Matching Renewal Energy Sources
to Rural Development Needs: A PROTOTYPE DESIGN
FOR A RURAL COMMUNITY DEVELOPMENT CENTER FOR
JAMAICA, W.I.

by Michael Onaje Jackson
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Signature of Author ______________________________
Department of Architecture
May 13, 1982

Certified by ______________________________
Tunney Lee
Associate Professor
Architecture and Urban Studies

Accepted by ______________________________
Chairman Departmental Committee
for Graduate Studies

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Submitted to the Department of Architecture on May 14, 1982, in partial fulfillment of the requirements for the Degrees of Master of Architecture and Master of City Planning.

ABSTRACT

The opportunities for utilizing Jamaica's rich supply of renewable energy resources as a base for steady, environmentally sound rural development is tremendous. This thesis explores a way of tapping this potential. Jamaica's current plans for both energy and rural community development are reviewed and general suggestions offered as to how the necessary integration of the two plans can be achieved for short and long term energy conscious planning and program implementation.

The focus of the proposal is on the development of Rural Community Development Centers that would be designed to build a renewable energy infrastructural base for the specific communities and generally respond to the energy, educational and productive needs as they change over time.

Thesis Supervisor: Tunney Lee
Associate Professor of Architecture and Urban Studies.

CONTENTS

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Almost a decade has past since the 1973 international oil crisis and what many solar energy enthusiats and environmentalists heralded as the "Dawn of The Renewable Energy Age". While it is clear that the world has not yet turned its back completely on petroleum in favor of bio-gas and solar energies, important strides have been made in developing renewable energies - solar, wind, biogas,hydro - as serious alternative sources for the world's energy needs.

Jamaica's recent renewable energy efforts represent one of these major developments. Spearheaded by the Ministry of Mining and Energy, Jamaica has begun the important, difficult process of going beyond discussion and pure research, activities that have dominated the past ten years internationally, and is actually attempting to tap their rich endowment of renewable energies on a national scale. Jamaica's National Energy Plan (to be reviewed in the text) sets out the specific goals for introducing a range of renewable energy systems to reduce the nation's reliance on petroleum while also maintaining economic growth.

It is in the spirit of this new phase of practical energy system application that I approach this thesis. My general desire is to make a positive contribution to Jamaica's efforts to bring about greater national energy self-reliance which will as a result, ease the particular burden expensive imported fuels have placed on poor rural communities and their inhabitants.

My specific objectives are as follows:

Based on national energy and community development policy and plans;

- To recomend ways in which comprehensive energy planning approaches can be more thoroughly intergrated into existing national rural com-

INTRODUCTION

munity development structures and plans.

- To propose a local planning process, that can be implemented in each rural community, for designing energy concious, comprehensive community development strategies.

Based on two rural community case studies;

- To design a Rural Community Development Center (R.C.D.C.), a physical plant out of which the development strategy can be implemented over the years. The R.C.D.C. would also be the institutional link to national development activities and structures.
- To make a set of general design recommendations, drawing from the two prototype R.C.D.C designs, which will inform the design of other R.C.D.C.s to be developed in the future.

The important assumptions underlying these objectives are:

- Jamaica's extreme dependency on expensive imported oil, renders even small alternative energy supplies very important. Therefore, if a community can, on an on-going basis, match their development needs with inexpensive locally available renewable energy sources, substituting (wherever possible) these energy sources for imported petroleum, the economic benefits locally and nationally, in the aggregate, will be considerable.
- The national goal of energy self-sufficiency can only be achieved through the thorough integration of energy analysis into all levels of planning and program implementation and the integration of national and regional planning mechanisms with those at the local level.

Clearly, these objectives cut across a very broad set of issues ranging from policy analysis to architectural design. This broad scope conveniently accomodated a synthesis of my background, degree requirements and interests in planning and architecture but also presented the danger of the study becoming unmanageable given time and resource constraints.

Given the complex, integrated nature of the topic as a whole, as well as my desire to provide a useful document to the Jamaican government, the decision was made to retain the broad scope of the thesis, but to approach it as a reconnaissance, first phase study, where an analytical framework encompassing all of the issues would be set up and analysis carried out within time and resource constraints of this first phase. Follow-on, second phase work could then build on this initial effort.

Thus I begin this thesis by setting out the overall analytical framework; a review of national energy and rural community development plans and set out a proposal for the development of energy conscious community development plans for each of the Township Development target communities. Both a short and long term process for developing, implementing, and revising the plans is detailed.

The functional heart of the proposal, a Rural Community Development Center, (R.C.D.C.) is described in generic terms next. Its functions, typological development, etc. are deliniated. As a way of clearifying the proposal, two real communities were examined as case studies where hypothetical R.C.D.C.'s are designed for each.

The first case study begins with a community overview of Duckenfield, a rural agricultural community in St. Thomas Parish. (South Eastern Jamaica) This includes a brief history of the communities development, a socio-economic summary of the population and a brief survey of the communities economic base. This is followed by a review of the communities energy assessment and strategy which summarizes present energy demand, examines the supply mix, and potential renewable energy development and reviews the strategy for matching these renewables with present and projected demand. Next, the process for R.C.D.C. site selection is outlined, followed by a detailed examination of the R.C.D.C. design.

The same case study outline is used in the examination of Smithfield, the second community case study.

The final section outlines a set of R.C.D.C. design criteria, and general design guidelines

The next section outlines a set of R.C.D.C. design criteria, and general design guidelines that are drawn from the two case studies.

The final section forwards suggestions on the next steps that would be taken in further developing the proposal.

CHAPTER 1

NATIONAL / INTERNATIONAL POLICY

The importance of highly integrative planning, design, and policy implementation approaches is the conceptual thread that ties all of the proposals forwarded in this study together.

What makes these integrative approaches so important? The answer lies in the nature of national development itself. The process of development is extremely complicated, involving every sector of the economy and population; every level and aspect of physical development. Energy - the key imput to development - has complex linkages to each of these sectors and the associated development activities. Thus in order to facilitate affective development, comprehensive energy and analysis must be integrated into all aspects of national, regional, and local planning. Integration should also occur amontst the various levels of government and policy making. Structures must be developed to facilitate the easy flow of information between central and local levels of organization.

Additionally, national development plans must be developed in light of ever changing international economic and political dynamics which not only impact the direct supply and demand of resources, but effect international cooperative development and lending policies and approaches as well.

This first section therefore, focuses on planning and policy setting at the international and national levels.

Jamaica's national energy and general community development plans, reflecting contemporary changes in international thinking and policy in light of these historic policy developments at the international level.

NATIONAL ENERGY PLAN

Jamaica's National Energy Plan, recently prepared and published by the Ministry of Mining and Energy, presents an assessment of the Nation's present energy supply and demand and sets out a strategy for reducing petroleum imports over the next eighteen years.

Jamaica presently relies on fuel imports for over 40% of its energy requirements whiel bagasse, wood and hydro-power supply the balance. Its per capita consumption is greater than most developing countries, measuring approximately seven (7) barrels in a population of 2.16 million.[3] Commercial energy consumption is presented in Table 1.

TABLE 1

	Year					
Petroleum, MBOE*	**1975**	**1976**	**1977**	**1978**	**1979**	**1980**
Avgas	15.96	15.16	14.36	13.6	15.2	12.8
Turbo Fuel	764.52	708.4	594.3	621.0	801.3	689.1
Gasolenes	1,647.3	1,703.2	1,587.1	1,532.1	1,429.1	1,261.5
Automotive Diesel Oil	1,630	1,532.1	1,690.8	1,431.7	1,583.6	1,307.4
Matine Diesel Oil	335.2	251.6	201.5	153.9	176.2	150.0
Fuel Oil	11,894.0	10,139.0	11,136	11,734	11,385	11,210.0
Liquified Petroleum Gas	298.5	299.2	304.1	313.9	291.5	244.6
Kerosene	400.2	397.4	414	402.0	351.9	259.4
Total Petroleum	16,985.7	15,046.0	15,942.1	16,202.2	16,039.0	15,135.0
Hydro Power						
Million kilowatt hr*	131	110	109	115	108	134
MBOE	231	194	191	202	189	235
Total Commercial Energy	17,216.7	15,240	16,133.1	16,404.2	16,228	15,370
Percent, Petroleum	98.65	98.73	98.82	98.77	98.83	98.47

Source: Jamaica National Energy Plan

The plan sets out four central objectives:

To reduce dependency on imported energy and to diversify the present energy supply mix.

To promote the efficient and effective utilization of energy while seeking to sustain economic growth.

To accelerate exploration for and development of indigeneous energy supply sources.

To cushion the impact of continually increasing energy prices on the low-income groups of the society while adopting pricing policies appropriate to achieve the above three objectives.

The energy policy strategy developed is divided into two componants; resource development and supply policy.

An overall timetable for achieving these goals by the year 2,000, has been divided into a) Near-term (1-5 years) b) Mid-term (5-10 years) and c) Long-term (over 10 years) according to projected time lags in research and development of the various project related technologies.

