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AN EVALUATION OF BIOGAS, WINDMILL AND OTHER RURAL ENERGY TECHNOLOGIES IN SRI LANKA

TRIP REPORT
Travel Period: April-June 1981

by

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Technical Memorandum TM-81-2

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OBJECTIVES

General: To gather field data and first-hand experience in support of the technology assessment methodology known as the FLERT (Fuel-Linked Energy Resources and Tasks) approach, which is intended to provide a framework for evaluating and comparing small-scale renewable energy technologies that have potential in developing countries (Smith and Santerre 1980; Santerre and Smith 1980, 1981).

Specific: (1) To expand the database about resource utilization for construction and operation of anaerobic digesters (biogas plants) and water-pumping windmills; (2) To assess the progress of development of these technologies in Sri Lanka; (3) To assess the users' or owners' experiences of operating these technologies; and (4) To collect information on the use of resources for manufacturing materials used in the construction of these technologies.

RESULTS AND DISCUSSION

Institutional collaboration for trip and acknowledgements

Prior to leaving on this trip, requests were mailed to various institutions in Sri Lanka through which various types of logistic support (e.g. access to libraries, site visits) were sought. A favorable reply was received from Mr. B.P. Sepalage of the Energy Unit of the Ceylon Electricity Board (CEB) in the Ministry of Power and Energy of Sri Lanka. During my visit the CEB was quite helpful in providing me with the necessary arrangements for site visits to biogas plants, and the Water Resources Board arranged for visits to their windmill sites. I am especially grateful to Messrs. D.R.R. Seneviratne and B.P. Sepalage of the CEB, and to Mr. K.S. Fernando of the Water Resources Board (WRB) for their assistance.

Other individuals were quite helpful in an ancillary activity not originally one of the principal objectives of the trip--project proposal development. These individuals included Mr. N.U. Yapa of the National Science Council of Sri Lanka, and Messrs. Fredrich Abeyratne and John

Farrington of the Agrarian Research and Training Institute (ARTI) and Reading University.

I would also like to acknowledge the kind support and advice provided to me by Dr. G.B.A. Fernando of the Ministry of Finance and Planning, and Mr. Vitus Fernando of the USAID mission in Sri Lanka.

Anaerobic digestion technologies

There are several biogas plant development programs in Sri Lanka, and a total of more than 143 digesters have been constructed to date. Estimates of the number of digesters floating-dome and fixed-dome biogas plants constructed in Sri Lanka under different programs are provided in Table 1. The estimates were arrived at through interviews with various persons, personal observations, and in one case, a news feature on the radio.

It is probable that the total number of digesters in Sri Lanka is underestimated, principally because of difficulties encountered in meeting Mr. G.H. Upawanse, who heads the Agriculture Department's biogas plant development program; biogas plants constructed by universities in Sri Lanka are also not reported in Table 1. It is also possible, of course, that the number of digesters in other programs is also underestimated.

Table 1. Inventory of biogas plants presently constructed in Sri Lanka.

Promoting organization	Estimated number of floating-dome ("Indian type") digesters	Estimated number of fixed-dome ("Chinese type") digesters
Ceylon Electricity Board	10	50
Industrial Development Board	45	18
Department of Agriculture	?	2 +
In-Service Training Institute	1	2
Ceylon Institute of Scientific and Industrial Research		1
United Nations offices (Colombo)		1
National Engineering Research and Demonstration Center	1	2

Unknown SL institution in collaboration with Khadi and Village Industries Commission of India (from radio news item)	10	
	67	76

Promotion of these energy technologies is proceeding at a relatively rapid rate. For example, the Ceylon Electricity Board (CEB) estimates that it will have constructed an additional 200 fixed-dome digesters by the end of 1981 (D.S.R. Seneviratne, personal communication). In addition, it should be noted that there is one community-scale floating-dome system in operation at the Rural Energy Center at Pattiyapola, and one community-scale fixed-dome system under construction at Suwodagama model village near Andarawewa village, both built by the CEB.

It was impossible to estimate accurately the number of biogas plants that are still in good working order in Sri Lanka without a comprehensive survey--no surveys of this type are apparently being conducted by any Sri Lankan institutions. However, Mr. S.K. Rajapakse of the Industrial Development Board (IDB) indicated that only 20 of the 45 floating-dome digesters installed since 1972 by the IDB are still operational. These digesters were installed in schools to demonstrate the production of biogas from cattle dung, and have been abandonned for a variety of reasons, including various operational problems, or lack of interest or motivation to keep them operating.

It was also observed that none of the attempts by the National Engineering Research and Development Center to construct a digester using low-cost floating- or fixed-dome biogas plants using concrete reinforced with coir fiber or plastic fiber have been successful. At this stage, however, these digesters are only laboratory prototypes and have not been promoted in the rural areas.

Resource requirements for biogas plant construction. Data were collected on the use of materials and labor for the construction of fixed-dome digesters in use in Sri Lanka. With the possible exception of the collaborative project with the Khadi and Village Industries Commission (KVIC) of India, fixed-dome digesters are the principal type of biogas system being promoted in Sri Lanka at the present time. Although a household-scale floating-dome digester is reported to cost about 10,000 Rs ($US 540; materials and labor only; excluding profit, land, and gas appliances; IDB estimate), a fixed-dome digester of similar size costs between 3,000 and 5,000 Rs ($US 160-270; CEB and IDB estimates). In addition, routine maintenance of the fixed-dome biogas plant is reported to be less under Sri Lankan conditions, because the floating-dome plants require annual painting of the steel dome and periodic replacement of the flexible rubber gas hose attached to the dome.

The construction materials and labor requirements of four designs of digesters being promoted in Sri Lanka are provided in Table 2 [note: the construction materials required by the National Engineering Research and Demonstration (NERD) Center digesters are not reported because these designs have been unsuccessful]:

Table 2. Estimated resource requirements for the construction of Sri Lankan digesters (IDB (undated); Seneviratne 1981; also: personal communications).

Manufacturer	CEB	IDB	IDB	CEB
Type	Fixed-dome	Fixed-dome	Fixed-dome	Floating-dome[a]
Pit size (m^3)	6	10	35	6
Gas production capacity (m^3 of biogas per day)[b]	1.2-3.0	2.0-5.0	7.0-17.5	1.2-3.0
Materials				
Bricks	1,500	2,000	5,200	300
Cement[c] (kg)	500	750	1,750	36
Sand[d] (kg)	1,220	1,830	4,590	120
Lime[e] (kg)	34	75	150	?
Crushed stone[f] (kg)	300	450	610	240
Iron reinforcing rod (0.6 cm diam)(m)	0	15	0	0
Water sealing cement (kg)	0	12	0	0
Concrete pipe (10-15 cm diameter)(m)	3	3	?	?
Culvert (spun hume) pipe 1.4 m diam x 4 m total length x 8 cm wall thickness (number)	0	0	0	1
Gas pipe	varies	varies	varies	varies
Labor				
Mason	12-14	14	30	?
Laborers	22-24	36	65-70	?
Costs (materials and labor only)	3,000-4,000 Rs ($US 160-220)	5,000 Rs ($US 270)	13,000 Rs ($US 700)	?

Footnotes: (a) digester constructed from spun hume pipe, 1.4 meters in diameter with 8 centimeter thick walls, and a total length of about 4 meters; cement, sand, and brick estimates are based on approximate dimensions of digester. (b) assumed biogas production: 0.2 to 0.5 cubic meters of biogas per cubic meter of pit [note: it appears that these production values are intuitive guesses by the promoters of these technologies because I was unable to find

anyone who has actually measured gas production in a biogas plant in non-laboratory situations in Sri Lanka.]; (c) cement assumed to weigh 50 kilograms per bag; (d) sand assumed to weigh 1,600 kilograms per cubic meter; (e) lime assumed to weigh 3,250 kilograms per cubic meters; (f) crushed stone assumed to weigh 1,600 kilograms per cubic meter.

Resource requirements for biogas and electric power distribution from biogas plants. Piping biogas from a household-scale anaerobic digester to the kitchen area requires a relatively small quantity of material, usually less than 25 meters of plastic or metal pipe. Some of the materials costs of distributing electric power from a community-scale facility were provided to me by CEB engineers at the Rural Energy Center in Pattiyapola village. This 84 cubic meter per day biogas plant supplies 40 households with electricity for household lighting. These households are situated in a four square-kilometer area. In addition to electrical generators, 9.6 kilometers of aluminum cable (7 strands x 3.4 mm diameter) and 140 transmission poles are required.

Resource requirements for obtaining construction materials. Very little information is available in the developing country literature concerning the resource costs of obtaining construction materials, especially those which are produced by relatively decentralized manufacturers in rural areas of developing countries (see: Santerre and Smith 1981). Some data were collected by informal interview and observations during this trip--no attempt was made to confirm these figures by actual measurements (weights, etc.), and hence, these information should be considered preliminary in nature. The resource requirements for manufacturing bricks and lime, mining river sand, and assembling the gas collector of a floating-dome digester are summarized below:

1. Brick kiln

   a. Location. Debahara village (Meevitiya Road; about 27 miles from Colombo along Kandy Road).

   b. Kiln description. This unit is a traditional kiln, with approximately 15,000 bricks stacked in a manner to provide suitable spaces among the bricks for the circulation of hot gases, and tunnels formed into the stacked bricks to accommodate pieces of firewood. The dimension of the kiln is about four-meters square by 2.5 meters high.

