irrigation pumping, but electrification has the potential to radically alter energy supplies and technology choices of a range of rural industries and to restructure a wide range of domestic activities. Clearly, much can be accomplished without extensive rural electrification, but just as clearly, it can open up many new production and consumption opportunities.

Legal systems affect the security of land ownership and the operation of rural land markets and in turn affect holding size and parcelization. Additionally, restrictions on farm tenure may reduce the ability of operators to compensate for other market imperfections.[25] Government policies affecting agriculture and rural areas clearly interact with development. Although these policies are subject to interest group pressure, they may, for many purposes, be considered exogenous by individual farmers and other rural residents. Both legal structures and government policies may hinder or foster economic efficiency and modernization.

---

[24]See Robert E. Evenson and Yoav Kislev, Agricultural Research and Productivity (New Haven: Yale University Press, 1975) on the importance of geographical tailoring of agricultural R&D to the transfer of agricultural technology, and John Adams and Balu Bumb, "Determinants of Agricultural Productivity in Rajasthan, India: The Impact of Inputs, Technology, and Context on Land Productivity," Economic Development and Cultural Change, vol. 27 (1978), p. 720, for evidence of the importance of credit institutions to the successful adoption of agricultural technology in Rajastahn.

[25]David M. G. Newbery and Joseph E. Stiglitz, "Sharecropping, Risk Sharing and the Importance of Imperfect Information," in James A. Roumasset, Jean-Marc Boussard and Inderjit Singh (eds), Risk, Uncertainty and Agricultural Development (New York: Agricultural Development Council, 1979), pp. 311-339.

3. ENERGY IMPLICATIONS OF RURAL DEVELOPMENT

This section assembles some scattered empirical evidence on the energy implications of developing agriculture and rural industry. First, some national-scale figures on energy use in agriculture at varying degrees of development are assembled and interpreted. The second section presents information on energy use associated with the components of agricultural modernization discussed in Sections 2.1 and 2.3. The third section presents similar information on energy use in rural industry, particularly agroprocessing. The structure of the paper so far has emphasized the production side of rural development, but a major aim of development is to ultimately improve consumption opportunities. The final section turns to changes in household, or domestic, energy use that can be anticipated to result from rural development.

3.1 MACROECONOMIC IMPLICATIONS

As noted in the introduction, historically the share of national energy consumed by agriculture has not increased as a country's agriculture has modernized and mechanized. As Table 1 suggests by the contrast between the four developing countries and the United States, which is representative of other developed countries on this characteristic, agricultural production's share of national energy consumption may stay roughly constant or even fall. The energy consumption shares of agriculture-related activities appear to decline as development proceeds. (In Table 1, the GDP per capita, in the last row, is a rough indicator of relative levels of development.)

However, the energy requirements of particular agricultural projects or of widespread mechanization can appear nontrivial when compared with current commercial energy consumption. For example, it has been found that increasing Chad's arable agricultural land by 5% through pumped irrigation would require a quantity of diesel fuel equivalent to 22.6% of its 1980 commercial energy consumption. Similar expansions in Somalia, Niger and Mali would require 15.8%, 8.5%, and 8.1% of 1980 commercial energy consumption or energy imports.[26] In the early 1970's, Indian agriculture was well mechanized in only two states, but farm tractor operation required a quantity of fuel equivalent to 16.8% of all oil imports.[27] Moving somewhat away from agriculture, fuel requirements for single, large industrial plants are even more prominent, running as high as 30% to 40% of national commercial energy consumption.[28]

---

[26]Jones and Samuels (1988), Table 1, p. 9.

[27]Donald W. Jones, "Urbanization and Energy Use," mimeo. (Oak Ridge National Laboratory, April 1985), p. II-105.

[28]Jones and Samuels (1988), Table 2, p. 15.

Table 1. Agricultural and related energy use, selected countries

	Bangladesh[a] 1974	Egypt[b] 1975	Morocco[c] 1980	Kenya[d] 1979	U.S.[e] 1976
% of Commercial Energy Used in:					
Agricultural Production	2.0	2.0	6.5	8.3	1.8
Agricultural Processing (excluding textiles)	3.5	0.6	n.a.	1.3	
Textiles	4.7	2.4	n.a.	0.4	
Fertilizer Production	6.9	1.6	2.8	0.2	
Subtotal	17.9	6.6	3.7		
% of Traditional Energy Used in:					
Agricultural Production					
Agricultural Processing (excluding textiles)	19.2				
Textiles	0.2				
Subtotal	19.4				
Traditional Energy as Percent of Total Consumption[f]	75.0	9.1	35.8	78.2	
Agricultural Share of GDP (%)[g]	57.8	23.3	18.1	38.0	2.8

[a]Source: Russell J. deLucia and Henry D. Jacoby, "The Bangladesh Case," in Russell J. deLucia, Henry D. Jacoby et al., Energy Planning for Developing Countries: A Study of Bangladesh (Baltimore: Johns Hopkins University Press, 1982), Table 2.1, p. 28.

[b]Source: Gordian Associates, Inc., An Assessment of the Energy Requirements and Selected Options Facing Major Consumers Within the Egyptian Industrial and Agricultural Sector. Mimeo., Washington, May 1978, Table 23, p. 112; Table 35, p. 158; Table 42, p. 189; Table 45, p. 192; for sectoral energy uses. International Energy Agency, Energy Balances of Developing Countries 1971/1982 (Paris: OECD, 1984), for total consumption.

[c]Sources: Andrew McWilliams, Energy Demand Study (Morocco), draft report, Kearney, Inc., for USAID, Alexandria, Va., 1984. Cited in Janine Finnell, Energy and Agriculture in Morocco: Linkages in the Food System. Mimeo., Washington: USAID (S&T/EY), February 1984, Fig. 7, p. 17, for sectoral energy use. OECD 1984) for total consumption.

[d]Source: Lee Schipper et al., Energy Conservation in Kenya's Modern Sector, Discussion Paper D-73I, (Washington: Resources for the Future, May 1982), Table 3.1, p. 23.

[e]Source: J. Frank Bodine, Marshall Vitullo et al., Industrial Energy Use Data Book (Oak Ridge, TN: Oak Ridge Associated Universities), 1980, Table 4.1, p. 4-2; Table 7.2, p. 7-4; Table 10.1, p. 10-2; Table 11.5, p. 11-4; 13.22.A, p. 13-38.

[f]Source: OECD (1984).

[g]Source: World Bank, World Tables, 3rd Ed. Vol. I. (Baltimore: Johns Hopkins University Press, 1983), Economic Data Sheet 1.

These major single-component impacts on national energy consumption must be reconciled with the observation that, as agricultural development proceeds, agriculture's share of national energy consumption stays roughly constant or even falls. The key to this reconciliation is that the rest of a nation's economy cannot stand still as agriculture develops. In fact, without the income increases and farm labor force reductions produced by industrial development and urbanization, there would be little demand for the agricultural productivity improvements. However, agricultural exports have been important in the early economic development of a number of countries, the United States being prominent among them. This is not to say that agricultural development always follows development elsewhere in the economy. It should be pointed out that agricultural productivity improvements can well initiate general, national capital accumulation and development elsewhere in the economy. However, because of low price and income elasticities of demand for agricultural outputs, development of other productive sectors of the economy is required to sustain the income increases initiated by increases in agricultural productivity. This is nothing more than a statement that the agricultural and industrial sectors of an economy, the rural areas and the cities, are connected in a general equilibrium in which the prosperity of each depends on the productivity of both. However, it is a reminder that planned development efforts in agriculture should be complemented by efforts to develop industry, and vice versa. Mechanization of agriculture will reduce agricultural employment opportunities. If those losing employment in agriculture are not absorbed in other work, aggregate income can fall, reducing the domestic demand for agricultural products and probably leaving the new farm equipment to rust.

Returning to Table 1, agricultural energy shares are presented for only a small number of developing countries, far fewer than the number for which published data are available (e.g., in O.E.C.D. or U.N. publications of energy balances with sectoral disaggregations). However, examination of those sources raises some major reservations about their reliability. The use of these sources for statements about rural and agricultural energy use is particularly questionable, although their usefulness for other purposes is probably not affected as strongly. Frequently, no liquid petroleum fuel use is recorded for agriculture in countries in which agricultural mechanization is known to be extensive (see reports for Chile, Egypt, Malaysia in International Energy Agency, 1984).[29] Industrial use of traditional fuels is almost always relegated to the sectoral categories "non-specified industry" or "non-specified other sectors." Much rural commercial fuel use probably is included in the "non-specified other sectors" category, but it is impossible to distinguish rural from urban uses. These published data are easy to criticize, but considering the low rural use of commercial fuels, much better information will not be forthcoming without relatively detailed

---

[29]See International Energy Agency, Energy Balances of Developing Countries 1971/1982. (Paris: OECD, 1984), for reports on Chile, Egypt, and Malaysia.

and expensive surveys. To give an example of the numerical dimensions of the observation problem, consider Thailand, which derived a reported 72% of its farm power from machines in 1980.[30] Despite this predominance of commercial fuel-using machinery on Thailand's farms, gasoline and diesel accounted for less than one one-hundredth of one percent of national rural energy consumption. Traditional fuels accounted for 92.5% of rural household (excluding agricultural) energy consumption, and LPG and kerosene accounted for another 6%.[31] This predominance of traditional fuels in rural areas of developing countries is not out of the ordinary. But a 1978 rural energy survey in the Philippines indicated only a 60% traditional energy share in rural household energy consumption; agricultural production energy use does not appear to have been included.[32] Clearly it will be difficult to observe accurately such relatively small fuel uses with nonsurvey methods. Accordingly, the developing countries for which agricultural energy consumption data are presented in Table 1 are restricted to countries for which survey data are available.

