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ECONOMIC AND SOCIAL ANALYSIS OF RENEWABLE ENERGY PROJECTS

The State of the Art

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ECONOMIC AND SOCIAL ANALYSIS OF RENEWABLE ENERGY PROJECTS

The State of the Art

I. Introduction

To support energy projects in rural areas of Africa will require information and analytical capabilities of four major types:

- technical (including scientific material on "non-hardware" approaches such as reforestation to meet firewood requirements);
- financial (private calculations of profitability of specific energy investments);
- economic (national calculations of social cost and benefit of particular projects);
- social/institutional (responsiveness of the project to local social conditions, including appropriate institutional forms for project development and implementation).

To date, however, serious attention has been given only to technical responses to rural energy problems. Virtually nothing has been done to develop the financial, economic, and social/institutional knowledge required if renewable energy projects are to be carried out successfully.

II. The State of the Art

A. Technical

A great deal of effort has already been applied to the design and testing of renewable energy devices: solar pumps, cookers, and stills; low-head hydroelectric generators; photovoltaic cells; pyrolytic converters; improved stoves; methane systems; etc. Programs to increase knowledge of tree species for reforestation projects are also underway. To be fully responsive to Third World energy needs, additional R&D will be needed in all these areas. Nonetheless, research into technical aspects of rural energy systems has far outpaced work on related, non-technical questions.

A specific review of relevant technical material is not within the scope of this report. However, a general introduction to this literature is provided in material listed under entries 3, 4, 6, 15, 38, 41, 51, 63, and 67 in the attached bibliography.

B. Financial

Systematic concern with use of renewable energy source is everywhere

sufficiently recent that relatively few financial analyses have been conducted of particular technologies. In the United States, for example, the degree to which solar devices are competitive with conventional power has only recently been given widespread attention. (Entries 42, 67, 68.) And no more than a handful of studies of Third World applications, generally using hypothetical data, have so far been completed. (For example, entries 2, 13, 15, 31, 41, 70.) Taken together, work to date has not been sufficient to give a clear indication of the financial viability of most systems in particular LDCs.

The major problem is a pervasive absence of real-world data. Most energy devices have been created in industrialized countries or in central research units of LDCs, and financial information is largely limited to that experience. In practice, however, commercial profitability in rural areas of LDCs will depend on a variety of local factors (transport costs, available management and maintenance capabilities, wages, price of output, etc.) that may vary greatly from area to area. Perhaps most problematic is establishing the price at which goods or services will be sold: where comparable sources of energy are not already available to the people concerned, any figures on demand at various prices will be largely imaginary. As a result, the reliability of estimated rates of return will be quite limited.

In the literature, such problems have sometimes been disguised by extensive calculations showing the cost of renewable-source energy versus the cost of diesel energy in a particular area. Commonly, however, neither system is in current use, and both sets of figures are therefore imaginary. The danger here is that the apparent "competitiveness," for example, of a fictitious photovoltaic array as opposed to a fictitious diesel system could obscure the fact that <u>neither</u> form of power could profitably be used in the location under review.

These difficulties follow from the fact that most renewable energy projects to date have concentrated primarily on technical R&D. Pending results in these areas, government agencies and concerned foreign donors have deferred consideration of other issues involved in applying technologies to the needs of actual people at actual rural sites. Commercial profitability is only one of these issues, and it is by no means the most important. Nonetheless, to acquire accurate information on this subject is now essential if large-scale programs to encourage renewable energy use are to be successfully undertaken.

Much of the above discussion relates to studies of energy hardware. As far as I have been able to discover, no serious work is now underway on the financial aspects of village woodlots or other "non-hardware" approaches to rural energy problems in Africa.

C. Economic

Policy-makers will wish to take a broader view of energy economics than financial analysis by itself can provide. "Shadow prices," for example, will show the social cost of labor to be lower and the cost of foreign exchange higher than is reflected in market prices used to make private financial calculations. In addition, governments may wish to take explicit account of the effects of various activities on income distribution. These factors will probably act in concert to make renewable energy projects more attractive than would be the case on financial grounds alone, but details will depend on careful analysis of specific projects.

Unfortunately, such analyses are most conspicuous by their absence. In part, this is due to the same problems that make sound financial estimates so difficult to carry out: important data are unavailable or uncertain; conventional power sources may be lacking in the area under study, meaning that no yardstick exists against which renewable energy activities can be measured; etc. In addition, methodological concerns arise that private investors need not confront: how are accurate shadow prices to be determined? how can proper weight be given to equity issues? The cumulative effect of all these questions is to make extremely complex the business of judging energy projects from a national economic perspective.

Methodological complexities alone, however, are insufficient to explain the lack of results in this area. More to the point may be the kinds of professional skills now being applied to these matters. For the most part, as the literature clearly indicates, work is being carried out by engineers or others with special talent for inventing, adapting, and providing technical evaluation of innovative energy devices. These jobs have been done with sufficient vigor to provide a healthy catalog of such devices. Equivalent talent, however, has not yet been applied to the question of whether these approaches make sense on financial and economic as well as technical grounds.

The beginnings of an answer to such questions lie in evaluation materials of the sort emerging, for example, from various World Bank offices concerned with rural projects. (Entries 46, 59, 71; entries 24, 30 address related issues.) Work remains to be done, however, in refining and standardizing these approaches, as well as in ensuring that they are not too complex to be applied to small-scale energy projects in (often remote) rural areas. Ultimately, a great many area- and technology-specific studies will need to be carried out if energy programs are to be responsive to actual economic conditions in LDCs.