      All but the outer layer of bricks become adequately heated during the firing process, for a total production of about 13,000 medium-quality bricks. The remaining 2,000 partially-fired bricks are fired in the next kiln that is constructed.

   c. Clay winning (mining), brick molding, drying. The source of clay used in brick manufacture is located less than 100 meters from the kiln. The clay is mined using hand tools, and then mixed with water and allowed to cure in a mound overnight. The bricks are

molded singly by hand in a wood frame which is coated on the inside with sawdust (apparently to prevent the clay from sticking to the wood), and stacked in rows to dry. The dimensions of a brick are 23 x 10 x 5 centimeters, each weighing about 1.5 kilograms (dried). No animal or machine power is used by this manufacturer during the brick-making process.

d. Resource requirements. The approximate resource requirements for the manufacture of bricks at this location were obtained by interview of the kiln owner and by personal observations. The resource requirements are given in Table 3 below:

Table 3. Resource requirements for the manufacture of bricks.

Resource	Quantity per 13,000 bricks	Quantity per 1,000 bricks
Firewood		
Coconut tree logs[a] (kilograms)	2,400.	180.
Rubber tree logs[b] (kilograms)	1,500.	110.
Clay (air dried weight in kilograms)	20,000.	1,500.
Labor[c] (person-days)		
Winning clay, transport 10 meters	11.	0.83
Kneading clay & water	11.	0.83
Molding bricks, stacking, drying	22.	1.7
Transport dried bricks to kiln	11.	0.83
Stacking bricks	5.2	0.40
Burning bricks (mostly tending fire)	5.2	0.40
Total person-days		5.0

Footnotes: (a) coconut logs: 60 required per 13,000 bricks; approximate dimensions: 1.4 meters x 0.2 meters diameter; logs assumed to weigh 40 kilograms each; (b) rubber tree logs: 6 cubic meters required; stacked rubber logs assumed to weigh 240 kilograms per cubic meter; (c) one person-day is here estimated to be about 10 person-hours; no attempt was made to assess the relative proportions of male and female labor.

e. Transport requirements. Firewood is transported from a three kilometer average distance from the kiln. At an average fuel consumption rate for lorries of 10 tonne-kilometers per liter of fuel (Diandas 1980), the one-way fuel requirement of transporting 3.9 tonnes of wood for one firing of the kiln is estimated to be 1.2 liters. No estimates are available for other resource requirements, for example, felling and loading trees, or transporting fired bricks.

2. Lime kiln

a. Location. Elukawela village in Kurunegala District.

b. Kiln description. This kiln is a 9 meters x 9 meters square x 5 meters high brick (or brick-and-earth) structure with a 1.4 meter diameter cylindrical pit running vertically down the center of the kiln. Crushed (5 centimeter pieces) of limestone (dolomite?) are stacked in alternating layers with firewood (coconut logs: 1 meter x 0.23 meter diameter each) in 0.3 meter thick layers at the top of the pit. As the firewood burns lower in the pit, the limestone is converted to lime, which is removed from an access port at the base of the pit. The process is semi-continuous, producing about one tonne of lime per day.

c. Resource requirements. The resource requirements for the manufacture of lime were obtained by interviewing the kiln owner and by personal observations. These estimates are provided in Table 4:

Table 4. Resource requirements for manufacturing lime.

Resource	Quantity per tonne of lime
Crushed limestone[a] (kilograms)	1,300-1,700
Firewood Coconut logs[b] (kilograms)	720
Labor[c] (person-days)	2

Footnotes: (a) 0.8 to 1.1 cubic meters of limestone required; estimated density of crushed limestone rock is 1,500 kilograms per cubic meter; (b) 24 coconut logs, with approximate dimensions of 1 meter x 0.23 meters are required; estimated weight per log: 30 kilograms; (c) one person-day estimated here to be about six person-hours of labor.

d. Transport requirements. Limestone is mined from a site approximately 40 kilometers from the kiln. At a fuel consumption rate of 10 tonne-kilometers per liter for lorry transport in Sri Lanka (Diandas 1980), transporting 1,500 kilograms of limestone per day (one-way only) requires 6.0 liters of fuel.

Firewood is obtained from an average distance of six kilometers from the kiln. At a fuel consumption rate of 2.0 tonne-kilometers per liter for tractor-trailer transport, transporting 720 kilograms of firewood per day (one-way only) will require 2.2 liters of fuel. No other resource requirements (e.g. felling, cutting, loading trees; transporting lime) were estimated.

3. River sand mining

a. Location. Unrecorded riverbed between Colombo and Kurunegala.

b. Description of activity. There are a number of similar operations along the roadways paralleling rivers throughout the country. We were able to stop only briefly, and observed a five-person sand mining operations. One man worked in the riverbed in water about one meter deep, scooping up sand from the river bottom with a bucket, and pouring the sand/water contents of the bucket into wicker baskets floating on a small raft. Four persons (three women; one man) each carried a basket of sand on their head up the approximately six meter high river bank.

Based on an estimated density of wet sand of 1,900 kilograms per cubic meter (dry sand weighs about 1,600 kilograms per cubic meter), and on an estimated basket capactity of 9 to 14 liters, the weight of an individual basket of wet sand could weigh 17 to 27 kilograms. One round-trip (fill basket, climb river bank, empty basket, return) by an individual carrier is estimated to require about three minutes. It is not known how many such cycles are performed during the course of the day. Transport of the sand is done by a tractor trailer (estimated capacity of about 0.7 to 1.0 cubic meters of sand) or by lorry.

4. Assembly of steel gas collector for floating-dome digester.

a. Location. Light Engineering Company, Kurunegala. This is the machine shop that was contracted to build gas domes for CEB's floating-dome digesters (6 cubic meter pit size: see Table 2).

b. Description of activity. Mild steel sheets of 2.0 mm thickness (14 gage British Imperial Standard) were obtained from a distributer in Colombo, and were arc welded to two-1.3 meter diameter steel hoops together with reinforcing rods of angle iron. The sheets are four meters long and 1.2 meters wide. After assembly, the gas dome is painted. Four domes were transported by 1.5 tonne lorry to the digester construction sites near Anuradhapura (a distance of about 120 kilometers).

c. Resource requirements. The resource requirements for fabricating a single gas collector are provided in Table 5. Only those resources consumed at the machine shop were tabulated. Estimates for the use of electricity by the arc welder were estimated from the approximate time the arc welder was switched on, and the power requirements of the device.

Table 5. Resource requirements for the fabrication of a single gas collector for a floating-dome digester with a pit size of six cubic meters.

Resource	Quantity
Steel, iron (mild steel sheet (4 m x 1.2 m x 2 mm); angle iron) (kilograms)	160
Electric power (kWh)	5
Paint (liters)	4
Labor (person-days)	
Skilled	9
Unskilled	6

Survey of owners or users of biogas plants. I prepared a preliminary survey questionnaire shortly after my arrival in Sri Lanka when I determined that there apparently was no organized effort of data collection based on user experience with renewable energy technologies in this country. Because this questionnaire was prepared rather hastily, it is not a very efficient survey instrument (see Appendix A). Much was learned, however, during its use and by comments received from persons with previous survey experience. These should assist in formulating an improved questionnaire in the future.

A total of six households were surveyed, although a larger number of other biogas plants were visited during the trip. This information is presented in Table 6, and should be considered to be preliminary in nature.

Wind energy technologies

At least three institutions in Sri Lanka are presently engaged in windmill development: the Water Resources Board (WRB), the Sarvodaya Movement, and the Light Engineering Company in Kurunegala. The Water Resources Board program is the largest, and at the time of my visit, 25 three-meter (diameter of area swept by blades) water pumping windmills have been installed in various locations throughout the country. By the end of 1981, it is anticipated that approximately 50 will have been installed; construction of 250 additional machines has been targeted for 1982.

Sarvodaya has installed six two-meter units, and the Light Engineering Company is experimenting with a three-meter windmill. With the exception of four Australian Dunlite electricity generating windmills located at the Rural Energy Center in Pattiyapola, virtually all the effort in windmill R&D in Sri Lanka appears to be directed towards water pumping systems.

Table 6. Results of a survey of six Sri Lanka households which operated biogas plants

	HOUSEHOLD A	B	C	D	E	F
1. Location						
a. Village	Ransedoda	Gannoruwa (Peradeniya)	Moragoda (Talawa)	Walagambahuwa (Dayagama)	Heeressagala	Gannoruwa (Peradeniya)
b. Latitude (approx.)	6° 02' N	7° 25' N	8° 15' N	8° 8' N	7° 10' N	7° 25' N
c. Longitude (approx.)	80° 35' E	80° 32' E	80° 25' E	80° 30' E	80° 35' E	80° 32' E
d. District	Matara	Kandy	Anuradhapura	Anuradhapura	Kandy	Kandy
e. 1) Nearest town or city with population > 8,000	Matara	Kandy	Anuradhapura	Anuradhapura	Kandy	Kandy
2) Distance from village to above town (kilometer)[a]	12	7	13	23	?	7
f. Distance from household to paved road (kilometer)	1	0.1	0.1	1	0.1	0.1
2. Household profile						
a. Number of persons residing in household[b]						
1) Adult males	4	1	2	1	1	1
2) Adult females	2	1	2	1	3	1
3) Children (5-14 years)	2	3	5	3		2
4) Infants, young children (< 4 years)	0		0	0		
5) Older adults (> 50 years)	1		0	0	2	
Total	9	5	9	5	6	4
b. Occupation of head of household	Postmaster (retired)	Institute director	CEB driver	Driver	Teacher (retired)	Staff In-service Trng. Inst.
c. Education (+: literate; -: illiterate; number years of schooling)[c]	11	>16	10	11	>16	>16
d. Quantity of land owned (hectares)	16	?	16	0.8	4	?
e. Water source (a. household well; b. piped water; c. community well or other sources)	b	b	c	a	?	b
f. Principal crops (Not ranked) 1)	Rubber	Home garden	Home garden "Chena" (mixed produce)	Home garden "Chena" (mixed produce)	Rice	Home garden
2)	Tea				Coconut	
3)	Rice		Gingerly oil seeds	Rice	Pepper	
4)	Cinnamon			Bananas	Mixed produce	
g. Livestock						
1) cattle[d] a) mature	4	0	0	0	6	0
b) young	1	0	0	0	5	0
2) pigs a) mature	0	0	0	0	0	0
b) young	0	0	0	0	0	0
3) chickens	0	0	8	0	0	0
4) goats	0	0	0	0	0	0
5) horses	0	0	0	0	0	0
3. Cattle confinement and feeding[e]						
a. Average hours per day confined	11	n.a.	n.a.	n.a.	19	n.a.
b. Average hours per day tethered	13	n.a.	n.a.	n.a.	0	n.a.
c. Average hours per day roaming free	0	n.a.	n.a.	n.a.	5	n.a.
d. Food types 1)	Browse	n.a.	n.a.	n.a.	Browse	n.a.
2)	Paddy straw				Paddy straw	
3)					Cut grass	