Thus, from a macroeconomic perspective, the mechanization of agriculture and the modernization of industry associated with agriculture (both input producers and output processors) does not threaten to radically alter the sectoral structure of national energy consumption, although the earlier comment about imbalances along the transformation paths applies. Absolute increases in agricultural energy consumption should be met by comparable increases in commercial energy consumption elsewhere in the economy as development proceeds apace On the other hand, as overall national economic development proceeds, predictions are that commercial energy consumption per capita will increase at approximately the same rate at which income per capita increases.[33] However, because of agriculture's relatively small claim on a nation's energy consumption, statistical identification of the effects of agricultural development on aggregate energy consumption per capita would

---

[30]Gajendra Singh, "Agricultural Mechanization in Selected Southeastern Asian Countries," Agricultural Mechanization in Asia, Africa and Latin America, vol. 15, (1984), Table 9, p. 38.

[31]Surapong Chirarattananon, "Analysis of Rural Energy Development in Thailand," in M. Nurul Islam, Richard Morse, and M. Hadi Soesastro (eds), Rural Energy to Meet Development Needs: Asian Village Approaches (Boulder: Westview Press, 1984), Table 1, p. 172; Tables 13-18, pp. 191-196; Appendices 2-6, pp. 228-237, presents data from which calculations were made.

[32]Planning Service, Ministry of Energy, The Philippines, "Philippine Energy Resource and Consumption Survey," in M. Nurul Islam, Richard Morse, and M. Hadi Soesastro (eds), Rural Energy to Meet Development Needs: Asian Village Approaches (Boulder: Westview Press, 1984), pp. 135-168.

[33]Jones (1985), Table 53, p. IV-10; Table 54, p. IV-12.

be difficult, if not impossible. Consequently, the quantitative estimates of energy consumption associated with particular components of agricultural development and the problems anticipated in meeting those increased demands will be assessed at the micro level.

3.2 ENERGY USE IMPLICATIONS OF THE COMPONENTS OF AGRICULTURAL MODERNIZATION

This section roughly parallels Section 2.1, which identified the major components of on-farm agricultural modernization, but reaches beyond the farm to include off-farm transport mechanization and the production of modern farm inputs such as fertilizers. The benefits of agricultural mechanization and the introduction of HYV seeds are widely documented, and that evidence will not be repeated here.[34] This section will focus on the energy implications of agricultural development--direct energy consumption requirements and associated problems.

3.2.1 Mechanization

Small power equipment such as tractors and power tillers consume between one-third and three-quarters of a liter of gasoline or diesel per hour, a reliable average figure being one-half liter per hour.[35] Taking the average figure, wide variations can be expected with the same machine, depending upon soil and crop conditions, Garg et al. found a range from 0.46 liters per hour to 0.65 liters per hour attributable to such variations.[36] Table 2 presents information on 1975 energy use, in liters of diesel equivalents per hectare, for mechanized agriculture, by operation, in specific regions of four countries in South and Southeast Asia -- Thailand, the Philippines, Sri Lanka, and Bangladesh. The operations include postharvest activities such as chipping and drying for cassava in Thailand and milling and parboiling of rice in the other three countries. The total energy use varies from 183 liters per hectare for cassava in Thailand to 310 for dry-season rice in the Philippines, and energy in rice production ranges from 267 and 286 liters per hectare in Bangladesh and Sri Lanka to 310 in the Philippines. The energy content of the fertilizer used in all the rice production cases accounts for half or more of the energy inputs in that crop. The transport costs are quite specific to the haulage distances involved from fields to mills and

---

[34]Jones (1985), Table 53, p. IV-10; Table 54, p. IV-12.

[35]For example, see I. K. Garg, V. K. Sharma, and Santokh Singh, "A Power Tiller-Mounted Vertical Conveyor Reaper-Windrower," Agricultural Mechanization in Asia, Africa and Latin American, vol. 15, (1984), pp. 40-44; and Javed Hamid, "Agricultural Mechanization; A Case for Fractional Technology," in Tan Bock Thiam and Shao-er Ong (eds), Readings in Asian Farm Management (Singapore: University of Singapore Press, 1979), pp. 199-219.

[36]Garg et al. (1984), p. 43.

Table 2. Energy use in mechanized agriculture, South and Southeast Asian countries, 1975 (in liters of diesel equivalents)

Cassava Production, Northeast Thailand[a]		Dry-Season Rice Production Central Luzon, Philippines[e]		Rice Production, North Central Sri Lanka[f]		Dry-Season Dinajour District, Northwest Bangladesh	
Operation	liters/ha	Operation	liters/ha	Operation	liters/ha	Operation	liters/ha
Land clearing[b] (including initial plowing)	6.17	Tillage	21.04	Tillage[g]	36.55	Pumping	103.00
Plowing	18.14	Fertilizer	192.02	Fertilizer	145.00	Tillage	0.00
Planting[c]	0.00	Cultural	0.00	Planting, weeding and harvesting	0.00	Seeding/transplanting	0.00
Hoeing[c]	0.00	Harvesting and threshing	6.17	Threshing	8.60	Weeding	0.00
Harvest[c]	0.00	Transport	3.27	Winnowing	16.64	Harvesting and threshing	0.00
Hauling roots	15.14	Drying	67.31	Paddy haulage[g] (farm)	0.93	Fuel hauling	0.00
Chipping & drying	2.15	Milling	30.85	Paddy haulage[g] (market)	3.46	Fertilizer	129.00
Hauling chips	0.93	Market transport	19.73	Parboiling	0.00	Transporting paddy[j]	0.00
Pelleting	86.38	Total	310.39	Milling	41.60	Parboiling paddy[j]	0.00
Hauling pellets[d]	54.22			Rice haulage[h]	33.47	Milling	35.00
Total	183.13			Total	286.25	Totals	267.00
				Water lifting[i]	516.06		
				Water application[i]	0.00		

Table 2. Energy use in mechanized agriculture, South and Southeast Asian countries, 1975 (in liters of diesel equivalents) (continued)

Source: William J. Chancellor, "The Role of Fuel and Electrical Energy in Increasing Production from Traditionally Based Agriculture," Transactions of the ASAE 21(1978), Table 1, p. 1061; Table 2, p. 1062; Table 3 p. 1063; Table 4, p. 1064.

[a]The average yield obtained was 6.10 short tons of root per acre (13,690 kg/ha) which is equivalent to 2.70 short tons (6059 kg/ha) of dry chip or 2.41 short tons (5407 kg/ha) of pellet. Farmers received an average price of $24.63 per short ton of root ($0.027 per kg) and chippers received $78.37 per short ton ($0.096 per kg) of chips. An approximate value of the pellets was $106 per short ton ($0.115 per kg). The equivalent energy content of the pellets from one acre is 171.43 U.S. gal. of diesel fuel (1603 L/ha). No fertilizer was used.

[b]Values shown are one tenth of the total for land clearing, representing distribution of this initial requirement on an annual basis.

[c]No fuel is used, labor only.

[d]The equivalent energy cost for transport of the pellets from Bangkok to Western Europe @ 8000 miles (12,800 km and 700 Btu/short ton-mile (508,000 joules per tonne-km) (Hirst, 1973) is 79.6 U.S. gallons of diesel fuel per acre (744 L/ha). This amount is not shown in the table.

[e]For farmers using tractor tillage, threshing, winnowing, and haulage.

[f]For farmers using tractor tillage, threshing machines, and motorized transport.

[g]Assuming that half of the land is serviced by 2-wheel tractors and the remaining half by 4-wheel units.

[h]Assumed that 60% of the rice produced is not used in the immediate area and is transported to Colombo.

[i]Based on an assumed growing season of 100 days for crops in upland areas.

[j]Computed on the basis (as reported by rice millers) that 25% of the rice received is parboiled at home and carried to the mill manually, while 75% is carried by bullock cart and parboiled at the mill in large batches. Rice husk is the fuel usually used for parboiling.

from mills to markets. Labor inputs are not shown in the table, but generally vary inversely with the energy inputs per hectare, with Bangladesh being an exception in having the highest labor hours per hectare.[37]

The fuel cost component of mechanized farming is not large. Wattanutchariya finds fuel and oil cost shares of tractor operation in selected areas of Thailand in 1979 between 27% and 34%, with an average of 30%.[38] Hamid, omitting driver costs, arrived at a fuel and oil cost share figure of 45% in West Pakistan in 1968-9.[39] When labor, land, seed, fertilizer, and other variable input costs are considered as well, fuel cost shares in farming shrink considerably below their shares in equipment operation costs only.

Prediction of the quantity of fuel that would be required for the mechanization components of agricultural development, for any given country, would be a complicated task. First, as noted in Chapter 2, the mechanization of particular operations, even dividing such operations into only the two categories of power-intensive and control-intensive, appears to be heavily influenced by local factor price conditions. There is ample evidence of substitutability among inputs as factor prices vary. So, not only will rates of mechanization of various types vary, but there will be some scope for fuel use substitution as, for example, tractors are used for different activities depending upon local prices. For example, in mainland China in the mid-1970s, and possibly later, most tractors were observed to be used as road transport vehicles because bullocks were a better substitute for labor in fields than they were for mechanically powered vehicles in long-distance transportation.[40] Second, the effectiveness of given quantities of direct inputs into farming appears to be modified by the level of infrastructural support of various types.[41] An example is offered by a study of power tiller owners in two districts in Bangladesh (Mymensingh District and Munshigonj Thana of Dacca District) between 1976 and 1980. Twenty-two percent of all owners reported "unavailability of pure diesel" as a major problem in tiller

---

[37]William J. Chancellor, "The Role of Fuel and Electarical Energy in Increasing Production from Traditionally Based Agriculture," Transactions of the ASAE, vol. 21 (1978), pp. 1060-1067.