The discussion above again reflects the concern with hardware of most current energy efforts. This bias, however, is not inherent in economic methodologies themselves. Such analysis is as applicable to village woodlots

as to solar cookers, and therefore can provide a neutral basis for evaluating a variety of conflicting approaches to meeting energy needs. These advantages, however, will follow only if economic studies of energy projects are actually carried out; so far, little of this work has been done.

D. Social/Institutional

On the evidence, foreign aid donors seem as often as not to have failed in attempts to promote use of village-scale technologies in LDCs. (Entry 12.) Most of these failures have resulted from the incompatibility of specific devices, or the manner of their introduction, with the social environments in which they were being placed. Unfortunately, we have far too little knowledge about the adoption of specific technologies as a function of social context. Particularly in the energy area, pertinent analytical material and case studies are scarce.

Conversely, we are equally unsure of the effects on social context of "successfully" implanting new technologies. Village energy systems are sometimes justified, for example, in terms of their restraining influence on migration of villagers to cities. However, a World Bank paper on rural electrification found little evidence of such an influence. (Entry 71.) And when AID installed small-scale electrical generators in 14 Colombian villages, there was a sharp increase in the number of local people wishing to move to urban areas. (Entry 62.) Clearly, this is an area where additional information would be valuable.

To improve the chances that technologies will fit their social environments, there is general agreement that village-based groups (village councils, extension services, PVOs) should be involved throughout the process of project planning and implementation. (Entries 7, 21, 23, 27, 35, 50.) To construct a national program around such groups, however, is an extremely complex process. Networks will have to be constructed of community leaders, village workers, anthropologists, economists, foresters, engineers, national planners, aid administrators, and others. Often, the administrative forms to do this properly will be inconsistent with existing patterns. Unfortunately, on this key point as on others, the applicable literature is thin. (See, e.g., entry 65.)

To some extent, the above difficulties will be common to all rural development programs. However, energy projects characteristically raise a further issue that not every rural activity must address. Most rural families will find most renewable energy technologies beyond their separate means. Cooperative or community-wide forms of organization will therefore be needed to purchase and use such devices as solar pumps, windmills, methane systems, hydroelectric generators, or photovoltaic arrays. Village-scale woodlots will make comparable demands on local institutions. Typically, appropriate organizations will not exist to meet these needs; and some form

of institutional development will be required before any project can be carried out. Of all developmental concerns, however, work with local institutions may be the area where existing theories are most inadequate and past experiences most disappointing.

III. Needs

Specific recommendations concerning economic and social analysis of energy projects will be provided in a later report. However, certain basic needs are immediately apparent.

Most generally, there is need to begin giving equal attention to all four of the analytical areas covered above. These obviously are complementary areas of concern. Technical advances allow us to conceive fresh developmental opportunities. Financial analysis can tell us whether individuals or groups will be able to invest in new approaches. Economic investigation can suggest whether it is in the nation's material interest that such investments be carried out. Social inquiries can determine whether the new ideas respond to human needs, make institutional sense, and will be adopted. No project is likely to succeed unless it is scrutinized from all these points of view.

In practice, however, we have reasonably solid information only on technical matters. Our conceptual apparatus is meager, and our recorded experience more limited still, when it comes to social, economic, or financial analysis of energy projects. Program development need not be suspended pending massive studies of these problems: much data in fact will emerge only as pilot activities are actually carried out. The degree of our current ignorance, however, does suggest considerable caution as to the scale and pace of initial programs.

In terms of people, the above implies an immediate need for greater involvement of economists and specialists in the social dynamics of rural areas, along with experts familiar with non-hardware approaches to meeting energy needs. This should be done within AID (where staff anthropologists and economists should be fully involved in program development), in supporting contracts (where greater use should be made of interdisciplinary groups like VITA or Inter-Culture Associates), and in LDCs themselves (where broadly-based energy committees might be encouraged in order to transcend normal bureaucratic divisions). The very fact of forging such links in some cases will be more important than the particular projects under review; in all cases, it will be necessary if such projects are to succeed.

Attachment

ECONOMIC AND SOCIAL ANALYSIS OF RENEWABLE ENERGY PROJECTS

An Annotated Bibliography

Note: The materials listed here deal primarily with economic and social analysis of renewable energy projects in Africa and other developing areas. Information from the United States is included where this addresses analytical issues of equal interest in the Third World. Largely excluded from this bibliography are: descriptions of particular energy devices (unless financial or economic implications are given specific attention); project documentation on current AID activities in the energy area (to be reviewed in a later report); and general materials on the social context of appropriate technology transfer (listed in entry 12).

1. ALLISON, H. Jack. Undated. Solar, Wind, and Biogas Energy Systems. Stillwater, Oklahoma: Oklahoma State University, School of Electrical Engineering.

Describes a "Rural Energy Center" being developed for a village in Sri Lanka by Oklahoma State University under the sponsorship of the U.N. Environment Program. People in the village selected appear to have abundant firewood and irrigation water and require only a small amount of imported kerosene for lighting. The OSU system would provide them with large amounts of mechanical energy plus approximately 100,000 kwh of electricity per year (or about 730 watt-hours per family per day) through an interconnected combination of windmills, photovoltaic panels, solar collectors, a Rankine engine, a methane digester system, electric storage units, and a back-up diesel generator. Such a system "will require little, if any, adjustment in the social structure of the village." Although cost data are not provided, the author estimates that this renewable energy system might ultimately be competitive with a hypothetical all-diesel electric system.