Continued

	HOUSEHOLD A	B	C	D	E	I
4. Biogas plant data						
a. Type	Fixed-dome	Fixed-dome	Floating-dome	Floating-dome	Fixed-dome	Fixed-dome
b. Pit size (m^3)[f]	6.0	8.0	~ 6	~ 6	~ 10	6
c. Rated daily gas production capacity (m^3)[g]	2.5 - 3.0	n.a.	2	2	?	?
d. Manufacturer/installer[h]	CEB	ISTI	CEB	CEB	Agriculture Department	ISTI
e. Date constructed	Dec. 1980	Jan. 1981	Sept. 1979	Sept. 1979	Jan. 1980	1979
f. Organic feedstock management facility						
1) Digester inlet connected to animal shed (+, -)	+	-	-	-	+	-
2) Digester inlet connected to latrine (+, -)	-	+	-	-	-	+
g. Size of sludge drying pit (m^2)	4	0	1	1	?	0
h. Distance from digester to dwelling (m)	12	4	20	20	15	5
i. Distance from digester to water source (m)	200	n.a.	25	15	15	n.a.
j. Type of organic residues usually used						
1) Animal dung (+, -)	+	-	+	+	+	
2) Animal urine (+, -)	+	-	-	-	+	-
3) Human wastes (+, -)	-	+	-	-	-	+
4) Household garbage (+, -)	-	+	-	-	-	+
5) Crop wastes (+, -)	-	-	-	-	-	-
k. Cost of plant at time of installation (Rs.)[i]	3,000+	3,500	0	0	8,000	1,500
5. Biogas plant operation						
a. Initial filling with dung						
1) Provided free by promoter (+, -)	+	n.a.	+	+	?	n.a.
b. Number of days until full gas production rate	14	?	?	?	?	?
c. Sufficiency of organic residue supply (+: owner feels supply is adequate; -: owner feels supply is inadequate)[j]	-	-	-	-	+	-
d. Frequency (#/day) waste added to biogas plant	2	?	0.5	0.3	3	?
e. Frequency (#/day) digester is stirred	2	0	1	?	0	0
f. Digester residue used in watery (W) state or in dried (D) state	W, D	W	D	D	W,D	W
g. Frequency of routine repairs and maintenance (#/year)[k]						
1) Unclogging biogas plant inlet or outlet	0	0	0	?	0	0
2) Unclogging gas pipe	0	0	0	?	0	0
3) Opening digester for cleaning or repair	0	0	0	?	0	0
4) Painting	n.a.	n.a.	0	0.4	n.a.	n.a.
h. Time required for digester-related activities						
1) Tending cattle (hr/day)	13[l]	n.a.	n.a.	n.a.	10	n.a.
2) Collecting organic feedstock, water (hr/day)	0.7	0	1	0.9	10	n.a.
3) Mixing inputs, stirring (hr/day)		0	.25			n.a.
4) Removing sludge (hr/day)	)					
5) Transporting sludge	) 0.5[m]	0.2	?	0.6	1[n]	0.1
6) Applying sludge to field	)					
7) Farmers impression of whether additional work (+ hours) or less work (- hours) or is same amount (0) of work is involved with operating biogas plant	+2	0	?	?	?	0

Continued

	HOUSEHOLD					
	A	B	C	D	E	F
i. Biogas use						
1) Number of meals per day cooked at household	3	3	3	3	3	3
2) Number of meals per day cooked with biogas[c]	1	0.5	1	0	2	0.5
3) Percentage of lamps used that are biogas-powered[p]	100	0	80	100	100	0
4) Use of other fuels for domestic tasks after installation of plant						
a) Cooking						
(1) Firewood (kg/day)[q]	7.3	0	?	?	12	0
(2) Kerosene (liters/day)	0	0	0	0	0	0
(3) Agricultural wastes (kg/day)	0	0	0	0	0	0
(4) Electricity (kWh/day)	0	?	0	0	0	?
b) Lighting						
(1) Kerosene (liters/day)	0	0	0.2	?	0	0
(2) Electricity (kWh/day)	0	?	0	0	0	?
5) Use of fuels for domestic tasks before installation of plant[q]						
(1) Firewood Kg/day)	3.4	n.a.	36	?	36-48	0
(2) Agricultural wastes (kg/day)	0	n.a.	0	?	0	0
(3) Kerosene (liters/day)	0.9	n.a.	1.1	?	1.3	?
(4) Electricity (kWh/day)	0	n.a.	0	?	0	?
6. General impressions						
a. Owner satisfaction (++ = satisfied; + = satisfied, but improvements needed; - = not satisfied)	++	+	++	++	+	++
b. Would owner install biogas plant again, based on present experiences (Y, N)	Y	?	Y	?	Y	Y

Notes:

?: data not available; n.a.: not applicable.

a. Distance is approximate straight-line distance from available maps.

b. Value could include live-in hired persons or hired persons consuming meals cooked by the household surveyed.

c. Education level indicated by "> 16" is value assigned to individuals who have university or post-graduate education or training.

d. No attempt was made to distinguish between the various species of bovines such as cattle or buffalo, although this will be important to measure in future studies.

e. Cattle confinement, tethering, or grazing patterns could vary within the animal population of a given household, depending on age or other factors. A single value is provided in this table in relation to the management practice used for the majority of animals.

f. Pit size of some of the digester are approximations based on available information on the dimensions of the digesters.

g. The daily biogas production capacitites of these digesters, where provided, are based on the impressions of the manufacturer, installer, or owner of the digester, and do not appear to be based on actual scientific measurements.

h. CEB: Ceylon Electricity Board; ISTI: In-Service Training Institute; digesters installed by Mr. Upawanse, who is now with the Agriculture Department.

i. Cost estimates are in Rupees at the time of construction. Costs may or may not include costs of excavation of pit, cost of biogas appliances, or cost of cowshed (if constructed with digester). Some digesters were built free of charge for households for demonstration purposes, with the households providing some labor assistance.

j. Many of the digesters were operated at a fraction of their designed capacity due to insufficient dung or other feedstock supply.

k. Does not indicate problems that are presently being experienced or impending (based on observation of improper maintenance). For example: Household B's digester has experienced a reduction in gas supply, possibly due to gas leaks or over-loading digester with feedstock; Household C's and Household D's digester has a brittle rubber gas hose which could begin leaking soon; Household E's digester has experienced a reduction in gas supply, possibly due to gas leaks, clogging of the gas pipe, or over-loading of the digester with feedstock.

l. Includes time for feeding cattle in stall.

m. The time requirements for digester residue management by this household differ depending on the temporary fertilizer requirements of the crop receiving the sludge. An average value is provided.

n. Residues are transported and applied three times each month, requiring one hour each time. An average value is provided.

o. Oftentimes, biogas is used for cooking certain types of dishes, such as curries. Other food items are cooked with other fuels when biogas supplies are insufficient, or for other reasons such as social preference.

p. For some households, this value is based on kerosene savings, not on the actual number of lamps involved. Kerosene is often used if biogas is in short supply, or because kerosene lamps are portable, while biogas lamps are not.

q. Firewood is often used for other purposes not detailed here, such as parboiling rice.

The size of windmills presently under development ranges from two to five meters, and are mostly horizontal-axis windmills. The estimated costs of some of these windmills are provided in Table 7 below:

Table 7. Size and estimated cost of windmills presently available or under development in Sri Lanka. Data were obtained from interviews of persons at these three institutions.

Manufacturer	Blade diameter	Estimated cost
Light Engineering Co.	2 meters	7,000-9,000 Rs ($US 380-490)
Sarvodaya Movement	2 meters	18,000-20,000 Rs ($US 970-1,080)
Water Resources Board	3 meters	15,000-18,000 Rs ($US 810-970)

These energy systems must seem rather costly to the average rural farmer in Sri Lanka, where average daily incomes in agriculture are less than $US 1.00-2.00. Unfortunately, windmill technologists in Sri Lanka do not appear to be very enthusiastic about the prospects for developing reliable low-cost alternatives to the expensive models that are presently available. This is partially due to previous experiences with low-cost units in Sri Lanka, in which the unit(s) tested were less than reliable. Consequently, the country is now left with windmill programs that will likely benefit relatively few persons in rural areas, because it appears that only relatively well-off farm households will find the present models affordable.