[38]S. Wattanutchariya, "Economic Analysis of the Farm Machinery Industry and Tractor Contractor Business in Thailand," in International Rice Research Institute and Agricultural Development Council, Consequences of Small-Farm Mechanization (Manila: International Rice Research Institute, 1983), Table 9, p. 48.

[39]Hamid (1979), Table 14.6, p. 215.

[40]C. Peter Timmer, "Food Policy in China," Food Research Institute Studies, vol. 15, No. 1 (1976), p. 59.

[41]Antle (1983).

use; the same number cited high fuel prices as a major problem, and 86% named "unavailability of spare parts" as a prime problem.[42] Third, local terrain, soil, and climatic conditions interact with local factor prices in farmers' choices of technological input mixes. For instance, minimal tillage practices are more or less useful depending upon soil and rainfall conditions, and depth of tillage affects fuel use in plowing. Considering the range of phenomena which affects mechanization choices and the subsequent fuel use, simple projections of increased energy consumption resulting from increases in agricultural mechanization cannot be made. Additionally, very little attention has been given to energy as an input to agricultural production in production-function studies for developing countries. The use of energy as an input in such studies could offer informed guidance to rough projections.

Mechanization of on-farm post-harvest activities can be separated from mechanization of field operations, but adoption of equipment such as rice hullers, threshers and dryers will still be subject to the influence of local factor prices. Two major incentives for employment of these pieces of equipment are to reduce crop losses and to increase the availability of labor to other activities.[43] However, Ahmed notes opposing views on the extent of postharvest losses in Bangladesh. Threshing and hulling equipment exist, and they improve labor productivity over traditional methods but still some (e.g. pedal threshers) use human power inputs. Small dryers can use a variety of power sources, including solar and commercial energy sources. Ahmed cites a fuel cost for a small-scale dryer in Bangladesh of $3.20 per ton of rice, but the only base for comparison of this operating cost is survey evidence showing an average value of loss due to constraints on drying of $25.70 per ton.[44] Compared to traditional local drying methods, this small-scale dryer cost is too high to be used by individual small farmers. Ahmed also notes availability of fuel as a constraint on farmers' demand for the small dryers.

Mechanization of off-farm post-harvest activities is deferred to the section below on agricultural processing, but transportation of farm products to markets will be discussed here since it can more directly

---

[42]M. A. Jabbar, M. S. R. Bhuiyan, and A. K. M. Bari, "Causes and Consequences of Power Tiller Utilization in Two Areas of Bangladesh," in International Rice Research Institute and Agricultural Development Council, Consequences of Small-Farm Mechanization (Manila: International Rice Research Institute, 1983), Table 6, p. 77.

[43]On Bangladesh, see J. U. Ahmed, "Labor Use Patterns and Mechanization of Rice Postharvest Processing in Bangladesh," in International Rice Research Institute and Agricultural Development Council, Consequences of Small-Farm Mechanization, (Manila: International Rice Research Institute, 1983), pp. 139-149; and Anthony et al. (1979), pp. 61-62, 296 on tropical Africa.

[44]Ahmed (1983), pp. 144-145.

affect farm operations. The example of Chinese farm tractor use for long distance agricultural prime movers merges on-farm mechanization with off-farm mechanization. Substitution of mechanically powered prime movers for bullocks and humans in commodity transport is heavily dependent on the existence of bitumined roads (especially in Asia; much less the case in Africa). Haswell estimates that the maximum distance maize could be transported profitably by a truck over a dirt road (passable no more than five months of the year in a dry season) is 8 kilometers.[45] Fuel consumption in motorized movers is dependent upon such widely diverse factors as road conditions, vehicle maintenance, load, and driver practices. No information was found on the fuel requirements for ton-miles of crops moved, but McGranahan et al. estimate the energy consumption involved in delivering food to urban markets in Kenya to be an additional 9.5% to 12% of the total embodied energy in food.[46] McGranahan and Taylor estimated the energy consumption in processing and transporting food to Mexico City as 50% of the embodied energy in the food.[47] Twelve percent of Kenya's population was urban in 1978, and some 65% of Mexico's was urban in 1976. These numbers can be interpreted to mean that, as agricultural mechanization releases rural labor to cities, the increase in mechanized transportation energy demands associated with delivering new urban residents' food may be as much as 10% of the energy required, indirectly as well as directly, to produce the food. As food production becomes more energy-intensive with increased farm mechanization, this ratio would probably fall; however, the quantities of energy involved in food transportation would increase.

What can be said in summary regarding the energy implications of increased farm mechanization? First, the actual quantities of energy involved would be quite country-specific, even location-specific. Additionally, the particular operations to be mechanized are determined by local conditions; mechanization is not an all-or-nothing proposition. Second, conditions of energy availability are at least as important as delivered energy prices. Reliability of supply to dispersed farmers is important, but apparently little study has been done on rural liquid fuel delivery systems. Third, spare parts supply and equipment maintenance are important to the energy performance and the overall performance of mechanized agriculture. Fourth, evidence on energy use in on-farm postharvest mechanization is limited but suggests that fueled equipment

---

[45]Margaret R. Haswell, Tropical Farming Economics (London: Longman, 1973), pp. 118-119.

[46]Gordon McGranahan, S. Chubb, R. Nathans, and O. Mbeche. Patterns of Urban household Energy Use in Developing Countries: The Case of Nairobi. mimeo. Institute for Energy Research, SUNY Stony Brook, April 1979, Table E-2, p. 49.

[47]Gordon McGranahan and Manuel Taylor, Urban Energy Use Patterns in Developing Countries: A Preliminary Study of Mexico City. mimeo. W. Averall Harriman College for Urban and Policy Sciences, SUNY Stony Brook, December 1977.

is more likely to be used at centralized sites than in dispersed fashion at the farm level. Fifth, mechanization of off-farm transportation is dependent upon road infrastructure development, but increased on-farm mechanization which releases rural workers to cities will increase the demand for motorized transportation of food crops to cities. A rough estimate of the magnitude of the increased fuel demand is 10% of the embodied energy in the food moved. Finally, mechanization of operations formerly performed by animals may leave farms without their accustomed supplies of animal dung, interrupting their customary fertilizer supplies, domestic fuel supplies, or both. At any event, farm mechanization can be expected to increase commercial fertilizer demand and demand for at least lower-income commercial fuels for household use, such as LPG or kerosene, and possibly for higher-income energy sources such as electricity as well.

3.2.2 Irrigation

Most opportunities for gravity flow irrigation have already been exploited, so most new irrigation will involve pumping. As with farm equipment fuel use, fuel use in pumped irrigation can be calculated rather straightforwardly once engine and pump specifications and pumping heights are known. Also as with farm equipment energy calculations, the straightforward engineering calculations are quickly interrupted by variations in local conditions: (1) depth of water table and its variations (drawdown) over the crop season; (2) additional pumping heights caused by local pipe placement conventions (i.e., unnecessary additions to pumping heights); (3) maintenance on engines and pumps; (4) water losses due to leakages and evaporation; (5) crop choices; and (6) local climate. Most examples of highly profitable, large-scale irrigation schemes are from countries and regions with high population densities -- e.g., Leach cites India, Pakistan, Thailand and the Philippines as worthy examples of successful pump irrigation.[48] However, Pingali and Binswanger cite pumped irrigation schemes as particularly sensitive to local factor prices, particularly land prices and hence population pressure on the land.[49] Output prices, influenced by both world demand and government price policies, will also be important to the success of irrigation schemes.

Tables 3 and 4 present fuel requirements for diesel-powered irrigation pumps in Subsaharan Africa. Comparison of these tables is of interest for several reasons. First, they refer to overlapping regions. Second, both tables' sources specify engine, pump and pumping height specifications, and the specifications are similar. Third, the quantities of water pumped per hectare are specified to be similar.

---

[48]Gerald Leach, "Energy and Agriculture." mimeo. Paper presented at USAID Meeting on Agriculture, Rural Development and Energy, Manila, April 1985, pp. 16-17.

[49]Pingali and Binswanger (1984), p. 13.

Table 3. Irrigation requirements--selected sites along the Senegal River Valley

Crop	Location		
	Podor	Kaedi[a]	Bakel
A. Water Requirements (cubic meters per hectare)			
Hivernage[b] rice	20,000	14,000	8,800
Contra season[c] rice	25,500	23,200	17,800
Mixed crops (rainy season)	9,900	9,900	3,700
Mixed crops (contra season)	15,100	15,100	5,400
B. Fuel Requirements (litres of diesel per hectare per crop)[d]			
Rice hivernage	126	118	113
Rice contra season	315	398	365
Mixed crops (rainy season)	98	36	58
Mixed crops (contra season)	155	138	95
Grain crop[e]	1,000+		

Source: Arthur D. Little, Inc., "Barriers to Expanding Irrigated Agriculture in Subsahara Africa Imposed by Pumping Costs." ADL50058, Cambridge, MA, June 1985, Tables 3.2 and 3.3.

[a]Kaedi is in Mauritania, the other two sites in Senegal.

[b]"Hivernage" refers to main rice crop grown through the rainy season July-November.

[c]"Contra Season" refers to an off-season rice crop typically grown from January to May.

[d]Lifts of 5 to 10 meters assumed.

[e]Based on the use of groundwater at a depth of 60 M on higher ground away from the river.