2. ALLISON, H. Jack et al. 1976. Final Feasibility Report No. ER-77-R-1: An Energy Center in Sri Lanka. Prepared for the U.N. Environment Program. Stillwater, Oklahoma: Oklahoma State University, College of Engineering, Engineering Energy Laboratory. June.

3. BOYLE, Godfrey and Peter Harper (eds.). 1976. Radical Technology. New York: Pantheon Books.

Includes discussions of solar, wind, and water power, plus bibliographies on these and related topics.

4. CANADIAN HUNGER FOUNDATION and Brace Research Institute. 1976. A Handbook on Appropriate Technology. Ottawa: Canadian Hunger Foundation. April.

Includes case studies of solar distillation in Haiti, a solar crop dryer in Colombia, a $300 biogas plant in India, and a smokeless cooking stove in Ghana. Summary sections give considerable attention to the role of "appropriate technology catalysts," who are cautioned to gain a thorough knowledge of the communities in which they work and to involve community members throughout the process of articulating needs, exploring solutions, and introducing new techniques.

5. CARR, Marilyn. 1976. Economically Appropriate Technologies for Developing Countries: An Annotated Bibliography. London: Intermediate Technology Publications Ltd.

Includes a number of listings covering such energy topics as solar grain drying, gobar gas, charcoal, windmills, biomass, and solar distillation. An introductory essay emphasizes the difficulty of generalizing from such selections, since specific technology issues and appropriate responses vary greatly depending on place, stage of development, government policies, etc.

6. DARROW, Ken and Rick Pam. 1976. Appropriate Technology Sourcebook (second edition). Stanford, California: Volunteers in Asia. November.

Extensive practical information on appropriate technologies for the Third World. Features 70 pages of references to groups and publications concerned with energy, including chapters on wind; water; solar; wood, sawdust and rice hull stoves; methane gas; and pedal-power. In their introduction, the authors emphasize that the key to effective use of alternative technologies lies less in gadgetry than in the process through which new technologies are found and applied. This process must be community-based and participatory, leaving room for outsiders primarily as catalysts and as sources of limited, short-term technical support.

7. DEVELOPMENT ALTERNATIVES, Inc. 1975. Strategies for Small Farmer Development: An Empirical Study of Rural Development Projects. Report to AID in three volumes: Final Report, Case Studies, and Executive Summary. Washington, D.C.: Development Alternatives, Inc. May.

The purpose of rural projects is assumed to be promotion of self-sustaining growth in the small farmer's income, agricultural knowledge, and self-help capability. Success appears to depend largely on whether farmers (a) are involved in decision-making during project implementation, and (b) commit their own labor or cash to the activity. To design projects responsive to these criteria takes more time and knowledge of local conditions than aid agencies normally assume is necessary. Such agencies need either to adopt a more locally-based, "organic" development approach or to support smaller institutions able to operate on this basis in developing countries.

8. deWINTER, F. and J.W. deWinter (eds.). 1976. Description of the Solar Energy R&D Programs in Many Nations: Final Report. Report for ERDA, Division of Solar Energy. Santa Clara, California: Atlas Corporation. February.

Describes programs within 32 countries (including Nigeria and Senegal), the Organization of American States, UNESCO, and a number of private organizations.

9. ECKHOLM, Erik. 1975. The Other Energy Crisis: Firewood (Worldwatch Paper 1). Washington, D.C.: Worldwatch Institute. September.

Firewood supplies are being rapidly depleted in much of the Third World. This is a direct threat to the poor, since nine-tenths of the people in most of these countries depend on firewood for fuel. In addition, the accelerating degradation of woodlands leads to soil erosion, flooding, desertification, and declining soil fertility. These problems are further accentuated as people turn from wood to dung for fuel, robbing farmlands of the nutrients that dung has traditionally supplied. Massive tree-planting projects are called for, along with research into alternative energy sources such as solar cookers or biogas plants.

10. FLORIDA INSTITUTE OF TECHNOLOGY, Center for Research on Energy Alternatives. 1975. Solar Cookers for Haiti: A Feasibility Study. November 12.

11. FRAENKEL, Peter L. 1975. Food from Windmills: A Report on the Windmill Irrigation Project Initiated by the American Presbyterian Mission at Omo Station in Ethiopia. London: Intermediate Technology Publications, Ltd. November.

12. FRENCH, David. 1977. Appropriate Technology in Social Context: An Annotated Bibliography. Mt. Rainier, Maryland: VITA.

An introductory section notes that people have been trying to transfer appropriate technologies for decades, as often as not unsuccessfully. Almost invariably, failure has followed inattention to social context. For the job to be done properly will require that communities in developing areas participate fully in the process of technological choice. For their part, outsiders will need to find ways to combine the skills and insights of development agencies, the applied social sciences, village-based programs, and sources of technical information.

13. GENERAL ELECTRIC COMPANY. 1963. Small-Scale Power Supplies for Rural Communities in Developing Countries. Report to R.E.P.A.S., AID. New York, N.Y.: General Electric Co. March.

Considers a range of possible small-scale generator technologies for supplying electric energy to rural communities in developing countries: diesel, gasoline, or gas engines; hydroelectric; Wankel, thermal, or Stirling engines; gas turbines; wind; fuel cells; photovoltaics. A lengthy appendix provides a cost-benefit analysis of biogas plants in India.