NATIONAL COMMUNITY DEVELOPMENT PLAN

Leading Jamaica's national community development efforts is the Comprehensive Rural Township Development Program. Based on the Governtment's long term program for the improvement of approximately one hundred and twenty (120) rural towns, a coalition of ministries and development agencies have come together to initiate the program, seeking to upgrade the economic base and social infrastructure of six pilot project communities.

An overview of the program, developed by Jamaica's Urban Development Corporation, states as its general objectives:

> "To increase the productive capacity (of the township) by bringing appropriate modern technology to bear on the available resources, both human and physical' ... 'A further objective ... is to facilitate financially viable and attractive projects, which will motivate people to remain in agriculture."[4]

Concerning program implementation, it is planned that the appropriate government agency would be responsible for the physical implementation of each program.

HISTORIC PERSPECTIVE

While renewable energy and rural development are two of the central concerns forwarded in the national plans and programs summarized above, only fifteen years ago, renewable energy sources such as solar, wind, biogas, etc., if considered at all, were considered incompatable with the kind of commercial energy mix needed for fast paced modernization.

Rural development was widely considered a secondary development issue, and certainly not the key to national economic growth. It has only been in the last ten years that institutions, plans or policies of any kind have been developed in either industrialized or developing countries to address the critical and complex issues of energy.

Major changes, particularly within Western/-Capitilist national development theory and policies and the rise of energy as an area of particular concern, did not begin until the late 1960's and early 1970's. From the post-second World War energence of the first attempts to analyze the process of economic growth in the World's poor nations to the later years of the 1960's, Western/Capitalist development thinking and policies were dominated by what has come to be known as the linear 'stages' development model.

Championed by American economic historian, W.W. Rostow, this theory held that the transformation from underdevelopment to development can be dsecribed in terms of a series of steps or stages through which all countries must proceed. As primarily an 'economic' theory of development, it held that the right quantity and mixture of monotary saving, investment, and foreign aid were all that was necessary to enable developing nations to proceed along an economic growth path which historically had been followed by the more developed countries.[5] Thus, national development became synonymous with economic growth - steadily increasing gross national product (GNP) was the primary objective.

The singular theme, underlying linear stages policies was clear: rapic economic growth can only be achieved through large scale, centralized, capital entensive projects.

By the late 1960's growing disenchantment with linear growth policies, many of which had economically failed and/or exacerbated national resource distribution inequities, brought a reexamination of the development process for Third World nations. Out of this period emerged a new school of thought, refered to broadly by economist Michael Todaro, as the 'strucutural-internationalist'.[6] WIthin this 'school' were two major streams of thought; the neo-Marxist/neo-Colonial Model- that attributed underdevelopment ot the historical evolution of highly unequal international capitalist system, and the 'false paradigm' model, that attributed underdevelopment to the faulty and inappropriate advice and policies of international assistance agencies and multinational donar organizations. Both, however, rejected the exclusive emphasis on accelerating growth of GNP as an index of development; they emphasized instead policies needed to eradicate poverty, to provide more diversified employment opportunities and to reduce income inequities.[7]

The Eastern Socialist countries, while sharing Lenin's treaties on imperialism as a basic understanding of the disperities amongst nations, embraced opposing approaches to national development throughout their histories. The Soviet Union prescribed urban based, rapid industrialization. The Chinese, with periodic departures since 1958, embraced rural, agarian based development.

Many of the Soviet's foreign assistance projects, such as the Egyptian Aswan Dam Project, reflected this urban industrial orientation. Looking like 'linear growth' projects, they involved capital intensive, centralized technologies.

China, with almost two decades worth of rural development experience achieved in international isolation, made impressive strides in developing rural based technology while the idea was only beginning to be considered in the West.[8]

For both East and West, the oil embargo of 1973 brought a watershed in international development theory and policy, and sparked the emergence of energy as a global area of concern. The assumed endless supply of cheap petroleum fuels had been halved. The many owners of large, petroleum fueled technologies faced order of magnetic increases in operating-costs. For developing countries, that had already assumed tremendous debt for capital costs, this was particularly traumatic.

The publishing of E.F. Schumacher's Small is Beautiful in 1973, was timely. The argument forwarded by the appropriate technology movement for developing and utilizing environmentally sound, local resources for decentralized, intermediate technologies offered an alternative to large, petro-based technologies.

The work of Arjun Makhijani in the mid to late 70's, helped to synthesize the ideas of the appropriate technology movement, emerging 'structural-international' development theory, and energy policy concerns. In Energy Policy for the Rural Third World, (1976), Makhijani asserts that the root causes of poverty lie in the neglect of the countryside and that therefore a humanist development policy focusing on rural communities must be developed. This policy would be based on technologies which people can understand and control, which would produce meaningful jobs, and would be coupled with an education system that enables their use for individual and collective benefits. Energy development would fit into this technological framework and would be based on human needs.[9]

During the mid 1970's programs began to be developed to test the technical feasibility of the full range of renewable energy technologies.

Energy planning also began to emerge through the activities of newly formed institutions, agencies and organizations, both within industrialized and developing countries, with the specific tasks of addressing energy issues. Projects such as an energy sector study of Bangladesh, administered by the Asian Development Bank under the United Nations Development Program in 1975/76, brought a broader view of the opportunities and difficulties facing developing countries in structuring nation-wide energy solutions.[10] For the first time, energy issues were not treated individually or on an ad hoc basis, but on a sector wide basis, focusing on the intersection of energy and the economy as a whole. The central objective of the emerging energy planning discipline was to dynamically integrate energy considerations into all aspects of national, regional and local development planning.

Jamaica's National Energy and community development plans clearly spring out of this framework of contemporary planning and development approaches containing elements of the rural focused, appropriate technology movement and the new energy planning discipline. In the following sector, a set of policy and program recommendations are forwarded based on this review of existing policy.

CHAPTER 2

POLICY / PROGRAM PROPOSAL

The preceeding review of Jamaica's national development plans and historic policy overview underlined the importance of integrative planning approaches for plan and program development. This was explicitly the guiding objective in the formulation of the planning approach and inter-displinary internal structure of the Comprehensive Rural Township Development Program. The historic policy overview showed integrated planning to be the central concept within the new energy planning discipline.

But, exactly how will these integrative approaches work when the implementation of plans begin? The National Energy Plan provides little information on how energy plans, particularly those aimed at the development of rural energy supplies, are going to be integrated into the larger community development activities. The organizational structure of the Ministry of Energy and Mining encourages interaction between the Alternative Energy Projects section and other ministries and agencies, (see Apendix 1) but, again there seems to be no explicit plan for interface and integrated implementation on the national level. The Comprehensive Rural Township Development Program, while clearly basing its planning and implementation on integrative methods, lacks a strategy and/or organizational mechanism, particularly for the local level, for long term maintainance of township development. In addition, the matching of implementation tasks with the sector related Ministry, establishes a strong vertical compartmentalization. Energy issues cut horizontally across all sectors, therefore the present structure will hamper direct consideration and analysis of many important energy impacts.

The following proposal therefore, offers a method for more theoroughly integrating energy analysis at the national and local planning levels and offers a mechanism for maintaining Township development on an on-going basis. The proposal, divided into short run and long run strategies, is summarized as follows:

- To develop, in the short run, an initial community energy strategy for each target community within the Township Development Program, which is to be integrated into the overall township development plan. To develop this plan, an energy sector analysis of the township and its designated Catchment Area is to be performed by an 'energy team' at the national level.
- To establish a Township "Development Advisory Board" whose task it will be to review development progress and regularly update the development plan at the local level.
- To construct a Rural Community Development Center (RCDC), out of which the Township development plan can be carried out. (This proposal is detailed in upcoming pages).
- To appoint (train & hire) a local development/energy manager whose primary functions will be to manage the R.C.D.C., oversee every day work on the development plan, and to act as liaison between the local and national planning levels. This will entail participating on the national level "energy team" as well as coordinating the Township's Development Advisory Board.

Underlying all aspects of this proposal are several views and assumptions which need delination.

- While energy is often treated as an independent, self-contained product or entity, the fact is that energy is only a means to an end, not an end in itself; energy is an intermdeiate good used to provide services ant to perform needed work. Thus priorities must be clear; the primary problem and goal for Jamaica is development - and development requires energization. Energy development, in tandem with overall national development, must be connected to specific end uses.

- National development in general and energy development in particular are very dynamic processes, changing constantly with time. Planning and implementation processes must be structured to allow for the review, revision, and evolution of plans over time.

- Like most developing countries, Jamaica suffers from a shortage of skilled labor and management expertise. As a result, development is impeded and depending on foreign expertise is fastered. Top priority must be placed on the development of educational mechanisms for broad based energy training and public education.

- Given the fact that the Comprehensive Rural Township Development Program has already begun planning activities in the pilot project communities, the sequencing of the various aspects of the proposal will need adjusting to fit current planning status.

SHORT RUN NATIONAL PLANNING PROCESS PROPOSAL

The objective in this first section of the proposal is to more thoroughly integrate energy analysis into the existing Comprehensive Rural Township Development Program and thereby better insure that the community development plans are as energy conscious as possible. Also, a method for the long term linking of national program planning and implementation with planning and implementation at the local level is also suggested.