Fourth, the predicted fuel requirements, although independently derived for similar circumstances, are quite similar. The A. D. Little projections of Table 3 are disaggregated by crop and season and report fuel requirements per hectare per crop, while the Jones and Samuels (1988) calculations in Table 4 project the irrigation fuel requirements against national commercial fuel consumption levels for several countries. The projections of Table 4 are more aggregated than those of Table 3, but the water coverage assumptions of Table 4 correspond to the low end of those of Table 3. Table 4 projects per hectare fuel

Table 4. Pumped irrigation energy requirements in Subsaharan Africa: energy requirements to increase arable land by 5% through irrigation[a]

	Irrigation energy requirements	
	As percent of 1980 energy imports	As percent of 1980 commercial energy consumption
Chad		22.60
Mali		8.13
Mauritania		4.52
Niger		8.50
Somalia	15.86	
Sudan	4.88 0.75[b]	

Source: Donald W. Jones and Garland Samuels Jr., "Energy Requirements of Development Projects." ORNL-6298. Oak Ridge, TN: Oak Ridge National Laboratory, 1988, Table 1, p. 9.

[a]Assumes 560 mm per hectare per year water coverage and 13-m lift.

[b]Requirement to increase currently irrigated area by 5%.

requirements similar to those of Table 3 to the case of using pumped irrigation to extend a country's current arable land by 5%. As noted earlier, the energy requirements can appear substantial, particularly if the country used little commercial fuel in the base year.

Energy cost shares in pumped irrigation are roughly comparable to those in farm equipment use. Leach cites the direct energy cost shares in Philippine surface pump irrigation systems and deepwell systems in 1978 as 41.6% and 34.1% of annualized total costs (including annualized investment cost).[50] Leach also suggests, on the basis of South and Southeast Asian experiences, that irrigation costs are easily recovered by irrigation's contributions to value added, but the A. D. Little report suggests considerable sensitivity of the profitability of crop production to irrigation costs.[51] Again, this may be attributable to population density differences, to government price policies, or both.

[50]Leach (1985), Table 10, p. 17.

[51]See Leach (1985) p. 16; and Arthur D. Little, Inc., Barriers to Expanding Irrigated Agriculture in Subsahara Africa Imposed by Pumping Costs, ADL 50058, Cambridge, Mass., June 1985, pp. 4-11, 4-15.

A final quantitative indicator of the relative magnitude of energy use in irrigation is offered by the Gordian Associates study of Egypt.[52] That report estimated energy consumption in irrigation and associated pumping in 1975 to be 6.8 petajoules, compared to 3.4 petajoules in agricultural equipment operation. However, that report projected irrigation energy use to increase to only 8.2 petajoules by 1985, while agricultural (nonirrigation) equipment fuel use would reach 7.9 petajoules. Projections to 2000 indicate a stable irrigation energy consumption but a tripling of (nonirrigation) equipment fuel consumption.

A major problem with energy use in irrigation is the seasonal peak that crop demands place on energy distribution systems, particularly rural electric systems in the case of electrically powered pumps. This may pose a greater problem than the aggregate quantity of energy used in a nation's farm irrigation, despite some of the significant percentages noted in Table 4. Again, this fits in with the pattern observed in the case of field mechanization, that if sectorally balanced development proceeds, the relative energy consumption of modernized agriculture will be small, and energy problems associated with agricultural development will involve agriculture-specific physical distribution problems. In the case of agricultural systems highly dependent on well-timed water deliveries, relatively minor interruptions of energy distribution could be disastrous.

3.2.3 Commercial Fertilizer Use

Fertilizer production is highly energy intensive. Of the two principal commercial fertilizer types, nitrogenous and phosphatic, nitrogen fertilizers by far require the most energy. Synthesis of ammonia for nitrogen fertilizers is accomplished with a hydrocarbon feedstock of one kind or another -- natural gas, fuel oil, naphtha,-- which considerably raises energy inputs in nitrogen fertilizer production.[53] An additional relevant characteristic of commercial fertilizer production is that there is no substitutability between commercial and traditional energy sources in its manufacture. Typically, developing countries use in the neighborhood of a four-to-one ratio, by nutrient value, of nitrogen fertilizer to phosphates, although Gordian Associates note that Egypt has long employed nitrogen fertilizers in a five-to-one ratio, partly because of peculiar soil conditions.[54]

---

[52]Gordian Associates, Inc., An Assessment of the Energy Requirements and Selected Options Facing Major Consumers Within the Egyptian Industrial and Agricultural Sectors. mimeo. (Washington, May 1978), Table 45, p. 192.

[53]Armeane M. Choksi, Alexander Meeraus, and Ardy J. Stoutjesdijk, The Planning of Investment Programs in the Fertilizer Industry (Baltimore: Johns Hopkins University Press/World Bank, 1980), pp. 17-18.

[54]See Gordian Associates, Inc. (1978), p. 95; and Choksi et al. (1980), Table 1, p. 155.

Egyptian nitrogen fertilizer production in 1978 was estimated to use 25 gigajoules of energy per metric ton of ammonium nitrate produced, 31 gigajoules per ton of urea (nitrogenous fertilizer), and only 5 gigajoules per metric ton of single superphosphate.[55] In the Choksi et al. Table 1, Egypt's fertilizer production was estimated to account for 1.6% of national energy consumption in 1975. Additional energy was contained in imported fertilizers, so import substitution in fertilizers could increase fuel consumption. Imports in the mid-to-late 1970s ran between 20% and 33% for ammonium sulfate and calcium ammonium nitrate and 46% for urea.[56]

Production energy requirements figures are unavailable for Bangladesh, but from the Choksi et al. Table 1 also, 6.9% of its 1974 national commercial energy consumption was devoted to fertilizer production, over four times the share in Egypt. These share differences are to be explained partly by the differences in the extensiveness of commercial energy use in the two countries: Bangladesh consumed 33.4 tons of oil equivalent (TOE) per 1000 people in 1980, compared with 409.0 in Egypt. Per million U.S. dollars of GDP, Bangladesh consumed 265.3 TOE, while Egypt consumed 714.5.[57] But regardless of the accounting for Bangladesh's share of commercial energy used in fertilizer production, 6.9% must be considered a large share of consumption from the national perspective.

Transportation of feedstocks and of manufactured outputs are important considerations in commercial fertilizer production. Choksi et al. cite transportation costs in the range of 4.5% to 15.5% of f.o.b. plant prices for nitrogen fertilizers and 15.5% to 16.5% for phosphates in Egypt, the differences being accounted for by the higher factory prices of the nitrogenous fertilizers.[58] Over 90% of fertilizer transport in Egypt in the early 1970s was conducted by higher unit-fuel-cost truck rather than by train or river because of higher speeds of delivery, greater safety, and the ability to avoid terminal transfer costs necessary with the other modes.[59] With this characteristic of product delivery, there is incentive to locate factories close to demand areas, but transportation costs for feedstocks and the existence of economies of scale in fertilizer production limit the dispersal of

---

[55]See Gordian Associates, Inc. (1978), Table 22, p. 111.

[56]Choksi et al. (1980), p. 179. Ammonium nitrate is 33.5% nitrogen while urea is 46% nitrogen, so urea actually used less energy per unit of nitrogen.

[57]World Bank, The Energy Transition in Developing Countries (Washington: World Bank, 1983a), Table 2, p. 97.

[58]Choksi et al. (1980), Table 10, p. 174.

[59]Choksi et al. (1980), pp. 171-172.

production.[60] Thus, there are limited possibilities to reduce transport energy consumption associated with commercial fertilizer production and use by choice of production locations.

Energy price increases affect both chemical nutrient prices and fuel prices for farm equipment. In the short-term, farmers can substitute back to animal and even human labor when fuel prices rise, but there is very little ability to substitute away from the chemical nutrients once the agricultural system has incorporated them.[61]

3.2.4 High Yield Variety Seed Use

The use of HYVs usually is accompanied by irrigation, although the reverse sequence is not particularly the case. Also, HYVs respond well to commercial fertilizer applications and generally require pesticide and insecticide application. The use of HYVs, commercial fertilizers, and irrigation often are considered to be a "package" technological innovation. Intuition suggests that the higher yields would increase harvest labor demands (and replanting labor demands for rice), thus encouraging mechanization of at least harvest operations, but this has not been confirmed in empirical studies.[62] Hybrid HYVs are, of course, sterile, so seeds cannot be saved back from crops and must be purchased instead, requiring energy use in delivery.

3.2.5. Infrastructural Development

The major elements of agricultural infrastructure noted above have a number of energy-related aspects. Most obvious is that the development of transportation infrastructure -- all-weather roads, bridges, railroads -- will lead to the use of more energy. The point is not, of course, to avoid using energy, but to apply energy inputs in methods that will have high payoffs. The development of transport infrastructure in rural areas is a sine qua non for the development of agriculture. The bulk of investment in rural transportation is aimed at motorized transport, but improved roads reduce even bullock transport costs and improve the delivery of inputs and the marketability of crops.

Agricultural research can reduce water, fertilizer, and pesticide requirements of local crops, thus reducing the energy requirements associated with those inputs. There is some question, however, regarding the tradeoffs between greater nitrogen fixing ability of plants and their

---

[60]Choksi et al. (1980), p. 4.

[61]Richard H. Day and Inderjit Singh, Economic Development as an Adaptive Process; The Green Revolution in the Indian Punjab (Cambridge: Cambridge University Press, 1977), pp. 181-185. However, farmers may be able to rotate a nitrogen-fixing crop with a traditional crop and provide much of the required nitrogen.

[62]Ruttan and Binswanger (1978), pp 361-362.

ability to grow biomass. But when nitrogen cannot be afforded by farmers, the economics of the tradeoff favors the development of varieties which can improve nitrogen fixation. There may be other indirect methods by which agricultural research efforts can substitute for direct energy inputs in agriculture. Agricultural extension certainly can educate farmers about more efficient equipment and pump operation and maintenance, as well as more efficient fertilizer application, all of which can reduce indirect and direct energy inputs into agriculture.