14. GEORGIA INSTITUTE OF TECHNOLOGY, Engineering Experiment Station, Economic Development Laboratory. 1975. Discussion Papers on the Problems of Science and Technology. Presented at the annual strategy and planning symposium, AID/OST, 6-9 May 1975. Atlanta: Georgia Institute of Technology. December.

A major section covers the interrelationship of energy and LDC rural development. See also listings under T.A. Lawand and R. Revelle (1975).

15. GEORGIA INSTITUTE OF TECHNOLOGY, Engineering Experiment Station, Economic Development Laboratory. 1976. Pyrolytic Conversion of Agricultural and Forestry Wastes in Ghana: A Feasibility Study. Report for AID/OST. Atlanta: Georgia Institute of Technology. July.

16. GLASER, Peter E. 1974. "Implications of Solar Energy for Developing Countries." In Seminar Series on Technology and Development - Volume II, Leatha S. Henson (ed.). Washington, D.C.: Howard University, School of Engineering. May.

17. GOLDING, E.W. Undated. Windmills for Water Lifting and the Generation of Electricity on the Farm (FAO Informal Working Bulletin No. 17). Rome: FAO Agricultural Engineering Branch.

Considers windmills for farms where fuel is expensive and tapping of main power grids unlikely. Concludes that effective use of windpower requires careful attention to a variety of economic and social factors, in addition to climate and topography.

18. HAYES, Denis. 1977. Energy: The Solar Prospect (Worldwatch Paper 11). Washington, D.C.: Worldwatch Institute. March.

An introduction to global prospects for use of "solar" energy sources: sunlight, wind, water power, biomass. Notes that higher oil prices and the increasing "internalization" of environmental costs have sharply reduced the advantage of traditional energy sources over solar alternatives. Reviews technologies now available or under study to provide heating, cooling, transportation, electricity, and mechanical work. Concludes that "Of the possible worlds we might choose to build, a solar-powered one appears most inviting."

19. HERONEMUS, William E. 1974. A Survey of the Possible Use of Windpower in Thailand and the Philippines. Report for AID/OST. November.

20. HITTMAN ASSOCIATES, Inc. 1976. Compendium of Energy-Technology-Related Assistance Programs for Less-Developed Countries: Final Report HIT-673. Report for U.S. Department of State, Bureau of Oceans and International Environmental and Scientific Affairs. Washington, D.C. September.

21. HOWE, James W. and Staff of the Overseas Development Council. 1977. Energy for the Villages of Africa: Recommendations for African Governments and Outside Donors. Washington, D.C.: Overseas Development Council. February 25.

African villagers need access to additional energy to improve the quality of life, raise production, and conserve dwindling resources such as firewood. There are strong reasons for investigating uses of "village source energy": sun, wind, water, animal and crop wastes, wood. African governments should conduct field tests of new energy devices, based on village-level surveys of present and potential patterns of energy use. To help with necessary research and training, a variety of national and international energy institutions should be created or strengthened.

22. ILLICH, Ivan. 1974. Energy and Equity. Scranton, Pennsylvania: Harper and Row.

23. JEQUIER, Nicolas (ed.). 1976. Appropriate Technology: Problems and Promises. Paris: OECD Development Center.

Includes 10 short papers, primarily case studies of a great variety of projects in specific developing countries. Energy is covered in articles on biogas in India and solar pumping in Senegal. In addition, a lengthy introductory essay by the editor summarizes important themes. Observing

that most foreign aid officials lack intimate experience with rural areas, the editor concludes that such groups as local government agencies or private voluntary organizations should assume primary responsibility for developing the "softwares" (local organizational, legal, and knowledge systems) necessary for a total "innovation system."

24. KATZ, Milton. 1971. "Decision-Making in the Production of Power." See listing under Scientific American, 1971.

Raises the issue of how to balance "efficiency" criteria in production of power against such social measures as health, safety, and aesthetics. Notes that any "externality" of social costs is arbitrary, deriving more from the nature of a country's legal system than from the fundamentals of economics or business. Discusses ways in which "external" costs can be internalized through tax policies, regulatory statutes, and private legal actions.

25. KEMP, William B. 1971. "The Flow of Energy in a Hunting Society." See listing under Scientific American, 1971.

Relying on field observations over a 54-week period, the author discusses energy requirements and yields of two Eskimo households in an Arctic village. For the most part, energy was absorbed in the form of food, fuel, and ammunition. In turn, energy was expended for such purposes as hunts, camp work, wage work, travel, and visiting. The resulting energy flows, generally measured in calories, are described in terms of annual totals and important seasonal variations.

26. KIDDER, Tracy. 1977. "Tinkering With Sunshine: The Prospects for Solar Energy." Atlantic. October.

Describes work being done on uses of solar energy by government agencies (Office of Technology Assessment, ERDA, National Science Foundation), major private organizations (Stanford Research Institute, Westinghouse, Mobil Corporation), and various "small entrepreneurs and lone wolves" (Steve Baer, Harry Thomason). Concludes that the technical and economic prospects for solar technology are intriguing but uncertain. Notes that many of the most promising systems have been produced by the "lone wolves," whose independence from large organizations and government money has prompted attention to economy and simplicity rather than sophisticated research.

27. LANCE, Larry M. and Edward E. McKenna. 1975. "Analysis of Cases Pertaining to the Impact of Western Technology on the Non-Western World." Human Organization. Spring.