As was reviewed in the previous section, the Comprehensive Rural Township Development Program is already integrative in form, involving the full range of Ministries and development agencies, including the Ministry of Energy and Mining. However, as outlined, energy analysis seems to be limited; only supply side support information on energy source development seems to be provided for.

Energy planning requires the examination of many interrelated issues concerning supply and demand.

Since energy supply development and demand determination should be part of the same proess, it is important, even in the assessment/survey stage, to examine them in their interrelationships. For instance, assessing the growth potential of a dairy farm may seem to be the responsibility of agriculturalists and economists. However, the accounting of its high energy demand for fertilizer, milk processing, etc., against its high energy supply - in biomass wast and waste process heat, etc. - involves energy analisis and could dramatically effect conclusions about the feasibility of enterprise growth.

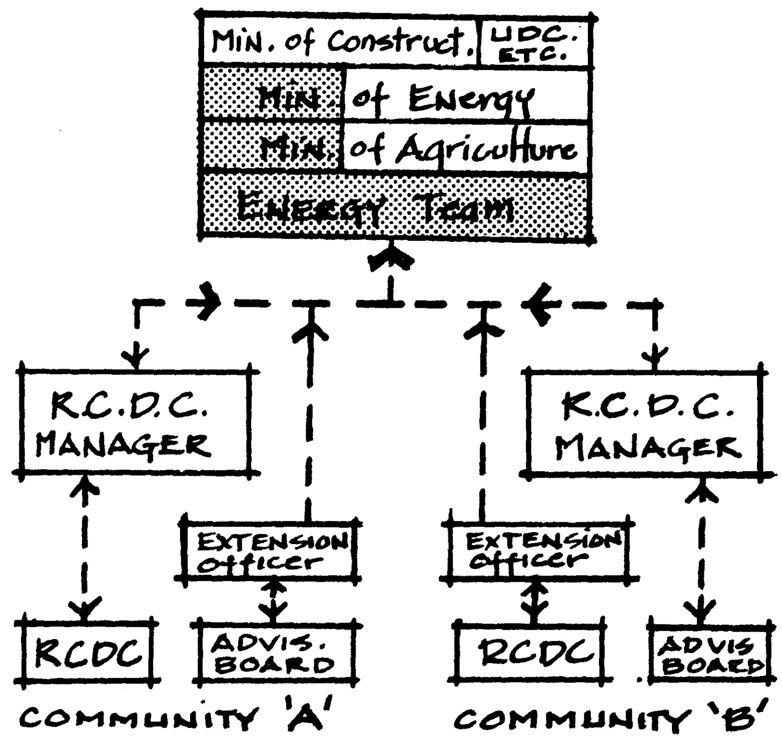
Thus, to achieve the goal of greater intergration, "energy teams" should be developed to carry out a thorough energy sector analysis of particular Township and its designated Catchment Area.

The makeup of these teams is important. They should include a representative(s) from the Ministry of Energy and Mining, a local extension representative from the Ministry of Agriculture and the Township's Rural Community Development Center manager. The rationale for this particular mix is straight forward.

The Ministry of Energy and Mining representtative(s) will bring the energy analysis/development skills, the Ministry of Agriculture - having the most direct interface with local productive activities - will bring specific knowledge of economic needs and knowledge of the local conditions in general. (see Chart #1 for workings)

The Rural Community Development Center manager, as the local coordinator of energy and overall community development efforts, (a specific discription follows) will bring energy skills, local knowledge and most of all, will represent the link between present and future development activities at the local level. In some cases, the team might work in conjunction with other appropriate specialists such as micro/macro economists in an analysis of industrial development potential.

The Specific details of the energy sector study will have to be determined by the program participants, taking into consideration the particular resource availability at the time. However, content and format guidelines are offered next.



The Integration of National and Local Levels of Planning and Implementation.
Chart #1.

The study should generally be divided into three processes: 1) Assessment of energy supply/demand conditons, and determination of the area's current energy balance. 2) Setting community development project priorities working in conjunction with the rest of the program's planning participants and using the energy balance and other needs profile data as a decision making base, and 3) Matching specific, renewable energy resources with priority community development needs.

A. Determining the Energy Balance:

The first step, the determination of the area's energy balance, can involve a process as complex or as simple as available resources allow. Naturally, with a large staff and extensive computer resources, comprehensive data bases can be prepared and the many complex interdependencies between energy supply systems, the interconnections between supply and demand, and the linkages of all of these to the economy can be modeled and analyzed. However, short of unlimited study resources, there are several study components that are prerequsite for the construction of a basic energy balance. 1) On the demand side, basic data must be collected on energy use in the dominant agricultural sector and other public and private industries. 2) Similar background work is needed on the supply side. Data as detailed as possible, must be collected on the area's energy resources.

The supply and demand surveying process should not be perceived of or organized as two independent processes. While many aspects of supply assessment are autonomous, like the accounting of renewable resources such as sun and wind, opportunities for conservation and process waste energy reuse can only be ffectively assessed as directly linked to energy use and demand.

To then construct the energy balance, the demand data for the various sectors is cross tabulated with the associated commercial or traditional energy supply resource. (An example of a summarized national energy balance from the Bangladesh Energy Study is found in appendix 2) A seperate accounting of conservation and process waste energy reuse opportunities would be evaluated on a cost benefit basis.

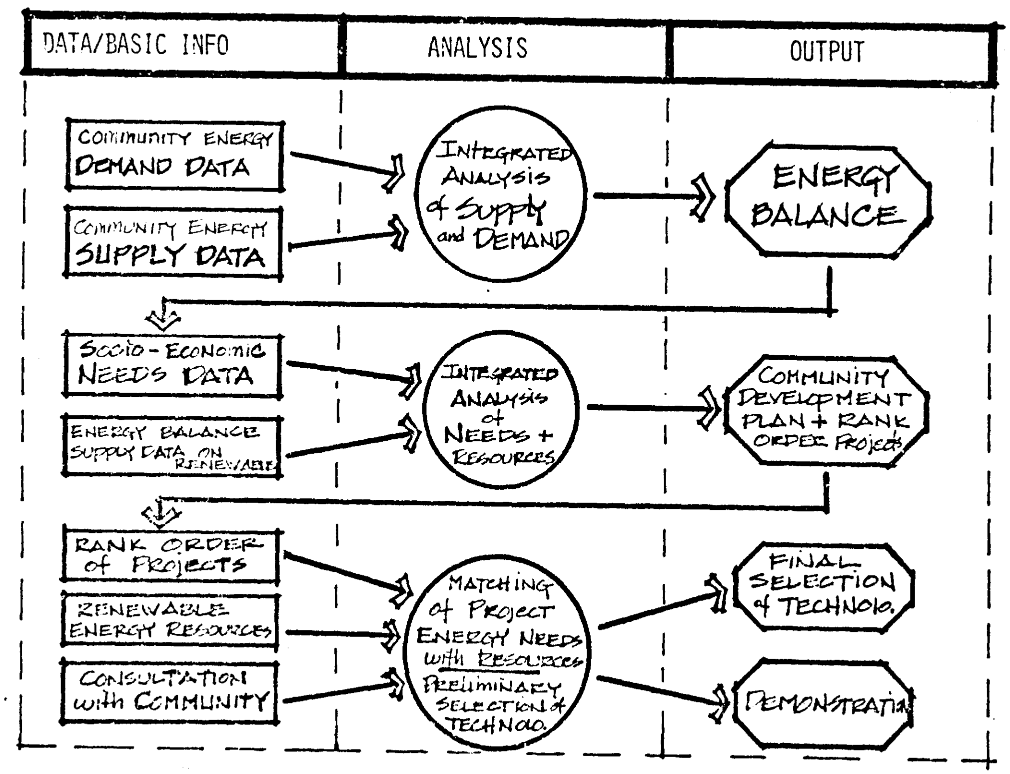
B. Setting Community Development Project Priorities:

This step brings the integration of the energy analysis (the quasi-independent work of the 'energy team') into the full planning process of the Comprehensive Rural Township Development Program. The energy balance analysis and additional supply data should be cross referenced with the broader socio-economic survey data to develop a detailed energy conscious development strategy for the comunity. The planned project phasing - the time/ranking of projects by order of initiation, should then clearly identify the target projects.

C. Matching Renewable Energy Resources with Community Development Needs:

Having determined the communitie's overall development strategy, the task for the energy team is then to clearly identify the specific energy needs associated with the target projects.

At this point, consultation should be held with members of the local community, particularly those that will be directly impacted by the introduction of new energy technologies. The goal here is to familiarize the users with the new technology and thereby ease its introduction. Though there is local input from the R.C.D.C. manager to the energy team concerning social/cultural traditions, traditional ways of doing things are not generally altered easily, therefore all efforts to educate the public about the operations and benefits of the new energy technologies should be made. The chart below summarizes the steps of the energy sector study.