Countries often enact, and occasionally even enforce, laws governing farm tenure institutions, particularly share renting, with little regard for the services those institutions may be performing. As noted above, sharecropping is widely regarded as a mechanism for achieving flexibility in input markets in the presence of rudimentarily formed or poorly operating markets.[63] Mangahas' study of Philippine sharecropping contract conditions reveals considerable variability in which contracting partner, landlord or tenant, pays for particular input costs.[64] Such variability suggests that the share contract has the flexibility to allow farmers to minimize some of the risks associated with more energy-intensive, mechanized agriculture. A simple recommendation that governments take a hands-off approach to share renting, however, could perpetuate current inequities, but blanket proscriptions could simply cause other problems. Tenure contracting is worth studying for its possibilities of helping smooth energy-related risks in transitional farming systems.

Finally, rural electrification is a major infrastructural investment which can radically transform the economies of rural areas. A major issue in rural electrification is choice between autogeneration and public grid extension. Capital costs of autogeneration are much lower than for grid extension, but the operating costs from grids are lower. Demand density, which is a function of population density and income per capita, is a major factor in the profitability of rural electrification choices. Reliability of power supply from rural electric systems is an important factor in determining potential users' willingness to pay for electric hookups, and availability of trained repair and maintenance personnel is essential. However, Brodman's study of Indonesia indicates that simple informational hiatuses among potential commercial consumers, as well as deficient demand among small businesses, are more serious

---

[63]See M. G. Quibria and Salim Rashib, "The Puzzle of Sharecropping: A Survey of Theories," World Development, vol. 12, No. 2 (1984), pp. 103-114, for a state-of-the-art review of thinking on sharecropping.

[64]Mahar Mangahas, "An Economic Theory of Tenant and Landlord Based on a Philippine Case," in Lloyd G. Reynolds (ed.), Agriculture in Development Theory (New Haven: Yale University Press, 1975), Table 6.5, p. 149.

barriers to the adoption of electricity use than actual poor reliability.[65]

3.3 RURAL INDUSTRIALIZATION

3.3.1 Employment Shares

Agriculture is far from the only activity in the rural areas of developing countries. Anderson and Leiserson show a range of nonagricultural shares of rural employment from 12% in Brazil (1970) to a high of 49% in Taiwan (1966), with an average share somewhere in the mid-20% range.[66] When rural towns are included, nonagricultural rural employment shares increase to the range of 24% to 43%. Processing of primary products typically is one of the earlier manufacturing opportunities for countries in the process of economic development, and because of proximity to raw materials, rural factory locations are often competitive with urban locations. Much rural industry, particularly traditional sector industry, is small, cottage type activity that uses traditional fuels, if any, but the scope for labor productivity improvements through mechanization is substantial.

Between roughly one-quarter and one-third of rural nonfarm activity qualifies as manufacturing, as indicated in Table 5 for ten developing countries. Table 6 presents evidence on the industrial distribution of the activity classified as manufacturing in Table 5. Food processing per se claims about one-fifth of manufacturing, but the textiles and wood groups add an additional 35% to 70% to the total employment shares in primary processing, or agroprocessing, industry. This definition of agroprocessing is used in Table 7, which shows the shares of agroindustry in manufacturing (rural plus urban) in fifteen developing countries over the past thirty years. Agroprocessing's shares have been declining but still dominate manufacturing.

A survey of rural small industry in Kenya identified several energy related problems (30 in woodworking and furniture, 6 sawmills and 1 baking establishment, but no food processing firms).[67] Thirty-nine of 83 firms surveyed used no power, but most expressed a desire for access to regular electrical service. Several had purchased electric-driven equipment in anticipation of East African Power's extension of service to their area, but had been left with unusable equipment for more than

---

[65]Janice Brodman, Rural Electrification and the Commercial Sector in Indonesia, Discussion Paper D-73L (Washington: Resources for the Future, September 1982), pp. 52-53.

[66]Anderson and Leiserson (1980), Table 1, p. 229.

[67]Frank C. Child, "Small-Scale Rural Industry in Kenya," Occasional Paper No. 17 (African Studies Center, University of California at Los Angeles, 1977), Table 2.1, p. 23.

Table 5. Manufacturing shares (%) in rural nonfarm employment, selected countries
(Employment in mining and quarrying is excluded.)

Country	Nigeria (1966)	India (1966-67)	Malaysia (1970)	Indonesia (1971)	Philip-pines (1970)	South Korea (1970)	Taiwan (1966)	Chile (1970)	Columbia (1970)	Brazil (1970)
Manufacturing Share (%)	49.0[a,b]	38.7	15.3[c]	24.7	34.1	30.3	23.0[c]	19.4	33.0	24.1

Source: Dennis Anderson and Mark W. Leiserson, "Rural Nonfarm Employment in Developing Countries," Economic Development and Cultural Change 28, No. 2 (1980), Table A2, p. 245.

[a]Includes construction employment. Rural districts of Ifo, Otto, and Ilaro in the western state.

[b]Excludes rubber processing.

[c]Includes rural towns.

Table 6. Industry distribution of employment in rural manufacturing for selected countries (%)

	Sierra Leone (1974)	India (1961)	West Malaysia (1970)	South Korea (1970)	Taiwan (1966)
Food processing	4.4[a]	20.3	22.2	20.2	16.6
Textiles, wearing apparel, and leather	52.9	39.3	13.7	40.9	26.5
Wood and furniture	19.2	16.0	31.4	4.7	10.6
Metal, machinery, and fabrication	20.7	17.5	13.8	5.9	16.2
Other	2.9	6.9	18.9	28.3	30.1
Total	100.0	100.0	100.0	100.0	100.0

Source: Dennis Anderson and Mark W. Leiserson, "Rural Nonfarm Employment in Developing Countries," Economics Development and Cultural Change 28, No. 2 (1980), Table A3, p. 246.

[a]Baking only.

two years. About half of he complaints regarding machinery focused on alack of power. However, most frequently mentioned of all complaints were about transportation, either poor roads or lack of access to carriers.[68] These complaints are reminiscent of the complaints among farmers about insecurity of access to fuel and spare parts for equipment.

3.3.2 Energy Use in Agroprocessing Industries

This section presents quantitative evidence, such as it is, on fuel use in particular rural agroprocessing industries in developing countries. The estimates are generally plant-specific, but occasionally additional information is available with which to derive some macroeconomic implications regarding energy use.

[68]Child (1977), pp. 32-33.

Table 7. Shares of agroindustry in manufacturing sectors in selected developing countries

Country	Agroindustry shares (percents)	Country	Agroindustry shares (percents)
LATIN AMERICA		ASIA (continued)	
Brazil		Philippines	
1949	66.1	1956	74.5
1969	41.6	1968-70	62.7
Colombia		South Korea	
1953	79.5	1958	67.9
1967-69	63.1	1967-69	55.1
Costa Rica		Taiwan	
1960	71.0	1954	68.8
1973	53.0	1967-69	43.1
Mexico		Thailand	
1950	58.6	1954	76.4
1967-68	51.1	1967-69	65.4
Venezuela		Turkey	
1953	73.5	1950	79.1
1971	51.7	1967-69	53.8
ASIA		AFRICA	
Iran		Kenya	
1963-64	73.3	1954	60.3
1967-68	65.4	1967-69	51.7
Malaysia		Nigeria	
1963	64.6	1950	78.2
1968-69	48.6	1967-68	67.3
Pakistan			
1955	75.1		
1968-70	66.7		

Source: James E. Austin, Agroindustrial Project Analysis (Baltimore: Johns Hopkins University Press/World Bank, 1981), Table 1-2, pp. 9-10, from United Nations Industrial Development organization (UNIDO), Growth of World Industry, vol. 2 (New York, 1973), except data on Costa Rica, from Fernando Caldas, "Consideraciones sobre las agroindustrias en Costa Rica" (UNIDO, August 1976; processed).

Table 8 offers estimates of energy requirements in ten rural activities, mostly but not exclusively in agroprocessing, in Thailand. They are developed from survey results generated by the 1980 Thai rural energy survey.[69] In rice milling, two processes are identified, small diesel mills and large mills using rice husks. The diesel mills are substantially more energy efficient, but the rice husks are free, permitting the larger mills to compete economically. Alternative fuels are also identified in brick and pottery making. The use of rice husks is more energy efficient than firewood in both cases, but insufficient information is presented to account for the differences. Chirarathananon cites 92 million liters of diesel used in cassava chipping and pelletizing in 1980, and 34.81 million liters of fuel oil in cassava flour milling.[70] These represent 4.10% and 1.64% of 1980 industrial oil use in Thailand.[71]

Plant specific survey evidence is available from Kenya on energy use in food processing (no further specification is offered on the type of processing) and in a creamery.[72] In Table 9, information from several years is available for both plants and indicates a generally downward trend in energy use per unit of output, with the exception of electricity use in the creamery. Whether the creamery's decrease in fuel use and increase in electricity use is a simple substitution cannot be assessed. In both cases, the operations are clearly in the modern sector, the food processing plant being owned by an international company, and the creamery being described as "modern." Schipper et al. estimate that food processing accounted for 28% of industrial electricity consumption in 1979, or 13.2% of total electricity consumption, and 20.5% of industrial fuel consumption, or 18.7% of industrial plus commercial fuel.[73] Fuel consumption in textile production was roughly half of that in food processing.

---

[69]As reported by Chirapathananon (1984).

[70]Chirarathananon (1984), Table 44, p. 223.

[71]See International Energy Agency, Energy Balances of Developing Countries 1971/82, (Paris: OECD, 1984), p. 287, for 1980 Thai energy balance.

[72]Lee Schipper, Jack Hollander, Matthew Milukas, Joseph Alcomo, and Stephen Meyers, with Scott A. Noll, Joy Dunkerley, and John E. Jankowski, Energy Conservation in Kenya's Modern Sector: Progress, Potential and Problems, Discussion Paper 73I (Washington: Resources for the Future, May 1982).