Misleadingly titled, since there is no discussion of "the impact of Western technology on the non-Western world." Instead, emphasis is on conditions under which innovations are "successful," apparently meaning that they have been adopted. In the 50 cases analyzed, "participation" was the only effective strategy for introducing change. Technology

hardwares were more successfully transferred than softwares. Where projects failed, a major cause was inadequate understanding of local cultural beliefs and political structures.

28. LAWAND, T.A. 1975. "The Implementation of Rural Energy Programs." See listing under Georgia Institute of Technology, 1975.

Warns that in the rush to promote renewable energy sources, development agencies may actually saddle developing countries with a variety of inappropriate devices. Genuine appropriateness can only be ensured if we first "(a) find out what are the problems; (b) determine a methodology of approach which will really ensure integration and continuity for the technology within the system." That these principles are often ignored in practice is evident from experience with energy programs in Bangladesh, Senegal, and elsewhere.

29. LITTLE, Arthur D., Inc. 1974. An Overview of Alternative Energy Sources for LDCs. Report to AID/OST. Cambridge, Massachusetts: ADL. August 7.

Considers relatively large-scale alternatives, both "conventional" (coal) and "non-conventional" (tidal, geothermal, waste, methanol, coal gasification, solar, nuclear). Includes profiles of 15 LDCs, including Ghana, Ivory Coast, Kerya, and Niger. Recommends aid programs in support of methanol for the transport sector and coal or nuclear power for generating electricity.

30. LOVINS, Amory B. 1976. "Energy Strategy: The Road Not Taken?" Foreign Affairs. October.

The U.S. can choose to pursue current, high-technology energy policies or to follow a "soft" path which would emphasize conservation measures and use of renewable energy sources. On all grounds, including social and political impact, Lovins finds the soft path to be preferable. In economic terms, this would be more evident if markets were subject to such "sound economic principles" as flat rate structures (rather than discounts for large users), removal of subsidies, assessment of total costs of energy-using purchases over their operating lifetimes ("life-cycle costing"), counting costs of complete energy systems including all support and distribution functions, proper accounting of environmental costs, replacement-cost valuation of assets, and appropriate discounting.

31. MAKHIJANI, Arjun. 1976. Energy Policy for the Rural Third World. London and Washington, D.C.: International Institute for Environment and Development.

Rural areas of the Third World need energy for such purposes as agriculture, cooking, water supplies, lighting, transport, and local public services. Traditional patterns of energy use are relatively inefficient, however, and access to "commercial" sources has largely been limited to the richest 20% of the population. Attention is therefore given to alternatives such as wind power, biogas, and improved stoves. To make these technologies generally available might require establishment of "village public utilities," which could borrow money, mobilize labor,

and run community-scale energy projects. In support of such efforts, research is needed on biogas plants, harvesting of tropical bogs for fuel, drip irrigation using earthenware pots, and solar cookers, as well as on existing patterns of energy use and specific areas of further need.

32. MAKHIJANI, Arjun. 1976. "Solar Energy and Rural Development for the Third World." Bulletin of the Atomic Scientists. June.

33. MAKHIJANI, Arjun and Alan Poole. 1975. Energy and Agriculture in the Third World. Cambridge, Massachusetts: Ballinger Publishing Co.

34. McDOWELL, Jim (ed.). 1976. Village Technology in Eastern Africa. Report of a seminar on "Appropriate Technology for the Rural Family," Nairobi, 14-19 June 1976. Nairobi: UNICEF.

35. McROBIE, George. 1975. "An Approach for Appropriate Technologists." In R.J. Congdon, ed., Lectures on Socially Appropriate Technology. Eindhoven, Netherlands. Technische Hogeschool.

Suggests a division of responsibility for three major tasks. First, Western experts can do state-of-the-art surveys and applied research to find models of appropriate technology for various uses. Second, people with thorough knowledge of local conditions can determine technology needs, community by community. Third, centers within developing countries can make specific adaptations of available technologies to local needs.

36. MERRIAM, Marshal F. 1972. Is There a Place for the Windmill in the Less Developed Countries? Honolulu: University of Hawaii, East-West Technology and Development Institute. March.

In places where winds are strong, fuels expensive, and central power connections far away, windmills can be useful for such purposes as pumping water, grinding grains, driving compressors for refrigerators, or charging storage batteries. The test of economic feasibility is often assumed to be whether windmill power is competitive in cost with power from diesel or other sources. However, this approach is inadequate in remote areas of LDCs, where both windmills and diesel engines may be inappropriate on economic or social grounds. If windmills are feasible, it may be desirable to rent them or to sell their output, thereby avoiding the financial and technical risks involved in outright sales to local users.

37. MERRIAM, Marshal F. 1972. "Windmills for Less Developed Countries." Technos. April.

Discusses information necessary to decide whether windmills would be economic in specific locations, including availability and cost of alternative power (animal and diesel).

38. MERRILL, Richard et al. 1975. The Energy Primer. Menlo Park, California: Portola Institute.

Primarily deals with small-scale energy systems for the use of individuals or small groups.

39. MOORCRAFT, C. 1974. "Solar Energy: Plant Power." Architectural Design Vol. XLIV, No. 1.

Argues that research into plants as a source of solar energy offers much greater opportunity for immediate social benefits than does work on such devices as photovoltaic cells. Discusses sewage farming and use of kitchen wastes for producing methane.

40. NATHANS, Robert. Undated. Assessing Small-Scale Energy Technologies for Rural Areas in Developing Countries - A Systems Approach. State University of New York at Stony Brook and Brookhaven National Laboratory.