Energy Sector Study Operations. Chart #2

With these measures completed, a preliminary lists of technologies should be matched with renewable energy supply data. Using specific performance and availability criteria, a final choice of technologies should be made.

THE MANAGER OF THE TOWNSHIP"S RURAL COMMUNITY DEVELOPMENT CENTER

This position is the managerial key to the proposal. For both short and long term program planning and implementation, the Rural Community Development Center Manager acts as the link between national and local levels. The primary short term role is to assist in the development of the Community's Development Plan as a member of one of the national 'energy teams'. Participating at this level, he/she would not only bring skills and knowledge of local conditions, but would gain intimate knowledge of the plan details which would allow for more effective decision making at the local level over time.

Participation at the national level would actually preceded the development of the local R.C.D.C. Thus, once the community's plan is completed, the R.C.D.C. manager would help to develop the center's program which would be based on the overall plan. He/she would then assume full-time management of the facility once completed.

The training of the R.C.D.C. managers for the various central importance, given the fact that not only will they be responsible for the operation of the center, including the various renewable systems, but may also lead local energy training and public education activities. Therefore appropriate training program should be developed by the appropriate Ministries to take into consideration the availability of resources, the range of technologies to be employed, the levels of skill requried for tasks, etc.

THE TOWNSHIP'S "DEVELOPMENT ADVISORY BOARD"

With short term community development planning concentrated generally at the national level, the purpose of the Development Advisory Board is to assist in the long term monitoring and development of the plan at the local level. The board should be made up of those community decision makers that most strongly effect the supply and demand of energy. Thus, membership should include representatives from the heavy energy consuming productive sectors - agriculture, industry, etc.; civic leaders, as the local policy setters, and cultural and neighborhood leaders - as representatives of the average residential consumer. The R.C.D.C. manager would act as the coordinator of the board. Meeting periodically, the board would review development progress, monitoring the concomitant impact on energy rewources, population growth, etc., and ammend the plan where necessary.

THE RURAL COMMUNITY DEVELOPMENT CENTER

The Rural Community Development Center is the functional heart of this proposal; the physical plant out of which the Community Development Plan is to be carried out.

But what -more precisely- is this R.C.D.C.? Is it an office building or a Community Center? Is it a electric generating facility? Where does renewable energy development fit into it?

Unlike a school or hospital, a Rural Community Development Center does not evoke immediate building type images. And it does not help that by nature, the form and uses range from one community to the next. But the central and common function is the servicing of primary community development needs, and with one of the keys to rural community development being the establishment of a renewable energy base, each R.C.D.C. provides the major supports out of which a renewable energy infrastructure can be developed. As will be seen in the case studies, this infrastructure will sometimes take the form or actual energy production and delivery systems while in other cases it will be the facilities out of which local energy technologies can be manufactured.

But in every case, the infrastructure introduced must be based on the future development invisioned for the community, it must be able to accomodate growth and evolve as the community and R.C.D.C. develop. For instance, in larger communities where industrial development is planned for the future, the R.C.D.C. might be strategically sited within the projected industrial zone to provide for power congeneration opportunities as industry develops. The renewable energy powered, electric generating facilities should be designed to accomodate incremental growth over time. A small agricultural community, on the other hand, may only require solar water distillation; but here again, future growth and development should be considered from the outset. Not only incremental expansion of the solar still grid but intermediate uses of the captured heat as well as opportunities for local manufacture of solar stills should be investigated initially.

Thus, inherent in this community needs approach is the variable character and scale of the R.C.D.C.'s in general and the energy infrastructure in particular.

Common to all R.C.D.C.'s, however, are three more specific functions and characteristics.

These include:

- The organization of research aimed at developing and/or refining new technologies that are local resource based and generally compatable with local conditions.
- The development of educational programs aimed at both broad based public education and more specific skill building.
- Each R.C.D.C. should be designed to be as energy self-sufficient as possible by utilizing energy conscious building and landscaping techniques and end use generating other energy needs whenever possible.

While hypothetical examples of the R.C.D.C. will be developed in the following chapter, two existing renewable energy based instillations have served as helpful references in the development of this proposal. They are summarized below.

CHAPTER 3

COMMUNITY CASE STUDIES

The following community case studies of Duckenfield and Smithfield are aimed at demonstrating how 1) a process of matching renewable energy sources to community development needs can actually work, and 2) how the community's Rural Community Development Center can be designed to respond to the specific implementational needs of the development plan.

It must be emphasized here however, that field research in each community was limited to only two to three days. Therefore, each case study must be seen as being exploratory in nature. The attempt was to glean as much accurate information, through abbreviated analytical procedures, as time and resource constraints would allow. Drawing from this information, quick conclusions about development needs, existing energy flows, renewable energy supplies, and possible development strategies were developed. With these conclusions, the more detailed design of the energy plan and the Rural Community Development Center was carried out- in a more deliberate way- at MIT.


Duckenfield
Montego Bay
Falmouth
Runaway Bay
St Ann's Bay
Ocho Rios
Annotto Bay
St Margaret's Bay
Port Antonio
Northeast Pt
The Cockpit Country
Alexandria
Christiana
Mandeville
May Pen
Spanish Town
Linstead
Bog Walk
Ewarton
Old Harbour
Port Henderson
Port Royal
Kingston
Blue Mountains
Morant Bay
Bath
Black River
Savanna la Mar
Bluefields
Negril
Green Island
Lucea
Long Bay
Portland Bight
Portland Pt
The Salt Ponds
White Horses
Alligator Pond
Milk River
Malvern
Newmarket
Ipswich
Albert Town
Stewart Town
Clark's Town
Duncans
Claremont
Moneague
Castleton
Richmond
Albany
Oracabessa
Port Maria
Galina Pt
Hope Bay
Buff Bay
Pedro Pt
South West Pt
Crab Pond Pt
Whitehouse Pt
Luana Pt
Parottee Pt
Gt Pedro Bluff
Hellshire Hills
Pigeon I.
Manchioneal
Morant Pt
JAMAICA
1:1,250,000
10 Miles
20 Kilometres

DUCKENFIELD

The first case study represents what can be done in a community with a rich variety of natural resources. The process used for examining Duckenfield- duplicated in full for the study of Smithfield- begins with an introduction to the community, followed by a sector by sector analysis of the energy glows, and ending with an design review of the Rural Community Development Center.

GEOGRAPHICAL/GEOLOGICAL OVERVIEW:

Duckenfield is a small agricultural community of approximately 1 1/2 square miles, located in easter St. Thomas Parish, just west of Morant Point on the southeastern tip of Jamaica.

The community is part of an extensive, extremely fertile costal plain that was at one time almost completely morass.[13] The northern section of Duckenfield is part of what was, in the previous centruy, a large sugar estate that was formed by draining the morass along the Plantation Garden River. The southern and western sections of the township rise up gradually from this plain as part of rolling hills that eventually become the southern coastal foot hills of the John Crow Mountains. Another small river, the Negro, flows to the sea through the central sugar fields while the larger Plantation Garden River forms the nothern border of the community.

SOCIAL/ECONOMIC BASE

Because of its rich endowment of fertile land, Duckenfield snd its surrounding communities have a tremendous mix of agricultural activities and have become one of the Island's center for the Sugar and Banana export industry.

The largest of these industries, sugar, is controlled by the government owned National Sugar Company which in turn owns 80% of the land in Duckenfield.[14] The Banana industry is controlled by a mix of public and private firms. The Banana Company of Jamaica, the largest concern, is operated as a statutory body with its main funding coming from the Jamaican government and European Development Fund.

Besides one other large private banana

company, there is also coconut farming and a sizable dairy farm, all owned by the same private company. The fields, partly located in Duckenfield property, also extend into the immediately adjacent communities.

The population of Duckenfield si approximately 2,000. Most of the population is employed as field workers for the Sugar or Banana Companies.[15]

A small commercial area located in the center of the community, and comprised of a moderate sized, open air produce market and a row of small repair and commodity shops, supplies much of the daily needs of many of the residents.

Two schools, a basic school (locally controlled elementary) and a large, regional secondary school serve the educational needs of the community.

COMMUNITY ENERGY ASSESSMENT:

A modest, two staged surveying process was used to gather information on the community's energy supply and consumption/demand.

The first step, which included gathering as much information on the community as possible (particularly climate data), before actually making the field visit, focused on an interview with the local Ministry of Agriculture Extension Officer who was able to provide a general overview of the entire community and some basic information on energy flows. This information included an outline of the major producers, their relative level of output and basic governance, information on community-wide power supply/utility networks, a generaly residential energy supply-demand profile, and a survey of major community service facilities.

With this initial information, the second stage, a series of interviews with industry managers, service facilitiy managers, and residents was organized to complie more detailed data on energy supplies and demand.. A windshield survey of the entire community was carried out to get a sense of the terrain and to locate possible sites of the community's R.C.D.C.