Although the experiences with low-cost designs of windmills have been negative in Sri Lanka, there is still considerable interest in such technologies in India. There are a number of institutions in India that have developed windmills using low-cost locally-available materials, but which are relatively efficient by virtue of having been designed using wind tunnel testing. It is possible that windmill technologists in Sri Lanka could benefit from the experiences of institutions in India, such as the Murugappa Chettiar Research Center in Madras or the Indian Institute of Science in Bangalore. A proposal for training technologists in India in the design, construction, and operation of low-cost windmills is included in Appendix B. [I prepared this proposal while in Sri Lanka, and received favorable reactions from local windmill specialists.]

Resource requirements for windmill construction. The data provided below (Table 8) were supplied by Mr. K.S. Fernando of the Water Resources Board. Detailed data were unavailable for the windmill designs of the Sarvodaya Movement and the Light Engineering Company.

Table 8. Description and resource requirements for a three-meter water pumping windmill.

Manufacturer: Water Resources Board, Sri Lanka
Type: horizontal axis, water pumping
Blades: 3 meter diameter (swept area); 6 GI sheet blades
Cut-in speed: 3 meters/second (7 mph)
Safety cut-out speed: 12.5 meters/second (28 mph)
Rated capacity: 36,000-45,000 liters/day @ 5 meter head[a] (approximate quantity of water required for irrigating 0.4 to 0.6 hectares).

Resource	Total
Materials (kilograms)	
Steel	250
Cement	250
Sand	830
Crushed stone	1,700
Labor (person-days)	
Manufacture[b]	
Skilled	27-32
Unskilled	27-32
Installation	
Skilled	8-10
Unskilled	12-15

Footnotes: (a) Rated water pumping capacity depends on wind velocity and other factors; reported capacity is assumed to be under ideal conditions; (b) Machine shop operations include: drilling, turning; no milling required.

General observations concerning biogas and other rural energy programs in Sri Lanka.

The individuals involved with biogas development in Sri Lanka are hardworking and dedicated, and appear to be experienced in all aspects of the construction and installation of biogas systems. At least one of these individuals has participated in the United Nations Environmental Programme's International Biogas Training Seminar in China. Consequently, the biogas plants being installed in Sri Lanka appear to be well designed and constructed, and if these plants are properly operated and maintained, should have the potential for providing years of service.

Based on my knowledge of the experiences that other countries have had with biogas plants and other rural energy technologies and my personal experiences in Sri Lanka, I would like to offer some constructive

criticisms of the efforts in this country to meet the energy needs of individuals in rural areas. Some of the problems that I observed could have important implications for the longer-term success of the Sri Lanka rural energy effort.

Follow-up services. In my opinion, perhaps the most serious shortcoming in the biogas development program in Sri Lanka is the apparent lack of coordinated follow-up services by the institutions promoting these energy systems. Owing to a general lack of experience among the recipients of this relatively new technology and a lack of institutional mechanisms for assisting persons who experience problems with their biogas plants, relatively minor technical problems (such as leaks) can be quite exasperating to plant owners.

With the number of biogas plants presently constructed in Sri Lanka estimated to be more than 140 units, and with expansion of this number proceeding rapidly, the coordination of follow-up consultative and repair services is imperative. Continuation of the Sri Lanka biogas program without such post-installation services could result in similar rates of abandonment of biogas plants--on the order of 25 to 60 percent--as have occurred in India (Bhatia 1981; Prakasam 1979; Sharma 1981) and Thailand (Ratasuk et al. 1979). A significant number of these biogas plants were abandoned due to lack of a means of ensuring the proper operation and maintenance of the digesters after being turned over to their new owners.

For example, one of the biogas plant owners whom I interviewed (Table 6: Household E) had been experiencing a gradual reduction in the biogas output of his plant for some time, and although he was quite well-educated, did not know how to troubleshoot or remedy the problem. During our visit to this household (our visit was not part of any intentional follow-up service), we observed the presence of gas bubbles in the sludge outlet of the plant, suggesting that the retention time of material (dung and water) in the digester was too brief. This might be due to an excessive rate of addition of material into the digester, thereby flushing out organic material and bacteria before decomposition could occur.

In addition to periodic scheduled visits to biogas plants (or other small-scale rural energy technologies) or other organized means of providing services, other suggested measures which could benefit the chances of successful introductions of biogas plants into the rural areas of Sri Lanka include the following:

a. Preparation of a Manual for Operating, Maintaining, Troubleshooting, and Repairing Your Biogas Plant, which could be distributed in three languages (Singhala, Tamil, English) to biogas plant owners, in order to provide them with information necessary to maintain their plants in good operating condition. Such a manual could be written by available biogas technology experts in Sri Lanka using information from published accounts of the Indian and Chinese experiences with biogas plants.

b. Setting up a Biogas Technology Information Office staffed by the biogas plant promoting agencies, which could be delegated the responsibility

of providing follow-up consultative services to biogas plant owners. This office could also compile a Biogas Newsletter to provide up-to-date information about the construction and operation of biogas plants, including a "letter-to-the-editor" column to facilitate the answering of questions regarding digesters, or practical suggestions from experts or current users of biogas technologies. Preparation of an annual directory of promoting institutions, research institutions, repair services, and other type of information would also be useful to plant owners as well as to R&D personnel.

Coordination and integration of rural technology programs. Another problem that I noticed was an apparent lack of overall coordination by some of the institutions involved in biogas development in Sri Lanka, with institutions involved with the development of other small-scale energy technologies or related non-energy technologies.

For example, most of the biogas development programs did not appear to be coordinated with cattle or buffalo development programs in the country, although this seems an ideal marriage because livestock are presently the most important source of organic feedstock for biogas plants. The possible exception to this might be the Agriculture Department's biogas program, although I was unable to obtain information about their projects.

Four to six adult cattle, or two to four adult buffalo could supply enough dung for a digester to meet the cooking, water purification, and lighting needs of a typical rural household, in addition to providing that household with a source of protein (milk) and draft power (see Ryan et al. 1980).

It would also seem worthwhile to coordinate livestock and biogas programs with institutions that promote improved access to water supplies. Besides being beneficial for other purposes, proximity of a reliable source of water to a biogas plant could significantly decrease the time requirements for operating this technology.

Coordination and integration could also be beneficially fostered among the various institutions in Sri Lanka that are involved in energy technology R&D. This coordination would help to ensure that their efforts to introduce their currently individually promoted energy systems into rural households or communities could provide for an optimum energy systems mix (i.e. the most suitable combination of energy technologies) and thereby meet the energy needs of their rural clientele in an efficient manner.

At the present time, there does not appear to be such coordination and integration. One site near Kurunegela which I had the opportunity to visit illustrates this problem. The farmer whom we visited was in the process of having a water-pumping windmill installed at a cost of about 18,000 Rs ($US 970). Since he also owned a diesel-powered generator, a kerosene-powered pump, and about 50 head of cattle, it is possible that he could have met his energy needs for irrigation, as well as his cooking and lighting needs solely from a biogas plant. This farmer had heard about biogas technologies, and was in correspondance with one of the biogas plant-promoting institutions in order to assess the potential and costs of

installing a digester. Because of lack of coordination among the different technology-promoting institutions, this farmer might have to invest in two different energy systems when, perhaps, the installation of only a biogas plant would have been sufficient.

Program emphasis. As was mentioned earlier in the case of windmill R&D in Sri Lanka, the rural energy R&D effort seems to put a disproportionate amount of emphasis in energy technologies that are affordable mainly by relatively well-off rural households. The comparatively high construction costs of some of the technologies presently available in Sri Lanka, for example, 18,000 Rs ($US 970) windmills and 5,000-10,000 ($US 270-540) biogas plants (not including other constraints such as the ownership of cattle or a well, or an adequate credit rating), appear to put these technology options out of the reach of the majority of rural households in this country. If either of these two groups of energy technologies are to have a greater impact on the energy situation in rural areas, than much more emphasis must be put on making them economically attractive.

Exploring the utilization of plant residues would seem a worthwhile approach in the biogas program in Sri Lanka, due to the limited availability of cattle and buffalo in many rural households. It appears that the only attempt to use plant feedstock materials is in a single fixed-dome digester in Colombo which is being fed with water hyacinth--a feedstock which is less commonly available than many types of agricultural wastes. Perhaps it would be worthwhile to begin experimentation with the use of plant residue feedstock (and the possible design modifications of the biogas plant that might be required) at one of the biogas demonstration plants, such as the fixed-dome digester at the Rural Energy Center in Pattiyapola.

There are engineering limitations that will govern how inexpensively these technologies (especially biogas plants) can be manufactured, while still maintaining an adequate degree of reliability and safety. There are also important resource constraints such as the availability of pasturage, water, and wind, that will limit the overall impact of biogas plants and windmills. Unfortunately, basic resource assessments for these two technologies have not been performed, or are limited in scope. For example, there are considerable discrepencies in the livestock census statistics among the agencies responsible for gathering these data. This makes estimation of the availability of dung difficult. There are also no adequate data on wind energy in various locations of the country.

Without access to this information, it is difficult to assess with any degree of certainty the importance of biogas technologies. Cooking and boiling water will undoubtedly continue to be the largest requirement for energy in rural Sri Lanka in the foreseeable future. From my own knowledge of the status of rural energy technologies, only a relatively few technologies are likely to have potential major significance in Sri Lanka within the next decade for supplying energy for domestic cooking and water sterilization. These technologies or fuels include: (a) firewood and charcoal technologies (b) biogas technologies; (c) peat; (d) coal burning stoves; and (e) direct combustion of plant and animal residues.