41. NATIONAL ACADEMY OF SCIENCES. 1976. Energy for Rural Development: Renewable Resources and Alternative Technologies for Developing Countries. Washington, D.C.: National Academy of Sciences.

An extensive summary of alternative energy uses, including direct employment of solar energy (for heating, cooling, distillation, crop drying, and power generation), indirect uses of solar energy (windpower, hydropower, photosynthesis), and other technologies (geothermal, energy storage). Concludes that with the exception of a few devices such as solar driers and homemade windmills, "there are no cheap alternative technologies of significance for...developing nations, and there probably will not be any in the near future." Nonetheless, some steps can be taken to further the use of alternative energy sources, including organization of workshops, creation of a pilot energy program for rural areas, and establishment of regional institutes for research and development.

42. NATIONAL BUREAU OF STANDARDS. 1975. Solar Heating and Cooling of Buildings: Methods of Economic Evaluation. Springfield, Virginia: NTIS.

43. ODUM, Howard. 1973. "Energy, Ecology and Economics." Ambio 2 (6).

44. ODUM, Howard and Elizabeth Odum. 1976. Energy Basis for Man and Nature. New York: McGraw Hill.

A recent treatment of net energy theory.

45. OKLAHOMA STATE UNIVERSITY. 1965. Utilization of Energy in Selected Developing Countries: Studies of the Feasibility of the Utilization of Unconventional Energy Sources to Increase Production and Employment in Isolated Areas in Selected Developing Countries. Stillwater, Oklahoma: Oklahoma State University. December.

46. PAK, Simon J. and Charles R.H. Taylor. 1976. Critical Factors in Economic Evaluation of Small Decentralized Energy Projects (Science and Technology Report No. 25). Washington, D.C.: World Bank. November.

Notes that projects to develop alternative energy sources should be evaluated in terms of total costs and benefits to the economy (not simply the investor), including calculation of secondary effects and appropriate shadow prices. Care should be taken not to overestimate benefits (e.g., by using data for plant capacity rather than actual output) or to underestimate costs (e.g., through excessive optimism as to the operating life of equipment). Where forms of energy are not already traded locally, their value may have to be set according to that of energy sources being replaced, or in terms of the project's net impact on the production of other goods. If this process of collecting and evaluating data were standardized, a useful body of international knowledge could ultimately be developed on the economics of alternative energy.

47. PIMENTEL, David et al. 1974. "Food Production and the Energy Crisis." In Energy: Use, Conservation and Supply, Philip H. Abelson, ed. Washington, D.C.: American Association for the Advancement of Science.

48. POOLE, Alan. 1977. Energy From Biomass: A Conceptual Overview. Study prepared for ERDA/APAE. Washington, D.C.: Institute for Energy Analysis/ Oak Ridge Associated Universities. September 30.

Includes a major section on "Bioenergy in Underdeveloped Countries." Such countries have great need for bioenergy (most notably for firewood) along with great potential for supplying this (due to high yields of biomass systems in tropical and subtropical regions). Biomass is also attractive for LDCs since its production is relatively labor-intensive.

49. PRASAD, C.R., K. Krishna Prasad, and A.K.N. Reddy. 1974. "Bio-Gas Plants: Prospects, Problems and Tasks." Economic and Political Weekly. August.

50. PROGRAM OF ADVANCED STUDIES IN INSTITUTION BUILDING AND TECHNICAL ASSISTANCE. 1976. Private Voluntary Organizations and Appropriate Technology. Bloomington, Indiana: PASITAM. June. (Reprinted in U.S. Agency for International Development, Proposal for a Program in Appropriate Technology, revised edition, February 7, 1977.)

Notes that the "appropriateness" of a technology must be measured against local needs in specific places. Since PVOs typically concentrate on field operations, especially in impoverished rural areas, they are uniquely qualified to identify and respond to these needs. Most PVOs are considerably less strong, however, in technical areas required for research and development, as well as in the formal assessment and dissemination of their experience. In a general conclusion, the authors stress the need for applied social science in evaluating those "vital conventions" of particular societies that will determine their response to given technology projects.

51. RAIN MAGAZINE. 1977. Rainbook: Resources for Appropriate Technology. New York: Schocken Books.

A lengthy section describes publications and groups concerned with renewable energy issues.

52. RAMAKUMAR, R. Undated. Technical and Socio-Economic Aspects of Solar Energy and Rural Development in Developing Countries. Paper presented at conference on "Sharing the Sun! - Solar Technologies in the Seventies." Proceedings, Vol. 9. Winnipeg.

53. RAPPAPORT, Roy A. 1971. "The Flow of Energy in an Agricultural Society." See listing under Scientific American, 1971.

Examines gardening and pig raising in a rain forest area of New Guinea. Measured in calories, the ratio of energy yields to energy inputs associated with gardening was approximately 16:1. In pig raising, on the other hand, yields at best were only slightly greater than energy expended. The care of pigs may be justified on other grounds, however, including their use in the rituals surrounding (and limiting) warfare and their ready availability as a protein source in time of illness.

54. REVELLE, Roger. 1975. "Energy and Rural Development." See listing under Georgia Institute of Technology, 1975.

Energy use in developing countries is already considerable (total energy consumed in growing and processing a ton of food grains is greater in India than in the United States), but conversion processes are quite inefficient. In the short run, improved stoves and other devices can conserve fuels used for cooking, water and space heating, and lighting. Over the longer term, there may be promise in biogas technology, the use of rapidly-growing trees, direct applications of solar energy, and development of small hydroelectric generators.