[73]Schipper et al. (1982), Table 3-2, p. 26; Table C-2, p. 87.

Table 8. Energy requirements in selected rural industries, Thailand, 1980*
(1000 Btu per metric ton of output)

Activity	Product	Fuel Type					
		Diesel	Fuel oil	Electricity	Firewood	Rice Husks	Sawdu r
Charcoal making	Charcoal				69,232[a]		
Rice milling, small mills	Milled rice	677					
Rice milling, large mills	Milled rice					3,120	
Cassava milling (chipping & pelletizing)	Pellets	52					
Cassava milling	Flour		2,327	725			
Ice making	Ice			311			
Brick making	Bricks				20,117		
Brick making	Bricks					7,359	
Pottery making	Ceramic				27,854		
Pottery making	Ceramic					18,839	
Salt production[b]	Salt						41,781
Rubber drying	Rubber crumb					13,927	

Note: I thank Garland Samuels for checking the calculations of these figures and for making some corrections. Remaining deficiencies in the table are mine.

Source: Surapong Chirarathananon, "Analysis of Rural Energy Development in Thailand," in M. Nurul Islam, Richard Morse, and M. Hadi Soesastro (eds.), Rural Energy to Meet Development Needs: Asian Village Approaches. Boulder: Westview, 1984, pp. 169-240; pp. 220-224; Appendix 1, p. 227.

[a]Uses rice husks equalling as much as 50%, by weight, of the initial fuelwood. Overall efficiency of conversion is 28.4%.

[b]Excludes electricity used in pumping water.

Table 9. Energy use in agroindustry plants, Kenya, 1972-1980

Line of production	Year	Fuel Use in 1000 Btu per unit of output: Electricity	Fuel (diesel and fuel oil)	Firewood[a]	Output unit
1. Food Processing, large plant, international company	1975-78	335	5958	0	Ton
	1976-77	249	4326	0	Ton
	1977-78	184	4250	0	Ton
	1978-79	171	4146	0	Ton
	1979-80	167	4725	0	Ton
2. Creamery, modern	1972	163	1841	66	1000 liters
	1975	175	1518	218	1000 liters
	1977	292	1385	0	1000 liters
	1979[b]	331	1404	0	1000 liters

Source: Lee Schipper et al., Energy Conservation in Kenya's Modern Sector: Progress, Potential and Problems. Discussion Paper D-73I, Resources for the Future, Washington, May 1982. Table 4-1, p. 47; pp. 114-115.

[a]Thermal content uncertain; assumed to be 6 GJ/m^3.

[b]"Data for the last part of 1979 are uncertain" (p. 115).

Bajracharya offers some numerical estimates of fuel use in a biogas rice mill in Nepal.[74] His estimates are engineering projections that were used in calculating the profitability of the project as an investment. The mill was subsequently put into operation and appeared to have operated satisfactorily close to the projections. The pre-operation projections are contained in Table 10. The mill was to produce three outputs, but the energy requirements for the plant were not disaggregated among the three processes. So the fuel use requirements are reported per unit of revenue rather than on a quantity-of-output basis as in the other energy requirements tables. One problem that arose in operation was that insufficient cattle dung was available to operate the plant at the intended fuel ratio of 80% biogas (derived from the dung) and 20% diesel. No information is available to extrapolate this single mill's fuel use to the national level.

[74]Deepak Bajracharya, "Organizing for Energy Need Assessment and Innovation: Action Research in Nepal," in M. Nurul islam, Richard Morse, and M. Hadi Soesastro (eds.), Rural Energy to Meet Development Needs: Asian Village Approaches, (Boulder: Westview Press, 1984), pp. 279-336.

Table 11 reports fuel use in a modern soybean processing plant in Haiti, for the calender year 1984. The requirements of 1721 BTU per metric ton of processed soybeans cannot be extrapolated to assess macroeconomic impacts of general expansion in the agroprocessing area.

Table 10. Projected energy use in biogas rice mill, Nepal, 1982[a]

Activities	Fuel use, in 1000 Btu per US $ of revenue		Revenue source mix, by weight (unhusked rice input, grain ground: oilseed extracted)
	Diesel	Biogas[b]	
Dehusking, grinding, and oil expelling	5.79	23.18	10.42: 6.86: 1.00

Source: Deepak Bajracharya, "Organizing for Energy Need Assessment and Innovation: Action research in Nepal," in Islam et al., (1984), pp. 291, 295, 305-306.

[a]Figures are project planning estimates; mill was subsequently built and was in operation at the time of writing.

[b]Assuming fuel ratio of 80% biogas: 20% diesel; 300 kg of fresh cattle dung per day required to maintain the 80% ratio. In actual operation, insufficient dung was available to sustain the 80% biogas ratio; milling rates were increased to cover increased diesel usage.

Table 11. Energy use in soybean processing, Haiti, 1984

Plant size	Product	Fuel Use in 1000 Btu per output unit[a]			Output unit
		Bunker C	Diesel	Total	
Capacity: 10,000 metric tons/month	Processed soybeans 2% to 3% of throughput as soybean hulls	1251	470	1721	Metric ton of processed soybean

Source: Garland Samuels, Jr., Oak Ridge National Laboratory, field survey, May 1985.

[a]Fuel use at full capacity output.

Kayira estimates coal consumption in Malawian tea drying at 5.3% of national coal consumption in 1982.[75] No other African country reported coal use in its tea industry, but Kayira reports fuel oil use in Kenya and Sri Lanka at 45.4 and 32.2 liters per 100 kg of product respectively. He notes that fuel oil consumption in the tea industry is generally negligible on a national scale.

A problem common to rural agroprocessing mills in many developing countries is low capacity utilization. Harriss notes that custom rice milling plants in rural Bangladesh averaged only 19% of engineering capacity in 1978, although she translates this to a 56% economic capacity.[76] This appears to be a decline in capacity utilization in Bangladesh since 1968. In South India, she found average engineering capacity utilization of rice huller mills to be only 14% and average economic capacity 40%.[77] Anthony et al. note similar problems encountered in Ghana and Nigeria in the 1960s.[78] Operational efficiency, including efficiency of energy use, is much lower, and fixed costs of plant are much higher, at these low capacity utilization rates.

Some interesting and relevant information on energy use in the food processing industry comes from a developed country, Canada. Lopez estimated a translog profit function for the Canadian food processing industry's 1979 operations and found that energy prices exert a strong negative influence on output that increases with time.[79] Short-, intermediate-, and long-run supply elasticities 3 with respect to energy price increases were -0.09, -0.27, and -0.45. Energy and labor were complements in the short-run but were substitutes in the intermediate- and long-runs. A finding relevant to the capacity utilization problem faced by agroprocessing in developing countries is Lopez's finding that energy and raw food inputs appear to be substitutes, i.e., more energy in processing can substitute for less raw food and vice versa.

---

[75]Gladson K. Kayira, "The Scope for Energy Conservation in the Tea Industry." mimeo. Energy Department, World Bank, Washington, November 1984, Table 5.3, p. 17; Table 5.1, p. 12; pp. 15-16.

[76]Barbara Harriss, "Post Harvest Rice Processing Systems in Rural Bangladesh: Technology, Economics and Employment," Bangladesh Journal of Agricultural Economics, vol. 2 (1979), p. 39.

[77]Barbara Harriss, Piecemeal Planning in Rice Markets, (Norwich, UK: Overseas Development Group, University of East Anglia, 1977), p. 284.

[78]Anthony et al. (1979), p. 66.

[79]Ramon E. Lopez, "Supply Response and Investment in the Canadian Food Processing Industry," American Journal of Agricultural Economics, vol. 67, (1985), pp. 40-48.

3.4 HOUSEHOLD ENERGY USE

Income increases are a principal aim of rural development, and of economic development in general. Income elasticities of demand for energy in general are in the neighborhood of one-half to unity in rural areas and possibly higher for commercial fuels.[80] Income elasticities of demand are somewhat higher in urban areas than in rural areas, and the shares of commercial fuels are almost always higher in urban areas than rural. Income elasticities of energy demand are relevant to the energy implications of rural development inasmuch as rural development can be expected to send populations to the cities.[81] Thus, as incomes increase with successful rural development, energy consumption can be expected to increase in a roughly parallel fashion.

---

[80]Judith C. Fernandez, Household Energy Use in Non-OPEC Developing Countries, (Santa Monica, CA: Rand, May 1980), pp. 35, 61, 65.

[81]Of course, rural development may also be prodded along by the outflow of rural labor to more attractive opportunities in cities. Unidirectional casualty is not implied.

4. SUMMARY

This study has attempted to identify and, where possible, document the energy implications of the modernization of the rural sectors of developing countries. Agriculture's share of national energy use is small in both developing and developed countries. In developing countries, where agriculture accounts for much larger shares of both the labor force and national income, the mechanization of agriculture and supporting activities is not extensive and fuel use is not high. Traditionally in developing countries, agricultural fuel use is almost nonexistent. As a nation develops and its agricultural sector develops and mechanizes, other sectors grow at relatively more rapid rates, taking labor out of agriculture and reducing agriculture's share of national income. Consequently more developed and mechanized agricultural sectors appear to claim roughly the same or even smaller shares of national energy consumption.

Farm mechanization, irrigation, commercial fertilizer use, and the introduction of high yielding variety seeds are the major elements of farm modernization which may be expected to increase fuel use. However, the actual quantities of energy used in each of these activities are quite country- and even location-specific. Fuel cost shares of farm equipment operation have been estimated to range between 25% and 45% of total equipment operation cost. These fuel cost share estimates are only for equipment operation; that is, they are not shares of total farming cost, which includes payments for labor, land, seed, etc. The availability of fuel and spare parts and the maintenance on equipment appear to be as important to successful mechanization as are low fuel prices. Evidence on energy use in on-farm, postharvest mechanization is limited but suggests that fueled equipment is more likely to be used at centralized sites than in dispersed fashion at the farm level. Farm mechanization is highly dependent on road infrastructure development. A phenomenon related to agricultural mechanization is the release of former farm residents to urban locations, where they require delivery of their food. A rough estimate of the magnitude of the associated increased fuel demand is 10% of the embodied energy in the food moved. Mechanization can leave farms without animal dung for either fertilizer, household fuel, or both.