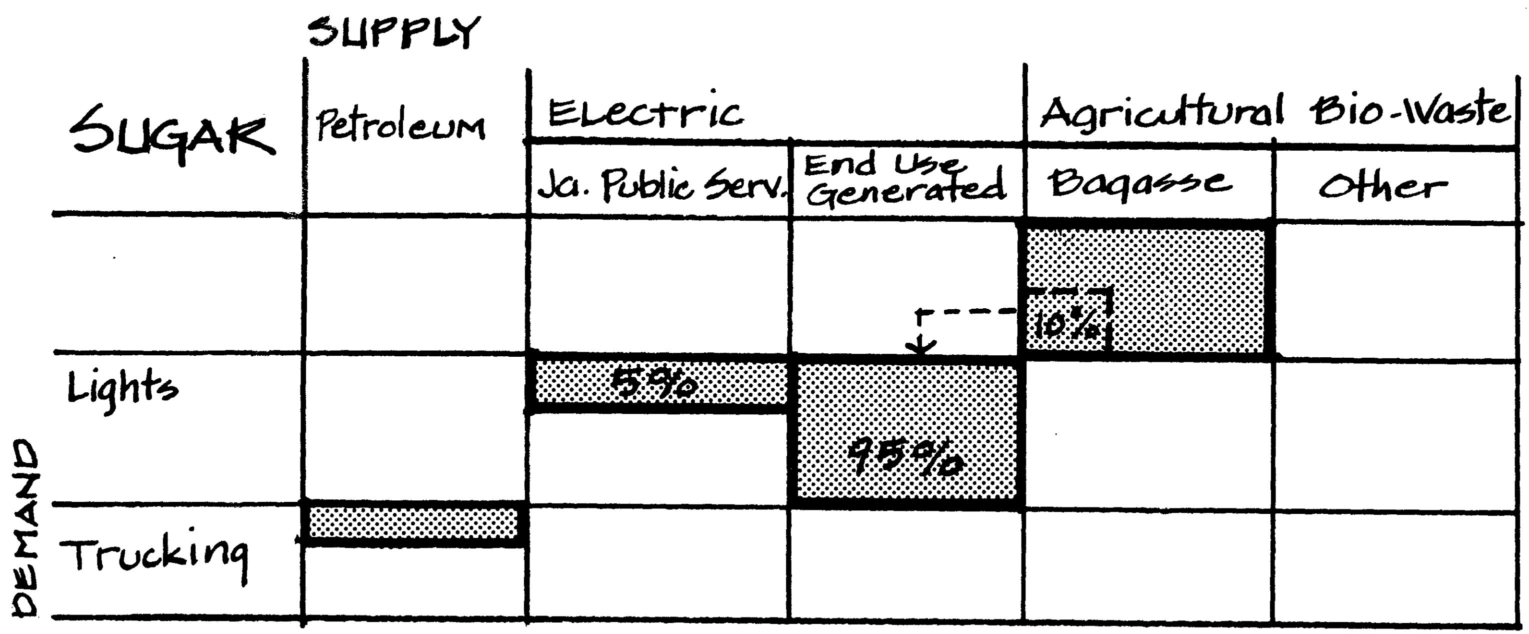
The following sector by sector energy balance analysis and production summaries give an overview of general operations and community-wide energy supply and demand. For the major concerns in each sector, an energy chart graphically shows the supply demand balance.

PRODUCTIVE (AGRICULTURAL) SECTOR
P

A. Sugar

The National Sugar Company

As the ebergy balance chart indicates, the Sugar Industry is largely energy self-sufficient utilizing its own bagasse for fueling both direct refining and electric generation. 100% of the industry's electric needs could be met if the present, inefficient, single wheel turbine was replaced with a modern, more efficient unit.



Sugar Industry Energy Balance.

B. Banana

The energy charts clearly show that the biggest energy factor in this industry is its residual supply of wast products.

Unfortunately for the companies evolved, upwards of 50% of the crop is presently rejected for export because of bruising or other imperfections.

While there were indications that efforts to improve harvesting are forthcoming, it was believed that reductions in rejection rate of over 15%-20% were unlikely.

Presently, much of the rejected bananas are allowed to rot and as with the stem and stalk, much of it is burned. A percentage of the waste bananas fron the private banana company are presently used as cattle feed. Plans are also underway to begin "banana chip" production for area food markets. This activity will reduce banana waste from the private company by 40% to 50%.

The bananas are prepared for shipping at boxing plants of which there are two public and three private plants in the general area.

SUPPLY

DEMAND

BANANA	Petroleum	Electric: Jamaica Public Ser	Electric: End Use Generated	Agricul.	Waste Product
Field Irrigation					
Lights Gen. Elec.					
Trucking					
Food Products					
Waste Disposal				30 TON/WEEK	40 TON/WEEK

C. Dairy

The enterprise is heavily dominated by electricity demand with large contributions from high use equipment like milking machinery and from the general need for large volumes of hot water for maintaining snaitary dairy conditions.

With 200 cattle confined for milking twice a day, manure volumes are considerable.

D. Coconut

Energy demand is divided between the two products, coir and copra.

SERVICE SECTOR

Regional Secondary School

This school, the largest public building and one of the largest public energy users in the community, is dominated by its electric (lights) load. Propane, the other major energy source, is purchased in 100 lb tank volumes on a bi-monthly basis from a local supplier.

RESIDENTIAL SECTOR

Households

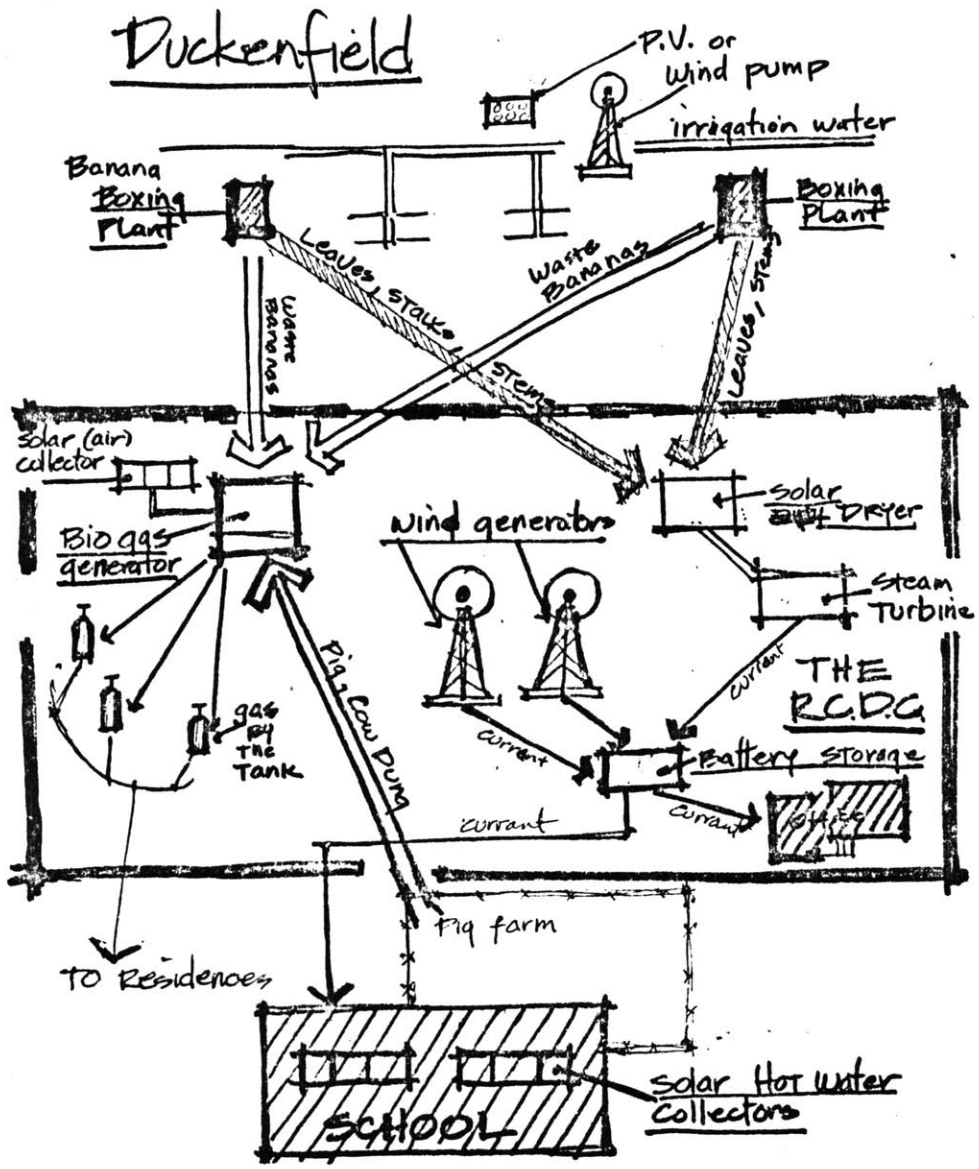
Approximately 50% of the communities households use propane for cooking and hot water while the other 50% use kerosene.

COMMUNITY DEVELOPMENT/RENEWABLE ENERGY DEVELOPMENT STRATEGY

After assessing the community's energy flows, basic assumptions had to be made about the community's general development needs given the absence of an existing plan or development assessment. Because of Duckenfield's rich agricultural production and importance as an area secondary educational center, the decision was made to concentrate on these two areas as community development foci.