The latter two fuels could have certain undesireable features that should be considered. Coal will have to be imported into the country, thereby having negative balance-of-trade effects. Burning plant and animal residues, as is widespread in certain parts of India due to lack of firewood, could have negative environmental and economic impacts in the rural areas--an inexpensive source of fertilizer (animal dung) will become unavailable, and additional removal of plant or animal residues from the soil could result in a decrease in soil fertility.

Within the present rural energy programs in Sri Lanka it seems possible that the number of households that are likely to be potential recipients of biogas technologies will be limited due to two factors: (a) the costs of the presently available biogas plants, including even the fixed-dome ("Chinese") designs, are relatively high in terms of average rural incomes; and (b) the present program emphasizes the use of animal manures, especially from cattle or buffalo, which essentially restricts this technology to those families possessing more than two to four head, or who can afford to collect or purchase manure elsewhere.

These problems are not without possible solutions. Cost reductions of biogas plants are possible, and subsidy and low-interest loan programs could also improve this situation. The latter two possibilities could be attractive in Sri Lanka because of the prospects for using biogas as a replacement for kerosene for lighting purposes in rural areas, thus reducing petroleum imports, and also for using biogas as a replacement for firewood for cooking. In addition, successful demonstration of the use of plant residues could make this technology available to the large number of rural households that do not presently own sufficient livestock to support a biogas plant.

Improved-efficiency stoves and household and community woodlots for firewood production should receive a large share of R&D emphasis in Sri Lanka because of their potential to reach low-to-moderate income groups in rural areas. Although an examination of these technologies was not in the list of objectives of this trip, it did seem that these rural energy technologies have generated only a relatively low level of interest among Sri Lankan institutions, at least in relation to the relatively high levels evident for biogas technology development. It is possible, however, that during my visit I simply did not (by coincidence) encounter the major programs in this area, although I did become aware of modest improved efficiency firewood stove and charcoal stove programs promoted by the Industrial Development Board and the State Timber Corporation.

The possibility of using the two other energy sources mentioned in the above list, coal and peat, for rural domestic purposes has yet to be subjected to close scrutiny in most developing countries. Peat resources have been identified in Sri Lanka, as mentioned in Sankar and Fernando (1978). The feasibility of using these fuels for cooking purposes deserves further examination.

One other energy technology could have a potential for rural cooking and boiling water--solar cookers. I did not include solar cookers

in the above list because of possible physical and social limitations to their use in Sri Lanka. These factors, however, require closer examination. Solar cookers (at least inexpensive ones) are limited in their use by the availability of bright sunlight, which could restrict their use during the monsoon seasons. There are also possibly important social limitations to cooking outdoors, the constant attention solar cookers require to orient them correctly towards the sun, and the lack of accurate control of cooking temperature. It seems, however, that solar cookers conceivably be used by communities or institutions for purposes of sterilizing drinking water.

Technology monitoring. Although not apparently done at present, there are important benefits to be derived from monitoring energy technologies that have been installed in rural households or communities. Such monitoring could be aimed toward product improvement by encouraging present users of the technologies to discuss their energy systems' problems, and perhaps suggest improvements in design or operation. Monitoring would also help to illuminate situations in which introductions of a given energy technology are appropriate or inappropriate.

At the present time, the biochemical and physical parameters associated with biogas plant performance, such as gas production rates, pH, and feedstock quality, are not being monitored in "real-world" situations. Having these data would facilitate sizing of the biogas plant to the needs and resources of the household or community. These data will also be important in determining the gas production potential of agricultural plant residues and comparing their use with the presently used cattle dung feedstock.

CONCLUDING REMARKS

I found this trip to Sri Lanka to be very useful and personally rewarding. The information that I was able to gather provided valuable insights into biogas and windmill technologies. Some of the data that I collected will be incorporated into a paper entitled, "Measurements of Appropriateness: The Resource Requirements of Anaerobic Digestion (Biogas) Systems", by M.T. Santerre and K.R. Smith, which has been accepted for publication in the journal World Development.

Although the development of biogas plants is being energetically pursued by a variety of institutions in Sri Lanka, a concerted effort to initiate follow-up services and performance monitoring programs seems advisable at this time to ensure the viability of these technologies in rural areas. At present, there does not appear to be any means (via operation and maintenance manuals, or consultative services) that biogas plant owners can use to acquire information to keep their systems in good working condition.

I believe that considerably more emphasis is needed to coordinate rural energy programs with other rural development activities, such as livestock promotion campaigns and rural housing schemes. Efforts could also be made to better coordinate the diverse array of institutions in Sri

Lanka that are promoting various rural energy technologies. The current lack of coordination seems to result in institutions fulfilling quotas of number of devices installed, rather than measuring the number of rural households that have achieved some level of energy self-sufficiency (or other welfare measure) through successful adoption of an appropriate mix of energy and non-energy technologies.

Institutions involved with biogas technology R&D might consider testing the use of agricultural plant residues in demonstration biogas plants, and the constraints and opportunities presented in the rural area for the use of these residues as organic feedstock for biogas production. Although water hyacinth are being researched at present, casual observations made during my travels in various parts of the country suggests that agricultural residues were more abundant.

Although certain institutions were interested in or had modest programs to promote energy technologies suitable for low- to middle-income rural persons, such as improved stoves, these programs were much less visible to me during my visit to Sri Lanka than those promoting more expensive options. This suggests a possible underemphasis in the overall rural energy development effort in meeting the energy requirements of the majority of rural households. The present rural energy systems R&D, although apparently providing well-constructed and reliable energy systems, appears to be oriented towards technologies that are generally affordable only by well-off rural households.

One possible means of improving the availability of low-cost rural energy technology options in Sri Lanka is by means of training workshops conducted in countries with established expertise in certain technologies. The biogas training workshop in China is a good example of the effects such activities can have, since most of biogas plants presently being constructed in Sri Lanka are based on Chinese designs. Similar training workshops could also be considered for technologies such as low-cost windmills* and improved efficiency stoves.

* I have written a draft proposal for such a program which can be found in Appendix B.

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Appendix A

1.

SURVEY QUESTIONNAIRE FOR BIOGAS DIGESTER USERS AND NONUSERS

DATE OF SURVEY: _____
SURVEYOR'S NAME: _____
NAME OF HEAD OF HOUSEHOLD BEING SURVEYED: _____

PART I: GEOGRAPHIC ASPECTS

1. NAME OF VILLAGE: _____
2. NAME OF DISTRICT: _____
3. LATITUDE: _____; LONGITUDE: _____
4. ELEVATION (in meters): _____
5. TEMPERATURE MEAN AND RANGE (in °Celsius):
   a. MINIMUM: _____
   b. MAXIMUM: _____
   c. AVERAGE: _____
6. AVERAGE SEASONAL RAINFALL (in centimeters):
   a. NORTHEAST MONSOON PERIOD (NOV.-JAN.): _____
   b. INTERMONSOON PERIOD (FEB.-MAR.): _____
   c. SOUTHWEST MONSOON PERIOD (APR.-JUN.): _____
   d. INTERMONSOON PERIOD (JUL.-OCT.): _____
7. AREA OF VILLAGE (hectares): _____
8. NUMBER OF FAMILIES IN VILLAGE: _____
9. POPULATION OF VILLAGE: _____
10. DISPERSION OR CLUSTERING OF HOUSEHOLDS IN VILLAGE:
    a. NUMBER OF DISTINGUISHABLE CLUSTERS OF HOUSEHOLDS: _____
    b. PERCENTAGE OF HOUSEHOLDS OCCURRING IN CLUSTER: _____
11. DISTANCE (in kilometers) TO NEAREST:
    a. PAVED ROAD: _____
    b. UNPAVED OR JEEP ROAD: _____
12. DISTANCE (in kilometers) TO NEAREST:
    a. TOWN OR CITY WITH POPULATION LARGER THAN 10,000: _____
    b. TOWN, CITY, OR VILLAGE WHICH IS A SIGNIFICANT CENTER OF COMMERCE IN AREA: _____
13. PRINCIPAL AGRICULTURAL CROPS:
    a. _____
    b. _____
    c. _____
    d. _____
14. PRINCIPAL RURAL INDUSTRIES LOCATED IN VILLAGE:
    a. _____
    b. _____
    c. _____
    d. _____
15. ADDITIONAL INFORMATION CONCERNING GEOGRAPHIC ASPECTS OF VILLAGE, DISTRICT, OR HOUSEHOLD:

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DATE OF SURVEY: _____
SURVEYOR'S NAME: _____
NAME OF HEAD OF HOUSEHOLD BEING SURVEYED: _____

PART II: PROFILE OF HOUSEHOLD

1. NUMBER OF MEMBERS IN HOUSEHOLD WHICH ARE:
   a. ADULT MALES (15-50 years): _____
   b. ADULT FEMALES (15-50 years): _____
   c. MALE CHILDREN (5-14 years): _____
   d. FEMALE CHILDREN (5-14 years): _____
   e. INFANTS AND YOUNG CHILDREN (less than 4 years): _____
   f. OLDER ADULTS (more than 51 years): _____

2. OCCUPATIONS OF WORKING MEMBERS OF HOUSEHOLD:
   a. MEMBER: _____; OCCUPATION: _____
   b. MEMBER: _____; OCCUPATION: _____
   c. MEMBER: _____; OCCUPATION: _____
   d. MEMBER: _____; OCCUPATION: _____

3. QUANTITY OF LAND (in hectares):
   a. OWNED BY HOUSEHOLD: _____
   b. LEASED BY HOUSEHOLD: _____ (i.e. household is leasee)
   c. LEASED TO OTHER HOUSEHOLDS: _____ (household is leasor)

4. NUMBER OF LIVESTOCK OWNED BY HOUSEHOLD:
   a. CATTLE: YOUNG: _____; MATURE: _____
   b. PIGS: YOUNG: _____; MATURE: _____
   c. CHICKENS: _____
   d. OTHER (specify): _____ _____

5. NUMBER OF HOURS PER DAY ANIMALS ARE:

	CONFINED IN PEN	TETHERED BY ROPE	ROAMING FREE
a. CATTLE (each)			
b. PIGS (each)			
c. CHICKENS (each)			
d. OTHER			

6. TYPE OF FOOD EATEN BY ANIMAL:
   a. CATTLE: _____; _____; _____
   b. PIGS: _____; _____; _____
   c. CHICKENS: _____; _____; _____

7. NUMBER OF MEALS COOKED AT HOUSEHOLD EACH DAY _____

8. FUELS CONSUMED BY HOUSEHOLD:

	TYPE OF FUEL	TECHNOLOGY USED	TASK PERFORMED	QUANTITY PER WEEK OF FUEL
a.				
b.				
c.				
d.				
e.				
f.				
g.				
h.				