55. REVELLE, Roger. 1976. "Energy Use in Rural India." Science. June 4.

Summarizes studies which measure energy sources (human and bullock work, firewood, cattle dung, commercial energy, etc.) and uses (agriculture, domestic, lighting, etc.) in rural India. Total per capita energy use was about one-fiftieth that of the U.S. farm population. To increase food production, India will need to increase energy use, especially with respect to irrigation, chemical fertilizers, and draft power for cultivating fields.

56. ROBERTSON, Thomas A. 1975. "Systems of Energy and the Energy of Systems." Sierra Club Bulletin. March. (Reprinted in U.S. Congress, 1976, Part 3.)

Describes the idea of "net energy," as formulated by Howard Odum of the University of Florida. This concept refers to the energy available from a given resource, less the energy expended in finding that resource, extracting and processing it, and delivering its energy to the place where this is to be used. Such analysis provides new perspectives on energy

issues which conventional economic methods only partially illuminate. For example, while the "energy-investment ratio" (showing energy returns to energy invested) has declined over time for petroleum resources, this ratio is still more than twice as favorable for imported oil (6.5:1) as for strip-mined coal (3:1) or nuclear power (2-3:1). Elsewhere (U.S. Congress, 1976, Part 1, p. 85), Prof. Odum has concluded that only oil, gas, and coal use can be energy-efficient, while both nuclear power and solar heating are unsatisfactory when energy costs as well as prices are taken into account.

57. SCIENTIFIC AMERICAN. 1971. Energy and Power. San Francisco: W.H. Freeman.

A series of eleven articles, reprinted from a special issue of Scientific American in September 1971, covering such topics as energy in the universe, the earth's energy resources, the flow of energy in traditional hunting and agricultural societies, energy conversion processes, and decision-making in the production of power. See separate listings under M. Katz, W. Kemp, R. Rappaport, and C. Starr.

58. SMIL, Vaclav. 1977. "Intermediate Energy Technology in China." Bulletin of the Atomic Scientists. February.

Summarizes small-scale uses of hydro, biogas, and solar energy. China has more than 60,000 small and medium hydroelectric stations, with an average output of 42 kw. (Units as small as 0.6 kw and costing only about $150 are currently in use.) In Szechwan province, more than 2.8 million peasant families produce their own biogas. Since 1974, solar stoves and water heaters have begun to be used in several provinces. Along with small-scale coal mining, exploitation of these energy sources has played a crucial role in the recent development of the Chinese countryside.

59. SQUIRE, Lyn and Herman G. van der Tak. 1975. Economic Analysis of Projects (A World Bank Research Publication). Baltimore: The Johns Hopkins University Press.

Covers basic notions of cost-benefit analysis. Gives particular attention to various sorts of shadow prices, including "social prices" that reflect the distribution of project income between investment and consumption and between rich and poor.

60. STARR, Chauncey. 1971. "Energy and Power." See listing under Scientific American, 1971.

An overview of past, present, and future patterns of energy use. Emphasis is on changes over time in major energy sources employed and in the technologies used to exploit these. Notes that our petroleum-based industrial economy is of relatively recent vintage: until the 18th century, waterwheels and windmills were the only significant machines in general use; and as late as 1850, wood accounted for more than 90% of U.S. fuel

consumption. Starr assumes that large, worldwide increases in energy consumption will be met largely by fossil fuels and nuclear power plants, although other, "speculative" energy sources may become important in the future.

61. STEINHART, John S. and Carol E. Steinhart. 1974. "Energy Use in the U.S. Food System." Science. April 19. (Reprinted in U.S. Congress, 1976, Part 3.)

Notes that "primitive" cultures obtained 5-50 food calories for each calorie of energy invested in food production. In industrialized food systems, however, each food calorie produced requires 5-10 calories of energy inputs. Any attempts to export U.S. agricultural techniques to the Third World are therefore likely to imply impossibly great increases in the demand for energy. Rather than copying Western methods, people working in LDCs should emphasize conservation and use of methane, solar and wind systems.

62. TORRES, Augusto, Stanley Lichtenstein, and Paul Spector. 1968. Social and Behavioral Impacts of a Technological Change in Colombian Villages. Prepared under contract for AID. Washington, D.C.: American Institutes for Research. April.

Results of a two-year study of the effects of placing small electric generators in 14 Colombian towns. Apparently positive effects included an increase in people's involvement in community groups and activities. In addition, electricity users began to think more about ways to employ capital and tools for personal betterment, although actual economic activity increased little over the period. Negative results included an increase in tensions between rich (who generally used the electricity) and poor (who often were unable to afford this service). Both users and non-users showed a sharp increase in desire to leave the community, although reasons for this are not clear.

63. UNITED NATIONS, Department of Economic and Social Affairs. 1957. New Sources of Energy and Economic Development: Solar Energy, Wind Energy, Tidal Energy, Geothermic Energy and Thermal Energy of the Seas. New York: United Nations.

Includes a 32-page annotated bibliography.

64. UNITED NATIONS, Department of Economic and Social Affairs, Center for Social Development and Humanitarian Affairs, Social Development Division. 1976. Monitoring and Evaluation Systems for Assessing Developmental Impact at the Local Level: An Annotated Bibliography. Document ESA/SDHA/Misc.17. New York: United Nations. October 11.