A three staged process was used to develop the community's renewable energy plan which was to be based on the development needs of the two target areas. With the results of the energy assessment in mind, a preliminary outline of the renewable energy plan was developed as the first stage in the plan development process. The sketch on page 46 graphically illustrates this initial thinking.

- At the heart of the proposal was the reuse of waste bananas and animal manures



Preliminary Outline: Duckenfield Renewable Energy Plan for biogas and fertilizer production. Combined with generation of electricity using wind and bana stem and stalk (to fuel a steam turbine), a fairly extensive renewables infrastructure - as part of the community's R.C.D.C. was forseen to be developed in close proximity to the secondary school.

- Locating the R.C.D.C. close to the school was seen as being beneficial for several reasons: 1) the actual supply of renewable energies to replace expensive, non-renewable energies (particularly propane) would bring cost savings that could be redirected towards improving educational services. 2) educational opportunities for tieing the school's curriculum into the R.C.D.C. operations and facilities - would be unlimited. Thus a broad base of the communities future adult population would be 'energy educated'.

  Solar technologies were considered for replacing central electric, and imported gas inputs for field irregation (Photo voltaics for central electric) and water heating (Solar hot water for electric).

- With large enough volumes of biogas generated, it was hoped that the gas could be tanked and distributed to residences, substituting imported kerosene and propane with locally produced biogas.

- Despite the considerable energy opportunities presented by the large volume of waste bananas, overriding concern was for the reuse of bananas as food for human consumption.

- Though the National Sugar Company is the largest industrial concern in the community and maintains the largest plant, it was not considered as a major factor in the initial energy plan because it is -for all intents and purposes- energy self-sufficient.

The second stage in plan development involved gathering reactions to the initial renewable energy development proposal form those in the community who would play an active role in carrying the plan out. This entailed follow-on interview with managers from the public banana company, the owner of the private firm, and dairy and coconut farms, the principal of the socondary school, residnets and the Extens ion Officer.

Most responses were positive. All felt that their cooperation could be counted on in helping such a program work.

Two proposal revisions were made at this stage however, in response to infromation gathered in interviews. Unless electric costs and general electric demand rose tremendously it was felt that the costs of steam turbine fuel by banana stems would probably be excessive and therefore was dropped from the plan. Also, the proposal for trucking the cow manuer from the dairy farm to the central R.C.D.C. degister was suspended, because the benefits of using the manuer for farm energy needs (farm scale digester) outweighed those associated with central generation, particularly given projected levels of demand.

The third and final stage involved testing the proposed renewable energy development strategy by analyzing the technical feasibility of the energy systems that would be involved. This provided the data from which the final selection of systems was made.

In the following section, the results of this study will be summarized as part of the over-all analysis of the R.C.D.C. design.

THE RURAL COMMUNITY DEVELOPMENT CENTER DESIGN

With the renewable energy development strategy providing the basis for developing the R.C.D.C. design, this section gives a detailed description of the design process and the design decisions made.

The design process involved three steps; 1) Program Development 2) Detailing of design objectives and criteria and 3) Design decision making. Each step and its results are detailed below:

R.C.D.C. PROGRAM DEVELOPMENT

The frist stage focused on fashioning the final systems tested, renewable energy development strategy into the specific program for the R.C.D.C. In summary, the program included the following.

A. Renewable Energy Systems

- Photovoltaic water pumps:
  to supply field irrigation
- Methan Digester:
  to provide a systems framework within which one or more low cost methane digesters that utilize waste bananas and animal manuers can be constructed.
- Methane Storage Tank:
  for the storage of methane to distribution to the R.C.D.C. office, adjacent school and surrounding residences.
- Methane Distribution Network:
  provide a low cost network of conduits to supply methane to the R.C.D.C. office, school and neighboring residences.
- Digester Sludge Storage Lagoon:
  to store/supply low cost soil donditioners for local agricultural use.
- Oxidation/Fish Pond:
  to provide water treatment for digester liquid waste, food supply (fish and chicken feed from algae

- Methane Fueled Electric Generator:
  to electrify R.C.D.C. office (auxiliary)
- Methaned Fueled Hot Water Heaters:
  to supply hot water for Secondary School, R.C.D.C. office and residences.
- Test Wind Generator:
  to electrify R.C.D.C. office and provide performance data.
- Test Photovoltaic Array (Optional)
  to provide Auxiliary electricity and provide performance data.

B. The Office Building

- Administrative Offices:
  provide centrally located office space for the R.C.D.C. manager as well as additional office space for other community service/development agencies.
- Research/Testing:
  provide interior and exterior-space for both research and testing of local technologies.
- Training/Public Education:
  provide flexable space for variable sized classroom teaching, open lecturing, and training. This space(s) should be adjacent or in close proximity to the research/testing spaces to provide for "hands-on" training when desired.

PHYSICAL DESIGN CRITERIA/OBJECTIVES

The second stage in the design process involved clearly setting out the priority concerns and objectives for the design of both the Rural Community Development Center site plan and the office facility itself. They are summarized as follows.

A. The Establishment of Frameworks

Because of the exploratory nature of the thesis in general and the community case studies in particular, each proposal forwarded should not be interpreted as being a complete ste of "final answers". Emphasis is on offering guidelines or frameworks out of which more detailed study and decision making can occur in the future within the specific Jamaican context.

The two case study designs are meant to demonstrate how a R.C.D.C. can be designed to meet specific needs, and therefore might be more detailed. However, emphasis again should be on setting up conceptual and structural frameworks within which local imput can be integrated.

B. Design Response to Climate

All design decisions should be based on a clear understanding of the site micro climate -sun intensity, prevailing winds, average rainall, etc. Priority should be given to achieving human comfort by designing the site and buildings to work in harmony with the local climate.

Landscaping, building orientation, building form, choice of materials, etc., all play a part in tempering climate extremes, promoting environmental balances, and maintianing interior building conditions within the human comfort zone.

C. Emphasizing the Growth Direction

The R.C.D.C. must be able to grow and evolve overtime in response to the development of the community with whom it is symbolically related.

Growth implies direction and therefore the R.C.D.C. design should establish and emphasize this growth direction in the interest of providing clues for future expansion decision.

Any number of elements in the immediate natural environment can suggest a reasonable growth direction. Existing landscape topographical formations, rivers, tree clusters, existing buildings, etc. can provide directional information.

D. Minimizing Cost - Maximizing Benefits

The energy systems and office building materials used in the development of the R.C.D.C. must be chosen with economy in mind. Whenever possible, renewable energy systems and construction methods that require the lowest possible capital expenditure and highest use of local materials and labor should be chosen for use in the R.C.D.C.

DESIGN DECISIONS

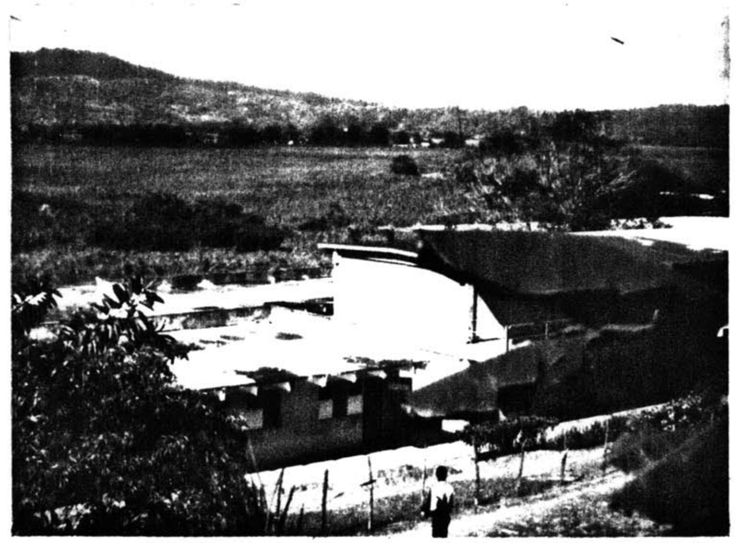
Specific site and office design decisions were made in this third and final stage.

An analysis of the site and microclimate provide much of the "data" for designing in accordance with set criteria and objectives.

Site Analysis

The proposed site for the Duckenfield R.C.D.C. is a .5 acre, linear section of land forming the northern edge of the Regional Secondary School grounds in north central Duckenfield. Having been sugar fields at one time, several acres were leased from the National Sugar Company by the Ministry of Education to provide a major regional secondary school, which now has a population of approximately 1,300 students and teachers.

Stokes Hall Secondary School



View of R.C.D.C. Site adjacent to school

With the addition of a large playing field across the street from the school, the proposed site, part of the old play area, was left vacant.