9. NUMBER OF MEMBERS IN FAMILY WITH THE FOLLOWING LEVELS OF EDUCATION:

DATE OF SURVEY: _____
SURVEYOR'S NAME: _____
NAME OF HEAD OF HOUSEHOLD BEING SURVEYED: _____

PART III. RECOLLECTION OF ACTIVITIES PERFORMED PRIOR TO INSTALLATION OF BIOGAS SYSTEM

1. QUANTITIES OF FUELS (in liters or kilograms) OF FUELS COLLECTED OR PURCHASED: (PLEASE INDICATE WHETHER COLLECTED (C) OR PURCHASED (P))

TYPE OF FUEL	TECHNOLOGY USED	TASK PERFORMED	QUANTITY PER WEEK	(C)	(P)
a.					
b.					
c.					
d.					
e.					
f.					
g.					
h.					

2. PRIOR TO USE OF DIGESTER, INDICATE NUMBER OF HOURS PER DAY ANIMALS ARE:

	CONFINED IN PEN	TETHERED BY ROPE	ROAMING FREE
a. CATTLE:			
b. PIGS:			
c. CHICKENS:			
d. OTHER			

3. WERE METHODS OF FEEDING CATTLE OR OTHER LIVESTOCK CHANGED AFTER INSTALLATION OF BIOGAS SYSTEM? ___YES; ___NO. EXPLAIN IF "YES":

4. INDICATE WHAT THE DUNG AND URINE OF THESE LIVESTOCK WAS USED FOR BEFORE INSTALLATION OF BIOGAS SYSTEM, AND APPROXIMATE TIME INVOLVED WITH THIS ACTIVITY: (indicate also if sold, burned, etc.)

WASTE MATERIAL	USE	TIME NEEDED TO HANDLE, TRANSPORT, APPLY
a.		
b.		
c.		
d.		

5. INDICATE WHETHER HOUSEHOLD HAULS WATER FOR IRRIGATING CROPS, AND DISTANCES INVOLVED AND TIME REQUIREMENTS:
   a. DOES HOUSEHOLD USE WATER TO IRRIGATE CROPS? ___YES; ___NO
   b. INDICATE SOURCE OF WATER: DISTANCE FROM DWELLING:
      1) GRAVITY FED SLUICE/PIPE
      2) TUBE WELL/PUMP
      3) SURFACE WELL
      4) OTHER(indicate)
   c. TIME REQUIREMENTS FOR HAULING WATER _____ PER DAY.
   d. NUMBER OF DAYS PER YEAR WATER IS HAULED _____

6. ATTEMPT TO GET FARMER'S IMPRESSIONS OF WHETHER HE WORKED MORE HOURS OR FEWER HOURS OR ABOUT THE SAME NUMBER OF HOURS PER DAY (INCLUDING MEMBERS OF FAMILY AND HIRED LABOR) BEFORE AND AFTER INSTALLATION OF BIOGAS SYSTEM:
   a. NUMBER OF HOURS PER DAY ADDITIONAL WORK: _____
   b. NUMBER OF HOURS PER DAY LESS WORK: _____
   c. NO CHANGE:

DATE OF SURVEY: _____
SURVEYOR'S NAME: _____
NAME OF HEAD OF HOUSEHOLD BEING SURVEYED: _____

PART IV. CONSTRUCTION OF BIOGAS SYSTEM

1. INDICATE OWNER'S REASONS FOR INSTALLATION OF BIOGAS SYSTEM:
   a. RISING FUEL COST: ___
   b. PRODUCTION OF BETTER QUALITY FERTILIZER: ___
   c. MORE CONVENIENT AND CLEANER-BURNING FUEL: ___
   d. OTHER (indicate):

2. INDICATE APPROXIMATE DATE HOUSEHOLD DECIDED TO INSTALL SYSTEM: _____

3. INDICATE APPROXIMATE DATE HOUSEHOLD (OR OTHERS) BEGAN CONSTRUCTING SYSTEM: _____

4. INDICATE APPROXIMATE DATE HOUSEHOLD (OR OTHER) FINISHED CONSTRUCTING SYSTEM: _____

5. INDICATE TYPE OF DIGESTER, PIT SIZE, AND RATED CAPACITY:
   a. DIGESTER TYPE: ____ FLOATING-DOME (INDIAN DESIGN)
      ____ FIXED-DOME (CHINESE OR JANATA DESIGN)
   b. PIT SIZE (cubic meters): _____
   c. RATED BIOGAS PRODUCTION CAPACITY (cubic meters per day): _____

6. INDICATE DIMENSIONS OF DIGESTER(IF POSSIBLE):
   a. SHAPE: _____
   b. LENGTH (OR DIAMETER): _____
   c. WIDTH: _____
   d. DEPTH (from bottom of pit to top of pit): _____

7. INDICATE MIXING TANK AND INLET CONFIGURATION:
   a. ___ MIXING TANK AND INLET NOT CONNECTED TO ANIMAL CONFINEMENT AREA
   b. ___ MIXING TANK AND INLET ARE CONNECTED TO ANIMAL CONFINEMENT AREA
   c. ___ MIXING TANK AND INLET NOT CONNECTED TO HOUSEHOLD LATRINE
   d. ___ MIXING TANK AND INLET ARE CONNECTED TO HOUSEHOLD LATRINE

8. INDICATE WHETHER:
   a. ___ANIMAL DUNG (SOLID FECAL MATERIAL) ONLY IS USED
   b. ___BOTH ANIMAL DUNG AND ANIMAL URINE ARE USED

9. INDICATE DIMENSIONS OF:
   a. DIGESTER RESIDUE (SLUDGE AND EFFLUENT) STORAGE AREA: (in meters)
      1) LENGTH (OR DIAMETER): _____
      2) WIDTH: _____
      3) DEPTH: _____
   b. DIGESTER RESIDUE (SLUDGE AND EFFLUENT) DRYING AREA (IN meters):
      1) LENGTH (OR DIAMETER): _____
      2) WIDTH: _____
      3) DEPTH: _____

10. INDICATE CONSTRUCTION MATERIALS USED:
   a. FORDIGESTER, INLET, OUTLET, DOME:

	MATERIAL	QUANTITY (metric)	QUALITY
1)			
2)			
3)			
4)			
5)			

5.

DATE OF SURVEY: _____
SURVEYOR'S NAME: _____
NAME OF HEAD OF HOUSEHOLD BEING SURVEYED: _____

11. (CONSTRUCTION MATERIALS--CONTINUED):
b. STORAGE AND DRYING PIT:

MATERIAL	QUANTITY (METRIC)	QUALITY
1)		
2)		
3)		
4)		
5)		

c. GAS DISTRIBUTION SYSTEM (PIPE/BAG):

MATERIAL	QUANTITY (METRIC)	QUALITY
1)		
2)		

12. INDICATE APPROXIMATE DISTANCES (IN KILOMETERS) TO:

	VENDOR	MANUFACTURER OR SOURCE
a. BRICKS		
b. CEMENT		
c. METAL COMPONENTS		
d. SAND, GRAVEL, STONE		
e. MACHINE SHOP/ SMITHY		
f. MASON/ BRICKLAYER		
g. SOURCE OF EXPERT ADVICE ON BIOGAS SYSTEMS		

13. INDICATE WHETHER OWNER HAD DIFFICULTY OR LONG WAITING PERIODS IN ORDER TO ACQUIRE CONSTRUCTION MATERIALS: ___YES; ___NO. IF "YES", EXPLAIN:

14. INDICATE LABOR REQUIRED FOR CONSTRUCTION OF SYSTEM (PD: PERSON-DAYS; PH: PERSON-HOURS):

	DONATED FROM FAMILY/FRIENDS	PAID UNSKILLED	PAID SKILLED	DONATED SKILLED
a. SURVEYING/PLANNING				
b. OBTAINING MATERIALS				
1) PURCHASED MAT.				
2) COLLECTED MAT.				
c. DIGGING PITS				
d. LAYING FLOOR				
e. MASONRY/BRICKLAYING				
f. CARPENTRY				
g. INSTALLING GAS LINE				
h. TOTAL				

6.