Large-scale irrigation appears to have been most successful in areas of high population density rather than simply where water is scarce. Most opportunities for gravity flow irrigation and natural flooding appear to have been taken already, so most additions to irrigated acreage will rely on pumping. Irrigation water and fuel requirements are highly dependent upon climatic regime, crop selections, and maintenance of water delivery infrastructure. Additionally, pump operation and maintenance practices can cause twofold variations in fuel use for a given quantity of water pumped. Fuel cost shares in pumped irrigation are roughly similar to those for equipment operation.

Commercial fertilizer production is highly energy intensive, particularly the production of nitrogen fertilizers, which are in heavy

demand in tropical regions. Transportation of both feedstocks and outputs are important considerations in the location of fertilizer plants. In Egypt, costs of transporting locally-produced fertilizers to local distribution points amounts to 4.5% to 16.5%, so energy use in transport is significant relative to feedstock and production energy costs.

Farm modernization must be supported by a wide array of agricultural and rural infrastructural development: agricultural research and extension, agricultural marketing, credit systems, legal systems dealing with farm tenure and land alienation, rural electrification, and of course, transportation infrastructure. Some of these infrastructural elements deliver energy, some require energy to construct and operate, some affect how securely energy can be delivered. Quantification of fuel magnitudes associated with them is impossible, but their interactions with rural energy delivery and utilization systems warrant careful attention.

Agriculture accounts for only between 50% and 75% of the rural labor forces of most developing countries, the remainder being largely accounted for by rural manufacturing and services. Rural manufacturing accounts for 25% to 50% of rural nonfarm labor, and agricultural processing--including textile and wood activities--can account for a large share of these. Nationally, agricultural processing may account for roughly half of all manufacturing employment, although rural-urban assignment of these shares is difficult. some survey information is available on energy use in rural agricultural processing, but little extrapolation to microeconomic implications can be made from them. In one exception to this rule of thumb, survey evidence from Kenya for 1979 indicated that food processing accounted for 28% of industrial electricity consumption and 20.5% of industrial fuel consumption--or 13.2% of total electricity consumption and 18.7% of industrial and commercial fuel consumption. Textile production in Kenya in the same year consumed roughly half what the food processing industry did. No rural-urban disaggregations can be made on these consumption shares, however. In another exception, cassava chipping and pelletizing apparently used 4.1% of Thailand's industrial oil consumption in 1980, and cassava flour milling used an additional 1.64%.

Thus, despite the optimistically small energy shares of agriculture at both "beginning" and "end" points of rural development, rural energy use appears to involve many transitional problems as well as benefits. As development proceeds, many activities other than agriculture often benefit from using modern energy. As rural development is more inclusive than agricultural development, rural energy use will be greater than agricultural energy use and will involve a wider array of problems. Second, there is no reason to suspect that development will proceed evenly across all sectors of an economy. Therefore, the introduction of modern-energy-using activities in rural areas can imply relatively large increments in energy use and, often, problematic foreign exchange bills. Third, the micro-level problems associated with the introduction of modern-energy-using activities or technologies in rural areas of

developing countries, such as increased risks, maintenance, and learning the efficient use of new technologies, can themselves be difficult to solve, although when they are solved they can look small and inconsequential from a retrospective macro-economic vista.

REFERENCES

Adams, John, and Balu Bumb. "Determinants of Agricultural Productivity in Rajasthan, India: The Impact of Inputs, Technology, and Context on Land Productivity," Economic Development and Cultural Change 27, No. 4, pp 705-722.

Adams, Martin E., and John Howell. "Developing the Traditional Sector in the Sudan," Economic Development and Cultural Change 27, No. 3 (1979), pp 505-518.

Adelman, Irma. "Beyond Export-Led Growth," World Development 12, No. 9 (1984), pp 937-949.

Ahmed, J. U. "Labor Use Patterns and Mechanization of Rice Postharvest Processing in Bangladesh." In International Rice Research Institute and Agricultural Development Council, Consequences of Small-Farm Mechanization, pp 139-149. Manila: International Rice Research Institute, 1983.

Anderson, Dennis, and Mark W. Leiserson. "Rural Nonfarm Employment in Developing Countries," Economic Development and Cultural Change 28, No. 2 (1980), pp 227-248.

Anthony, Kenneth R. M., Bruce F. Johnston, William O. Jones, and Victor C. Uchendu. Agricultural Change in Tropical Africa. Ithaca: Cornell University Press, 1979.

Antle, John M. "Infrastructure and Aggregate Agricultural Productivity: International Evidence," Economic Development and Cultural Change 31, No. 3 (1983), pp 609-619.

Antle, John M. "Human Capital, Infrastructure, and the Productivity of Indian Rice Farmers," Journal of Development Economics 14, No. 1-2 (1984), pp 163-181.

Arthur D. Little, Inc. "Barriers to Expanding Irrigated Agriculture in Subsahara Africa Imposed by Pumping Costs." ADL 50058. Cambridge, Ma., June 1985.

Austin, James E. Agroindustrial Project Analysis. Baltimore: Johns Hopkins University Press/World Bank, 1981.

Binswanger, Hans P., Vernon W. Ruttan, and others. Induced Innovation: Technology, Institutions, and Development. Baltimore: Johns Hopkins University Press, 1978.

Bajracharya, Deepak. "Organizing for Energy Need Assessment and Innovation: Action Research in Nepal." In M. Nurul Islam, Richard Morse, and M. Hadi Soesastro (eds). Rural Energy to Meet Development Needs: Asian Village Approaches, pp 279-336. Boulder: Westview Press, 1984.

Bodine, J. Frank, and Marshall Vitullo (coordinators). Industrial Energy Use Data Base. Oak Ridge: Oak Ridge Associated Universityies, 1980.

Brodman, Janice. Rural Electrification and the Commercial Sector in Indonesia. Discussion Paper D-73L. Washington: Resources for the Future, September 1982.

Chancellor, William J. "The Role of Fuel and Electarical Energy in Increasing Production from Traditionally Based Agriculture," Transactions of the ASAE 21 (1978), pp 1060-1067.

Chao, Kang, with the assistance of Jessica C. Y. Chao. The Development of Cotton Textile Production in China. Cambridge: East Asian Research Center, Harvard University, 1977.

Child, Frank C. Small-Scale Rural Industry in Kenya. Occasional Paper No. 17, African Studies Center, University of California at Los Angeles, 1977.

Chinn, Dennis L. "Rural Poverty and the Structure of Farm Household Income in Developing Countries: Evidence from Taiwan," Economic Development and Cultural Change 27, No. 2, pp 283-301.

Chirarattananon, Surapong. "Analysis of Rural Energy Development in Thailand." In M. Nurul Islam, Richard Morse, and M. Hadi Soesastro (eds). Rural Energy to Meet Development Needs: Asian Village Approaches, pp 169-240. Boulder: Westview Press, 1984.

Choksi, Armeane M., Alexander Meeraus, and Ardy J. Stoutjesdijk. The Planning of Investment Programs in the Fertilizer Industry. Baltimore: Johns Hopkins University Press/World Bank, 1980.

Day, Richard H., and Inderjit Singh. Economic Development as an Adaptive Process; The Green Revolution in the Indian Punjab. Cambridge: Cambridge University Press, 1977.

deLucia, Russell J., Henry D. Jacoby, et al. Energy Planning for Developing Countries: A Study of Bangladesh. Baltimore: Johns Hopkins University Press, 1982.

Dixon, Ruth B. Rural Women at Work; Strategies for Development in South Asia. Baltimore: Johns Hopkins University Press, 1978.

Ellis, Frank. "Relative Agricultural Prices and the Urban Bias Model: A Comparative Analysis of Tanzania and Fiji." In John Harriss and Mick Moore (eds), Development and the Rural-Urban Divide, pp 28-51. London: Cass, 1984.

Evenson, Robert E., and Yoav Kislev. Agricultural Research and Productivity. New Haven: Yale University Press, 1975.

Fernandez, Judith C. Household Energy Use in Non-OPEC Developing Countries. Santa Monica, Ca.: Rand, May 1980.

Finnell, Janine. "Energy and Agriculture in Morocco: Linkages in the Food System." mimeo. Washington: USAID (S&T/EY), February 1984.

Garg, I.K., V.K. Sharma, and Santokh Singh. "A Power Tiller-Mounted Vertical Conveyor Reaper-Windrower," Agricultural Mechanization in Asia, Africa and Latin America 15, No. 3, pp 40-44.

Gordian Associates, Inc. An Assessment of the Energy Requirements and Selected Options Facing Major Consumers Within the Egyptian Industrial and Agricultural Sectors. mimeo. Washington, May 1978.

Hamid, Javed. "Agricultural Mechanization; A Case for Fractional Technology." In Tan Bock Thiam and Shao-er Ong (eds), Readings in Asian Farm Management, pp 199-219. Singapore: University of Singapore Press, 1979.

Harriss, Barbara. "Post Harvest Rice Processing Systems in Rural Bangladesh: Technology, Economics and Employment," Bangladesh Journal of Agricultural Economics 2, No. 1 (1979), pp 23-50.

Harriss, John, and Mick Moore (eds). Development and the Rural-Urban Divide. London: Cass, 1984.

Haswell, Margaret R. Tropical Farming Economics. London: Longman, 1973.