Includes references to material on data collection, project goals, social and economic indicators, evaluation of community needs, use of evaluation results, etc.

65. UNITED NATIONS, Department of Economic and Social Affairs, Center for Social Development and Humanitarian Affairs, Social Development Division. 1976. Innovative Approaches to Popular Participation in Development: An Annotated Bibliography. Document ESA/SDHA/Misc.18. New York: United Nations. October 11.

Includes references to material on animation rurale, assessment of community needs, cooperatives, institutional and governmental arrangements, planning for local needs, etc.

66. U.S. CONGRESS. 1976. Middle- and Long-Term Energy Policies and Alternatives. Hearings before the Subcommittee on Energy and Power of the Committee on Interstate and Foreign Commerce, House of Representatives, on "Energy Choices Facing the Nation and Their Long-Range Implications" (March 25-26, 1976). Serial No. 94-63, 65-67, 75-77 (seven volumes). Washington, D.C.: U.S. Government Printing Office.

Includes volumes on "New Perceptions of the Current World," "Enlarging Economic Doctrine to Include Ecological and Human Goals," "Industry's Airborne Assault on Agriculture" (pollution), "Energy Policy in Transition," "Mobilizing for Social Goals," and "Energy Demand Studies." See also listings under T.A. Robertson, 1975; J.S. & C.E. Steinhart, 1974.

67. U.S. CONGRESS, Office of Technology Assessment. 1977. Application of Solar Technology to Today's Energy Needs (2 volumes). Washington, D.C.: Office of Technology Assessment. Prepublication draft. June.

According to OTA, this report is based on "the most exhaustive survey of small-unit solar technology ever undertaken." Major sections cover policy issues, onsite electric power generation, legal aspects and various impacts of onsite solar energy, energy conversion and storage, solar collectors, and heating and cooling equipment. Using data from four U.S. cities, the report concludes that solar energy may soon be competitive with electricity (although not with gas or coal) for space and water heating. In countries where "conventional" energy is more expensive and labor cheaper than in the U.S., the attractiveness of solar techniques should be even greater. Notes that evaluation of energy alternatives requires life-cycle costing, along with recognition that perceived costs will vary between users depending on tax status, sources of capital, and economic expectations.

68. U.S. ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION, Division of Solar Energy. 1976. An Economic Analysis of Solar Water and Space Heating. Washington, D.C.: U.S. Government Printing Office.

Concludes that solar water and space heating are now competitive with electric systems throughout most of the U.S., and would become widely competitive with oil heating if solar expenses could be reduced to a system equivalent cost of $20 per square foot of collector. Cost effectiveness is measured according to two primary methods: "positive

savings," or the number of years until the solar fuel bill (including amortized capital costs) is less than the conventional fuel bill; and "payback," or the number of years until the compounded net savings equal the remaining principal on the mortgage for the solar system.

69. WARPEHA, Paul R., Laura Goldman, and Dudley Fechner. 1976. Proposed Methane Gas/Nutrition-Health/Agriculture Project in Iluman, Imbabura (Ecuador). Mimeo.

A proposal for an integrated village development project to be carried out by three Peace Corps Volunteers in cooperation with 11 Indian families. Major elements of the project include: a stable in which manure would be gathered; an anaerobic digester to convert manure into methane gas for cooking and slurry for fertilizer; a solar hot-water unit for heating the digester tank; a wind rotor for pumping the water; and complementary educational programs in food preparation, agricultural methods, etc. Expenses over a three-year period would be $5447, excluding tools, rocks, gravel, land, and labor (all to be provided by the 11 local families) and the cost of the PCVs.

70. WEISS, Charles and Simon Pak. 1976. Developing Country Applications of Solar Cells (Science and Technology Report No. 7). Washington, D.C.: World Bank.

At present prices, solar cell systems are competitive with primary cells, and sometimes competitive with gasoline generators, as these are now used for operating educational TV receivers in developing countries. Given anticipated reductions in price (to about $5/peak watt), solar cells might power refrigerators for remote health centers or tourist resorts. Since solar cells require an initial investment 3-6 times greater than that for conventional energy sources, purchasers of solar technology may need credit from suppliers or export banks.

71. WORLD BANK. 1975. Rural Electrification. Washington, D.C.: World Bank. October.

In 1971, rural electrification served 4% of the "village-rural" population of Africa, vs. 15% in Asia and 23% in Latin America. By 1985, service will reach less than one-tenth of Africa's village-rural population, vs. about one-fourth in Asia and about one-third in Latin America. In evaluating rural electrification projects, the paper notes, there may be reasons to accept internal rates of return somewhat below the opportunity cost of capital: benefits to households may exceed the price of power, subsidies may be desirable on social grounds, unquantifiable but positive side effects may follow from introduction of electricity, etc. Nonetheless, since normal economic criteria cannot be disregarded altogether, rural electrification is likely to be extended first to areas where development is already well underway and demand relatively great.

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72. WORLD BANK. 1976. Appropriate Technology in World Bank Activities. Washington, D.C.: World Bank. July 19.

In the energy area, the Bank has given most attention to possible ways of reducing the cost of centrally-generated electricity without unduly lowering standards of reliability. With respect to renewable energy sources, the Bank "regularly reviews" developments in the technologies of biogas, windmills, solar heating and solar electric systems, with photoelectric and biogas systems considered of greatest potential interest. As part of an industrial development project in Israel, the Bank supported applied research into use of Rankine cycle engines and solar ponds.