DATE OF SURVEY: _ _____
SURVEYOR'S NAME: _____
NAME OF HEAD OF HOUSEHOLD BEING SURVEYED: _____

PART V. OPERATION OF DIGESTER

1. INDICATE THE NUMBER OF DAYS (PERSON-DAYS) NEEDED TO FILL DIGESTER WITH DUNG AND WATER: _____

2. INDICATE THE NUMBER OF DAYS FOLLOWING THE BEGINNING OF FILLING THE DIGESTERTHAT BIOGAS PRODUCTION STARTED: _____

3. INDICATE THE NUMBER OF DAYS FOLLOWING THE BEGINNING OF FILLING THE DIGESTER THAT BIOGAS PRODUCTION WAS AT ITS MAXIMUM RATE: _____

4. INDICATE WHETHER USER FEELS HE HAS ENOUGH DUNG TO MEET HIS REQUIREMENTS FOR GAS PRODUCTION: ___ YES; ___ NO. IF "NO"; EXPLAIN PROBLEM:

5. INDICATE THE PERCENTAGE OF AVAILABLE DUNG THAT THE OWNER IS USING IN DIGESTER ___% . INDICATE THE QUANTITY OF DUNG (KILOGRAMS): _____.

6. INDICATE THE QUANTITY OF WATER ADDED PER KILOGRAM OF DUNG: _____.

7. INDICATE THE FREQUENCY DUNG IS ADDED TO DIGESTER:
   a. ____ CONTINUOUSLY OR SEMI-CONTINUOUSLY (I.E. AUTOMATIC SYSTEM)
   b. ____ ONCE DAILY
   c. ____ TWICE DAILY
   d. ____ THRICE DAILY
   e. ____ NUMBER OF TIMES PER WEEK: INDICATE NUMBER: _____

8. INDICATE NUMBER OF TIMES PER DAY OR WEEK DIGESTER IS STIRRED: ____/____

9. HOW OFTEN IS THE FOLLOWING MAINTENANCE OR REPAIR PERFORMED, AND INDICATE HOW LONG (HOURS) IT REQUIRES EACH TIME:

	FREQUENCY	TIME REQUIRED
a. UNCLOGGING INLET OR OUTLET		
b. UNCLOGGING GAS PIPE		

10. INDICATE FREQUENCY AND TIME REQUIRED TO COMPLETELY CLEAN (AND EMPTY AND REFILL) DIGESTER: FREQUENCY _____/_____; TIME REQUIRED: _____DAYS; LABOR REQUIRED: _____PERSON-DAYS.

11. INDICATE FREQUENCY OF REPAIR OF: (or replacement of)

COMPONENT	FREQUENCY OF REPAIR	NATURE OF PROBLEM
a.		
b.		
c.		
d.		
e.		

12. IF DIGESTER IS INDIAN DESIGN (FLOATING METAL DOME) INDICATE FREQUENCY OF PAINTING AND TIME REQUIREMENTS:
    a. FREQUENCY OF PAINTING: _____
    b. LABOR REQUIREMENTS (PERSON-DAYS): SURFACE PREPARATION_____: PAINTING_____.
    c. NUMBER OF LITERS OF PAINT REQUIRED: _____; _____ PERCENTAGE OF INSIDE AND OUTSIDE SURFACES PAINTED

DATE OF SURVEY: _____ 39
SURVEYOR'S NAME: _____
NAME OF HEAD OF HOUSEHOLD BEING SURVEYED: _____

PART V. (CONTINUED)

13. INDICATE THE APPROXIMATE TIME IT TAKES TO PERFORM THE FOLLOWING, AND WHO PERFORMS (USUALLY) THE TASK: (PERSON-HOURS PER DAY)

	ADULT MALE	ADULT FEMALE	MALE CHILD	FEMALE CHILD	OLDER ADULT	DRAFT ANIMAL
a. TENDING CATTLE						
b. COLLECTING DUNG						
c. MIXING INPUTS						
d. STIRRING DIGESTER						
e. REMOVING SLUDGE						
f. TRANSPORTING SLUDGE						
g. APPLYING SLUDGE TO FIELD						
h. COOKING						

14. INDICATE WHETHER:
   a. DIGESTER RESIDUE IS USED IN WATERY STATE: ___YES; ___NO
   b. DIGESTER RESIDUE IS USED IN DRIED STATE: ___YES; ___NO
   c. DIGESTER RESIDUE IS FED TO ANIMALS: ___YES; ___NO
   d. OTHER (DESCRIBE):

PART VI. GENERAL IMPRESSIONS

1. INDICATE WHETHER OWNER IS SATISFIED WITH BIOGAS SYSTEM:
   a. ___ YES; OWNER IS SATISFIED WITH SYSTEM
   b. ___ YES; OWNER IS SATISFIED WITH SYSTEM, BUT FEELS THAT THERE IS MUCH ROOM FOR IMPROVEMENTS.
   c. ___ NO, OWNER IS DISSATISFIED WITH SYSTEM
2. INDICATE WHETHER OWNER WOULD INSTALL BIOGAS SYSTEM IF HE HAD TO MAKE DECISION AGAIN:
   a. ___ YES, OWNER WOULD INSTALL A BIOGAS SYSTEM AGAIN
   b. ___ NO, OWNER WOULD NOT INSTALL A BIOGAS SYSTEM AGAIN

   EXPLAIN REASONS FOR ANSWER:

3. WHAT DOES OWNER LIKE LEAST ABOUT BIOGAS SYSTEM: (EXPLAIN)

4. WHAT DOES OWNER LIKE MOST ABOUT BIOGAS SYSTEM: (EXPLAIN)

Appendix B

PROPOSAL FOR THE TRAINING OF TECHNICAL PERSONNEL FROM SRI LANKA IN THE DESIGN, CONSTRUCTION, OPERATION, AND MAINTENANCE OF LOW-COST INDIAN-DESIGN WATER PUMPING WINDMILL.

INTRODUCTION

One important means of improving agricultural productivity in the dry zone of Sri Lanka is by increasing the availability of irrigation water. In many areas of the dry zone it is not practical to divert water from catchment areas by way of canal, sluice, or pipe. Some of these locations have groundwater resources within a reasonable depth, and with a suitable pump the water can be made available for irrigation.

Since only about 10 percent of the villages in Sri Lanka are connected to a power grid, electrical pumpsets have only a limited potential in rural areas. This has confined non-gravity based irrigation to internal combustion pumpsets, or using animate energy in lifting water. Unfortunately, the high costs of internal combustion pumpset and the ever-increasing costs of petroleum-based fuels have limited this technology to relatively few farms in the dry zone. Also, the use of human or animal-powered lifting of subsurface water has practical limitations to the area of cropland that can be cultivated in this manner.

The Water Resources Board in Sri Lanka has developed a reliable water pumping windmill capable of lifting 8,000 to 10,000 gallons of water per day, which is suitable for irrigating about 1 to 1.5 acres of land. The diameter of the area swept by the blades of this windmill is three meters, and the attached pump is capable of water delivery at a five meter head. Fifty of these units are scheduled to be built in 1981, of which 21 have already been commissioned.

Manufactured in Sri Lanka utilizing metal components and technical skills readily available in most major population centers in the country, the total costs for intalling this windmill is approximately Rs.15,000 (US$800). Although this is a relative inexpensive technology, it is affordable mostly by relatively well-off farmers in Sri Lanka, or successful farmers who can qualify for long-term low interest loans.

Having already developed a reliable windmill for water pumping, and having developed the technical expertise for research, demonstration, ad development of wind energy systems in Sri Lanka, it seems logical that the experiences gained to date should be applied to the development and testing of even lower cost water pumping windmills. Such a device should be available to a broader spectrum of income levels in the rural area, be simple in design, contructed as much as possible from materials indigenous to Sri Lanka, and be capable of being operated and repaired using locally-available skills and materials.

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Rather than initiate an entirely new windmill development and testing effort involving lengthy research, testing, and demonstration, it is proposed here that appropriate persons (already actively engaged in windmill or energy for rural development RD & D) from Sri Lanka travel to India for training in the design, construction, operation, and maintenance of the low-cost windmills, such as those that have been developed at the Murugappa Chettiar Research Centre (MCRC) at Tharamani, Madras.

The windmills designed at MCRC have undergone extensive development and testing, and are constructed of locally-produced poles and wood, and have sails made from jute fabric. Metal components are kept to a minimum, and are used only if necessary to ensure reliability or significantly increase efficiency. It is expected that the experience gained by members of the Sri Lanka study group will permit these persons to adapt these low-cost designs to local conditions.

METHODOLOGY

An appropriate committee will be formed to select participants for this study tour. Eight persons will be selected for the study tour by the committee, who will ensure that properly qualified persons actively engaged in windmill or energy for rural development activities are selected. The committee will also seek to ensure that both public and private development organizations are adequately represented in the study tour.

A coordinator of the study tour will be selected from among the eight participants, and will work with the MCRC in India in making the final arrangements for the tour, and in developing an itinerary of activities. The study group will travel by air to Madras, and be provided suitable guest house accommodations, per diem, and transportation arrangements. The MCRC staff will be augmented by providing airfare and accommodations for two other Indian experts on low-cost windmills. The entire group will spend one week at the MCRC (or in nearby villages) working with and receiving instruction from the MCRC staff and Indian experts, and become directly involved in all aspects of the design, construction, operation, and maintenance of low-cost windmills.

Following their return to Sri Lanka, the coordinator of the study tour will coordinate the preparation of a detailed report of the study tour, including appropriate diagrams, tables, and descriptions of the design, construction, operation, and maintenance of these windmills. This report should be completed within two months after returning to Sri Lanka. It is then anticipated that some members of the study tour will develop follow-up proposals for adapting and demonstrating these low-cost designs in Sri Lanka.