Hayami, Yujiro, in association with Masakatsu Akino, Masahiko Shintani, and Saburo Yamada. A Century of Agricultural Growth in Japan. Minneapolis: University of Minnesota Press, 1975.

Hirschman, Albert O. The Strategy of Economic Development. New Haven: Yale University Press, 1958.

Hirst, Eric. "Transportation Energy Use and Conservation Potential," Science and Public Affairs 29, No. 9 (1973), pp 36-42.

Ho, Samuel P.S. "Decentralized Industrialization and Rural Development: Evidence from Taiwan," Economic Development and Cultural Change 28, No. 1 (1979), pp 77-96.

International Energy Agency. Energy Balances of Developing Countries 1971/1982. Paris: OECD, 1984.

Islam, M. Nurul, Richard Morse, and M. Hadi Soesastro (eds). Rural Energy to Meet Development Needs: Asian Village Approaches. Boulder: Westview Press, 1984.

Jabbar, M. A., M. S. R. Bhuiyan, and A. K. M. Bari. "Causes and Consequences of Power Tiller Utilization in Two Areas of Bangladesh," in International Rice Research Institute and Agricultural Development Council, Consequences of Small-Farm Mechanization, pp 71-83. Manila: International Rice Research Institute, 1983.

Jones, Donald W. "Urbanization and Energy Use." mimeo. Oak Ridge: Oak Ridge National Laboratory, April 1985.

Jones, Donald W., and Garland Samuels, Jr. "Energy Requirements of Development Projects." ORNL-6298. Oak Ridge: Oak Ridge National Laboratory, 1988.

Kayira, Gladson K. "The Scope for Energy Conservation in the Tea Industry." mimeo. Energy Department, World Bank, Washington, November 1984.

Leach, Gerald. "Energy and Agriculture." mimeo. Paper presented at USAID Meeting on Agriculture, Rural Development and Energy, Manila, April 1985.

Lewis, W. Arthur. The Theory of Economic Growth. London: George Allen & Unwin, 1955.

Lipton, Michael. Why Poor People Stay Poor; Urban Bias in World Development. Cambridge: Harvard University Press, 1977.

Lopez, Ramon E. "Supply Response and Investment in the Canadian Food Processing Industry," American Journal of Agricultural Economics 67, No. 1 (1985), pp 40-48.

Low, A. R. C. "The Effect of Off-Farm Employment on Farm Incomes and Production: Taiwan Contrasted with Southern Africa," Economic Development and Cultural Change, 29, No. 4 (1981), pp 741-747.

Mangahas, Mahar. "An Economic Theory of Tenant and Landlord Based on a Philippine Case." In Lloyd G. Reynolds (ed.), Agriculture in Development Theory, pp 138-161. New Haven: Yale University Press, 1975.

McGranahan, Gordon, and Manuel Taylor. Urban Energy Use Patterns in Developing Countries: A Preliminary Study of Mexico City. mimeo. W. Averall Harriman College for Urban and Policy Sciences, SUNY Stony Brook, December 1977.

McGranahan, Gordon, S. Chubb, R. Nathans, and O. Mbeche. Patterns of Urban Household Energy Use in Developing Countries: The Case of Nairobi. mimeo. Institute for Energy Research, SUNY Stony Brook, April 1979.

Morris, Morris D. The Emergence of an Industrial Labor Force in India; A Study of the Bombay Cotton Mills, 1854-1947. Berkeley: University of California Press.

Newbery, David M. G., and Joseph E. Stiglitz. "Sharecropping, Risk Sharing and the Importance of Imperfect Information." In James A. Roumasset, Jean-Marc Boussard and Inderjit Singh (eds), Risk, Uncertainty and Agricultural Development, pp 311-339. New York: Agricultural Development Council, 1979.

Pingali, Prabhu L., and Hans P. Binswanger. "Population Density and Farming Systems - The Changing Locus of Innovations and Technical Change." Discussion Paper No. ARU 24, Agriculture and Rural Development Department, World Bank, Washington, October 1984.

Planning Service, Ministry of Energy, The Philippines. "Philippine Energy Resource and Consumption Survey," in M. Nurul Islam, Richard Morse, and M. Hadi Soesastro (eds), Rural Energy to Meet Development Needs: Asian Village Approaches, pp 135-168. Boulder: Westview Press, 1984.

Quibria, M. G., and Salim Rashid. "The Puzzle of Sharecropping: A Survey of Theories," World Development 12, No. 2 (1984), pp 103-114.

Ranis, Gustav. "Industrial Development." In Walter Galenson (ed.), Economic Growth and Structural Change in Taiwan; The Postwar Experience of the Republic of China, pp 206-262. Ithaca: Cornell University Press, 1979.

Rondinelli, Dennis A., and Kenneth Ruddle. Urbanization and Rural Development; A Spatial Policy for Equitable Growth. New York: Praeger, 1978.

Roumasset, James, and Ganesh Thapa. "Explaining Tractorization in Nepal; An Alternative to the 'Consequences Approach'," Journal of Development Economics 12, No. 3, pp 377-395.

Ruttan, Vernon W., and Hans P. Binswanger. "Induced Innovation and the Green Revolution." In Hans P. Binswanger, Vernon W. Ruttan and others, Induced Innovation; Technology, Institutions, and Development, pp 358-408. Baltimore: Johns Hopkins University Press, 1978

Schipper, Lee, Jack Hollander, Matthew Milukas, Joseph Alcomo, and Stephen Meyers, with Scott A. Noll, Joy Dunkerley, and John E. Jankowski. Energy Conservation in Kenya's Modern Sector; Progress, Potential and Problems. Discussion Paper 73I. Washington: Resources for the Future, May 1982.

Schmitz, Hubert. Manufacturing in the Backyard; Case Studies on Accumulation and Employment in Small-scale Brazilian Industry. London: Frances Pinter, 1982.

Scitovsky, Tibor. "Comment on Adelman, "World Development 12, No.9 (1984), pp 953-954.

Sekhar, A. Uday. Industrial Location Policy; The Indian Experience. World Bank Staff Working Paper No. 620. Washington, 1983.

Singer, H. W. "Success Stories of the 1970's: Some Correlations," World Development 12, No. 9 (1984), pp 951-952.

Singh, Gajendra. "Agricultural Mechanization in Selected Southeastern Asian Countries," Agricultural Mechanization in Asia, Africa and Latin America 15, No. 3 (1984), pp 33-39, 44.

Timmer, C. Peter. "Food Policy in China," Food Research Institute Studies 15, No. 1 (1976), pp 53-69.

Wattanutchariya, S. "Economic Analysis of the Farm Machinery Industry and Tractor Contractor Business in Thailand," in International Rice Research Institute and Agricultural Development Council, Consequences of Small-Farm Mechanization, pp 39-49. Manila: International Rice Research Institute, 1983.

World Bank. World Tables, 3rd Ed., Vol. I. Baltimore: Johns Hopkins University Press, 1983.

World Bank. The Energy Transition in Developing Countries. Washington: World Bank, 1983a.

INTERNAL DISTRIBUTION

1. V. D. Baxter
2. C. L. Brown
3 B. L. Bush
4. L. M Cochran
5 D. M Evans
6. W. Fulkerson
7. C. L. Gaudreau
8. R. K. Goel
9. C. B. Grillot
10. G. Harrison
11. E. L. Hillsman
12. R. Honea
13-37. D. W. Jones
38. J. O. Kolb
39. P. N. Leiby
40. J. M. MacDonald
41. L. N. McCold
42. R. D. Perlack
43. A. M. Perry
44. C. H. Petrich
45. S. Rayner
46. J. H. Reed
47. D. E. Reichle
48. E. Rogers
49. G. O. Rogers
50. R. D. Roop
51. R. B. Shelton
52. S. Stevens
53. G. G. Stevenson
54. P. J. Sullivan
55. E. J. Szarleta
56. T. J. Wilbanks
57. S. B. Wright
58. Central Research Library
59. Document Reference Section
60-62. Laboratory Records
63. Laboratory Records-RC

EXTERNAL DISTRIBUTION

64. Mr. J. J. Cuttica, Vice President of Research and Development, Gas Research Institute, 8600 W. Bryn Mawr Avenue, Chicago, IL 60631

65. Dr. David J. Jhirad, Office of Energy, U.S. Agency for International Development, SA-18, Room 509, Washington, DC 20523

66. Dr. J. P. Kalt, Professor of Economics, Kennedy School of Government, Harvard University, 79 John F. Kennedy Street, Cambridge, MA 02138

67. Dr. D. E. Morrison, Professor of Sociology, Michigan State University, 201 Berkey Hall, East Lansing, MI 48824-11111

68. Dr. R. L. Perrine, Professor, Engineering and Applied Sciences, Civil Engineering Department, Engineering I, Room 2066, University of California, Los Angeles, CA 90024

69. Mr. Ross Pumphrey, Office of Energy, U.S. Agency for International Development, SA-18, Room 509, Washington, DC 20523

70. Mr. Alberto Sabadell, Office of Energy, U.S. Agency for International Development, SA-18, Room 509, Washington, DC 20523

71. Mr. William H. Steigelmann, P. E., TechPlan Associates, Inc., 15 Cynwyd Road, Suite 200, Bala Cynwyd, PA 19004

72. Mr. James B. Sullivan, Office of Energy, U.S. Agency for International Development, SA-18, Room 509, Washington, DC 20523

73. Ms. Shirley Toth, Office of Energy, U.S. Agency for International Development, SA-18, Room 509, Washington, DC 20523

74. Office of Assistant Manager for Energy Research and Development, DOE-ORO, Oak Ridge, TN 37830

75-84. OTSI, U. S. Deparment of Energy, P.O. Box 62, Oak Ridge, TN 37831 (10)