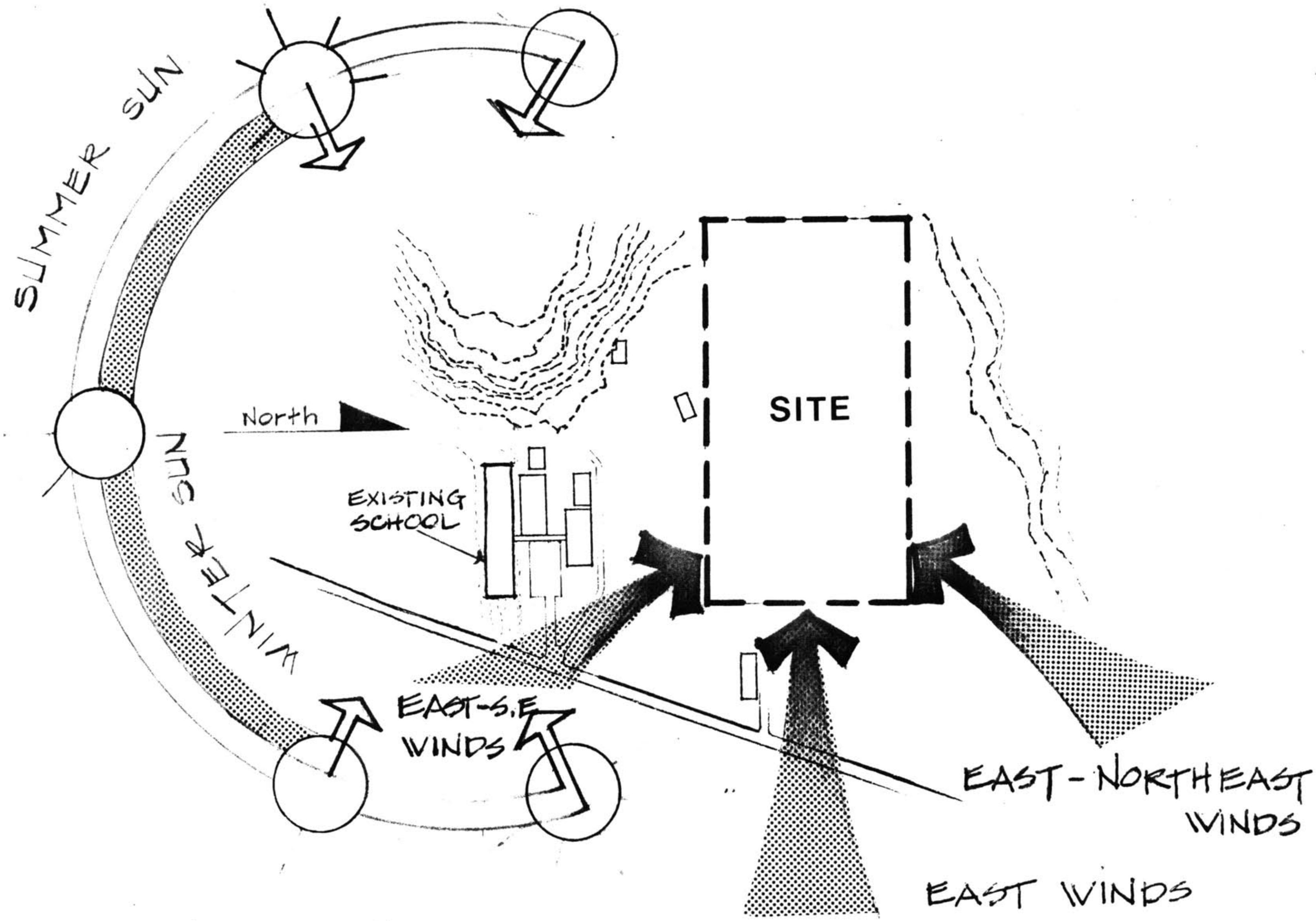
There are few existing trees, land contours - except for a hill to the southwest of the site, therefore the site plan responded almost exclusively to microclimate, the given geometry of the site and the operational demands of the renewable energy systems.

Microclimate Analysis

In all hot and humid climates, such as Jamaica's, two climatic factors must be thoroughly understood; solar access/insolation and wind. Human discomfort in this climate is caused by high air temperatures produced by intense solar radiation in combination with high air vapor pressure (humidity). Winds (ventilation) are the primary natural source of relief from these conditions in that they increase evaporation which decreases dry-bulb temperature.

The solar analysis of the site focused on 1) monthly sunny day rates and 2) the solar patterns - to determine the times and orientations of the most sever, low angle solar penetration.

While specific wind data was not available for this site, extrapolating from Morant Point data shows prevailing winds to blow out of the east-northeast, due east and east-southeast. Diurnal up and downdraft air movements - due to temperature differentials between the near by water temperature and that of the land-also have an effect on general wind patterns. (see Site Analysis, pg. 55).



SITE ANALYSIS

SITE DESIGN

With the results from the site and micro-climate analysis in hand, an attempt was made to weave the two components of the Rural Community Development Center- the renewal energy systems and the center offices- into a harmoniously integrated plan. (see Site Plan , pg.57)

The prevailing east/west direction of the site organization, established in part in response to the long and narrow geometry of the site, sets up a consistant directional framework out of which both the renewable energy systems and the office building can grow in a coherent fashion, maintaining their spatial-functional relationship with each other. As will be seen, the formal response to the microclimate in the office building design strongly reinforced this direction.

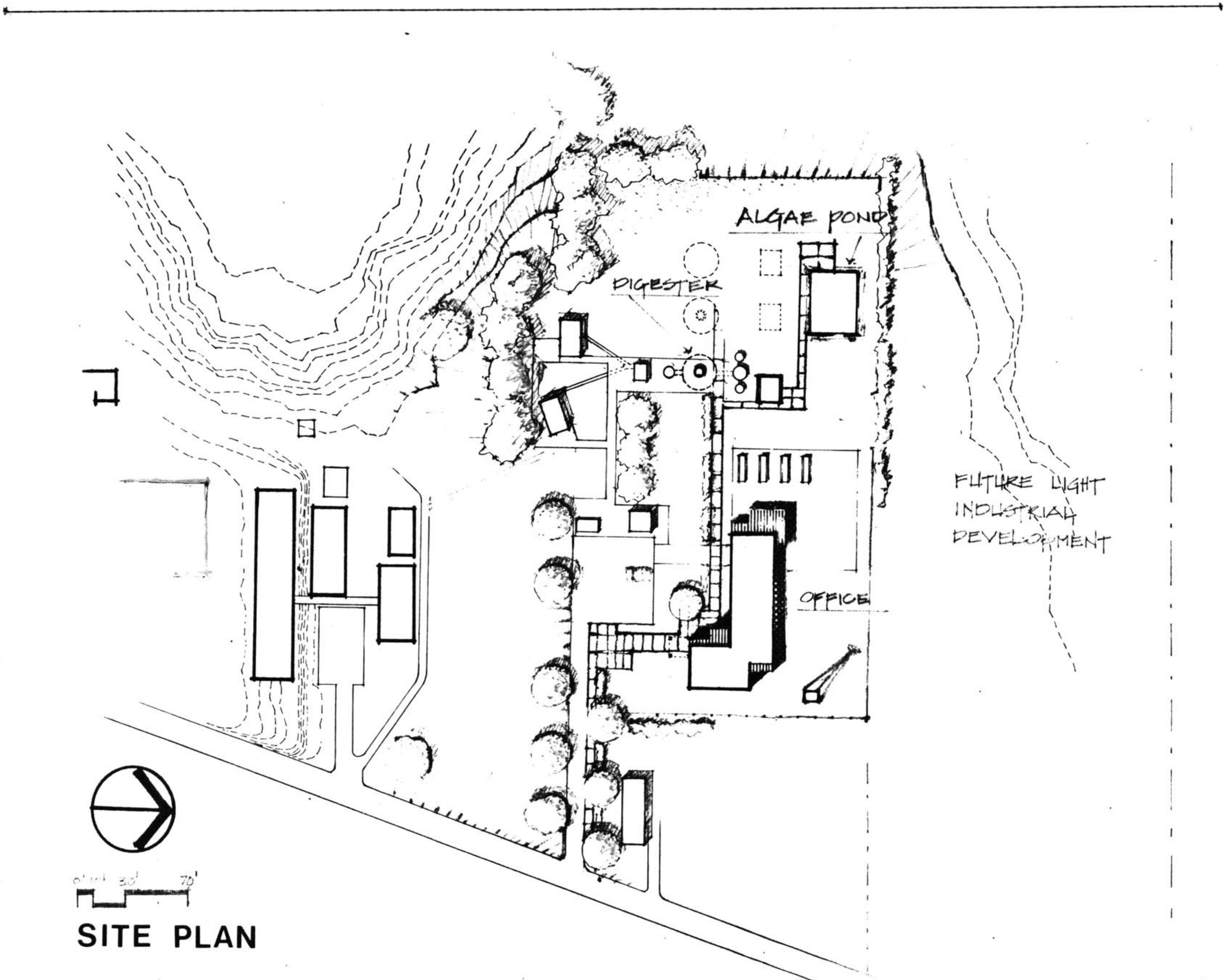
The other major influences in the site design were the operational/functional needs of the renewable energy systems. Their siting and operations are examined below.