TIMETABLE

(note: the proposed starting dates could be changed to allow for suitable scheduling with the individuals involved, or to allow for ideal wind conditions or working conditions in Madras).

	1	2	3	4	5	6	7	8	9	10	11	12	13
1. Organize selection committee; participants selected; arrangements made;									x	x	x		
2. Study tour in Madras											x		
3. Preparation of final report												x	x

BUDGET (incomplete)
(US dollars)

Institution	Donor	Coordinating	MCRC
Personnel			
a. Coordinater(0.5 person-months)		x	
b. MCRC staff and Indian experts (2.5 person-months)	x		
Air travel			
a. Eight round-trip airfares Colombo-Madras	x		
b. Two round-trip airfares in-country India	x		
Ground transportation			
a. 20/day x 7 days x 10 persons	1,400		
Facilities			
a. coordinating institution		x	
b. MCRC			x
Field equipment, construction materials	2,000		
Photocopy, duplication, postage	500		
Final report (2 x 100 copies)	200		

AUTHOR'S PROFILE

MICHAEL T. SANTERRE, M. S., Oceanography, University of Hawaii, 1974. Prior to being awarded a fellowship at the East-West Center, was a research associate at the Hawaii Institute of Marine Biology and the Hawaii Natural Energy Institute. He assisted in planning and writing the State of Hawaii's Aquaculture Development Program. He has researched various aspects of applied aquatic ecology with emphasis on waste utilization, aquaculture, and environmental physiology. His current research interests include the evaluation of small-scale renewable energy technologies that have potential applications in developing countries, and in building an information exchange network that focuses on energy and rural development.

THE ENERGY FOR RURAL DEVELOPMENT PROGRAM

The principal aim of the Energy for Rural Development (ERD) program is to support the intercountry sharing of experience, insight, and information among rural energy planning, research, and implementing agencies in eight countries: Bangladesh, India, Indonesia, Nepal, Philippines, Sri Lanka, Thailand, and the United States. The ERD program is guided by a Steering Committee composed of members from each participating country. The Steering Committee is chaired by Dr. Sanga Sabhasri, Secretary-General of the National Research Council (NRC) of Thailand. The Program Secretariat is located in the offices of the NRC. Research continuity and interaction are fostered by involvement of a small ERD team and information support facilities at the East-West Resource Systems Institute, Honolulu, Hawaii, co-sponsor of the problem definition and concept workshops that cooperatively launched the program.

Objective

The overall ERD objective is to clarify key energy policy and technology development issues faced in meeting rural development needs. The research undertakes to account for the felt needs of rural people in both the formulation of rural development objectives and the planning and implementation of rural energy programs. Specific objectives include:

1. Definition of policy issues, particularly those arising from uncertainties in the supply of energy for agricultural production and rural domestic needs, that give focus to the development and application of relevant methods, technologies, and policy analyses.

2. Development of methods to assess felt needs and the bearing of these needs on technical, economic, and social attributes of viable energy technologies.

3. Refinement of methods to assess viability of technologies and to gain understanding of village characteristics and capabilities bearing on technology adoption. These methods are focused on specific technologies being developed by institutions who are participating in the program.

4. Progress in development and adoption of biogas, fuelwood, solar, and other selected technologies. This program objective involves close interaction with the results of needs assessment, viability assessment, and policy studies.

Research Plan and Organization

The ERD program is based on a cooperative action plan for intercountry research and communications support. The plan involves four interrelated activities:

1. Rural Development Objectives, Energy Needs Assessment, and Data Development.

2. Biogas: Technology, Assessment, and Social Organization.

3. Fuelwood: Technology, Assessment, and Social Organization.

4. Solar and Other Systems: Technology, Assessment, and Social Organization.

In these four activity sets, some 14 committed projects are underway in the participating countries while some 16 firm proposals are at advanced stages of funding review. Further, the intercountry ERD Research Committee has referred some 24 pre-proposals back to their sponsoring institutions to strengthen their quality of detail and relevance in line with ERD proposal guidelines.

The makeup of country institutions participating in ERD in its first operational year, 1980-81, is indicated in Attachment 1. A key to the interest generated by the program, and to its potential effectiveness, is the mix among fields of specialization represented in these institutions. They include capabilities in energy planning and technology, rural development planning and organization, agriculture, forestry, manufacturing and marketing, science policy, economics, sociology, and public systems management.

Program Development and Products

In ERD's first year of operation, participating groups have organized and exchanged basic reference materials; designed rural energy surveys and reported their first fieldwork results; formulated criteria for evaluating small-scale energy technologies; applied these criteria to the assessment of biogas and wind energy systems; adopted standards and a program for intercountry performance trials of fast-growing fuelwood and fodder species; and established a basis for comparative analysis of rural energy systems. A partial list of reports in each activity set is provided in Attachment 2.

Projects scheduled for completion and advanced development in 1981-82 include: a manual on rural energy research methods; comparative analysis and interpretation of village energy studies for policy and program application; development of accounting methods on fuelwood supply and demand, and of data and coefficients for estimation of biomass resource inventories; and cooperative writing of a major project book. Further, somewhat earlier than originally planned, work is in hand to apply and adapt research results (a) for use by local community groups in assessing and planning their own renewable energy development projects, and (b) for training technologists and extension workers in techniques of engaging with local communities in selection, design, and organization of appropriate energy technologies.

Funding

Support for ERD intercountry activities has been provided through a grant from the U.S. Agency for International Development which concludes in the current year, with additional support from the East-West Center Resource Systems Institute and other ERD member institutions. Support for incountry activities is provided by national and state governments, research institution budgets, energy and rural development corporations, industry, and voluntary organizations. The level of research need, however, and the momentum of policy and action-oriented projects and proposals organized by the ERD program to meet this need, are not yet matched by international resources on a scale adequate to meet critical energy and rural development objectives.

Attachment 1

TABLE 1

ENERGY FOR RURAL DEVELOPMENT PROGRAM

Participating Institutions by Country and Type of Institution
September 1980

Type of Institution / Country	National Policy Agencies			Academic Institutions		Implementing Agencies		
	Planning and Finance	Energy	Science and Technology	Scientific and Technological	Social and Institutional	Agriculture, Forestry and Rural Development	Technology Research, Development and Extension	Energy and Industry
ngladesh	Planning Commission			Bangladesh Univ. of Engineering and Technology	Bangladesh Inst. of Development Studies	Department of Forestry	Inst. of Fuel Research and Development, Bangladesh Council of Scientific and Industrial Research	
dia			Department of Science and Technology	Madurai Kamaraj Univ. University of Kalyani	Indian Inst. of Management, Ahmedabad	District Forest Dept, Madurai	State Planning Inst., Lucknow Appropriate Technology Development Assn. Centre of Science for Villages. Central Salt and Marine Chemicals Research Inst.	Central Electricity Authority. Central Electronics, Ltd. Jyoti Ltd.
nesia		Ministry of Mines and Energy		Inst. of Technology Bandung, Development Technology Center	Center for Strategic and International Studies	Bogor Agricultural Univ. Forest Products Research Institute. Directorate of Rural Development, Community Development Department		National Electric Co. Oil and Gas Technology Development Centre
pal	National Planning Commission		National Council for Science and Technology	Research Center for Applied Science and Technology, Tribhuvan Univ.		Agriculture Project Service Center		
ilippines		Ministry of Energy		Univ. of Philippines at Los Banos	Institute of Philippine Culture Development Academy of the Philippines	Ministry of Human Settlements		Center for Nonconventional Energy Development
i Lanka	Ministry of Finance and Planning. Ministry of Plan Implementation	Ministry of Power and Energy.	Ministry of Industries and Scientific Affairs	Univ. of Peradeniya		Department of Agriculture. Ministry of Mahaweli., Development and Forest Dept., Water Resources Board		Ceylon Electricity Board. Ceylon Institute for Scientific and Industrial Research., National Engineering Research and Development Organization
iland		National Energy Administration	National Research Council	Chulalongkorn Univ., Chiang Mai Univ., King Mongkuts Inst., Khon Kaen Univ., Mahidol Univ.	Institute of Agricultural Technology	Royal Forest Department, Department of Agriculture		
ted States America S.A.)				Lawrence Berkeley Laboratories	Resource Systems Inst., Environment and Policy Inst., Univ. of Hawaii. State Univ. of New York. Univ. of California (Berkeley)		Volunteers in Technical Assistance	

Best Available Document

Attachment 2

ENERGY FOR RURAL DEVELOPMENT PROGRAM REPORTS AND REFERENCE MATERIALS (Partial list)

RESEARCH PLAN AND ORGANIZATION

National Research Council of Thailand and East-West Resource Systems Institute Energy for Rural Development Implementation Plan for Intercountry Research Activities, 1980-1983. ERD-PR-80-1. Chiang Mai April 1980.

National Research Council of Thailand and East-West Resource Systems Institute. Energy for Rural Development Steering Committee Decisions and Program Management Plan. ERD-PR-80-2. Honolulu. July 1980.

National Research Council of Thailand and East-West Resource Systems Institute. Energy for Rural Development: Report and Recommendations of Research Committee. ERD-PR-80-3. Pattaya. October 1980.

ACTIVITY 1. RURAL DEVELOPMENT OBJECTIVES, ENERGY NEEDS ASSESSMENT, AND DATA DEVELOPMENT

Raymond Atje and James Tarrant. Aspects of Rural Energy Use and Resources in West Java: A Preliminary Analysis of the Household Sector. In Atje et al., Energy Analysis in Rural Regions: Studies in Indonesia, Nepal, and the Philippines. ERD PR I-80-2: USA I-2/INA I-2.

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