A. Methan Gas Production:

With approximately 31 tons of banana and animal wastes available per week for use as raw materials for bio-gas production, the methane digester naturally bacame the heart of R.C.D.C. energy system. Distress over using a highly nutritious food stuff - like bananas - for gas energy production was also diminished because of the fact that rich fertilizers and chicken-feed are produced abundantly as part of the digestion process.

B. Growth Direction

An east-west directional pattern best suited


ALGAE POND
DIGESTER
FUTURE LIGHT INDUSTRIAL DEVELOPMENT
OFFICE
0' 30' 70'

SITE PLAN

the growth of the secondary school and with possible development of light industry occuring on acreage adjacent and to the north, cogneration systems as well as additional digesters using the waste products of increased overall production could be added within this linear framework. Several of the sub-systems such as the sludge storage lagoon, the algae and fish ponds, working in tandem with the digester, could be expanded linearly towards this western, more flexible boundary.

C. Operations

The following description of the biogas system operation, graphically summarized in diagram #1 is based on design and performance calculations that can be found in Appendix 3.

In general, a methane digester is simply a container which holds organic wastes in a manner which allows natural bacterial degradation of the organic matter to occur in the abscence of oxygen. Not only is methane gas generated, but the sludge and effluent by-products make excellent fertilizing materials.

The first step in the operation of the preparation of the feed slurry For proper digestion, the bananas must be shredded and made into a liquid mixture of 7-9% solids which along with the animal manuers are collected in a feed tank.

In the second step the slurry is fed into the digester on a daily basis. The digestion process that follows produces methane gas which rises and collects in the top of the digester while the liquid supernatants and heavier sludges stratefy throughout the rest of the tank.

The thrid step involves drawing the

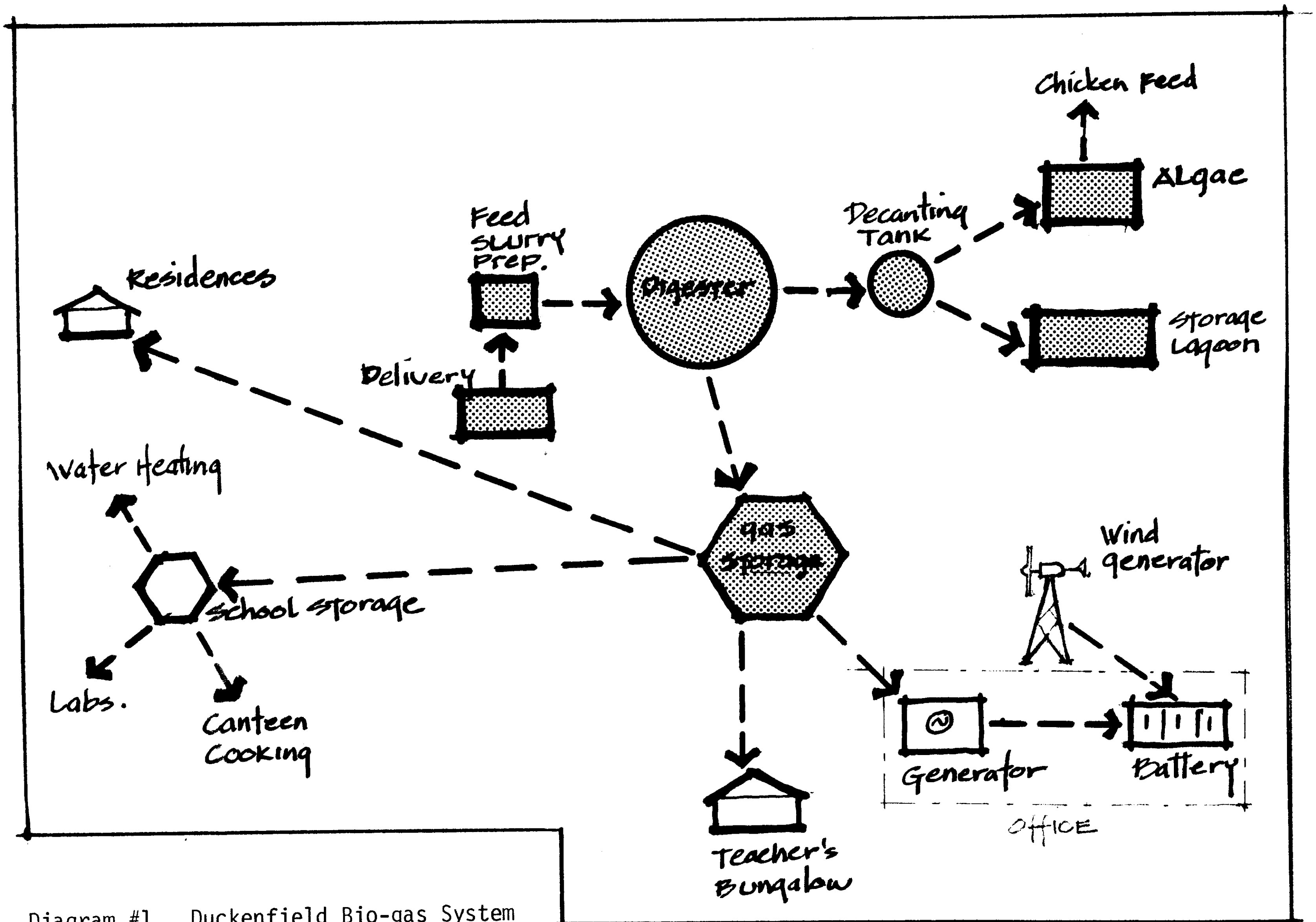


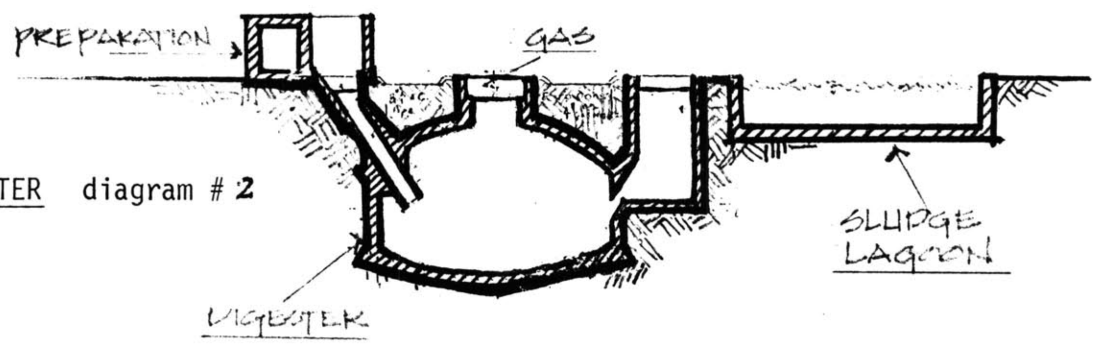
Diagram #1. Duckenfield Bio-gas System

methan off into a floating-cover gas collection tank where through the use of counterweights, the gas pressure is regulated for distribution..

With approximately 116 Ft^3 of slurry available to be fed into two 2,550 ft^3 digester (each 10 - 12 ft in diameter) every one to two days, over 7,880 ft^3 of methane - or 7,880,000. But can be produced everyday. This volume of gas is more than enough to satisfy the water heating, cooking, and laboratory gas needs of the secondary school; the water heating and cooking needs of three neighboring faculty residences, plus the water heating, general gas and electric needs (via use of a methane fueled generator) of the R.C.D.C. office facility. Existing gas (propane) water heaters in the residences and school can be easily converted by changing the orifice size on the unit. Like wise, standard electric generating units can be converted to accept methan fuel.

In the 4th step, excess slurry is

METHANE DIGESTER diagram # 2



removed from the digester and channeled into a decanting tank where, again, liquid super natants are seperated from heavier sludges. With the Chinese digester used in the design, this process occurs automatically through an over flow pipe as a fresh slurry is added.

The 5th step includes drawing off and channeling the heavier sludge -rich in nitrogen (principally as ammonium ion NH_4)- into a storage lagoon where it can be either promptly blended into crop soils or kept in storage with a lid or a thick covering of straw where it can be drawn on for use as a soil conditioner.[16] Both options will prevent the loss of nitrogen by the evaporation of ammonia (NH_3) which occurs when heavily exposed to air.

In addition, the supernatant is channeled into an algae pond where the liquid is treated by taking advantage of the algae's ability to trap solar energy through photosynthesis and to do this is in a symbiotic relationship with bacteria in the pond which utilize the supernatant's organic waste as their energy source.

In the 6th step, the pond waters can be either be returned to the digester or support a fish pond using fish that feed on algae and other materials in the water. The algae itself can be gathered and dried for use as an excellent chikken feed.

SYSTEM COST

Appendix 3 summarizes the financial costs and benefits of the Bio-gas system. While exact prices for the various systems could not be developed, a pay-back financial analysis, using cost estimates from other bio-gas projects, showed a 'break even' pay back period for the entire system of 5 to 7 years.

A. Wind Generator:

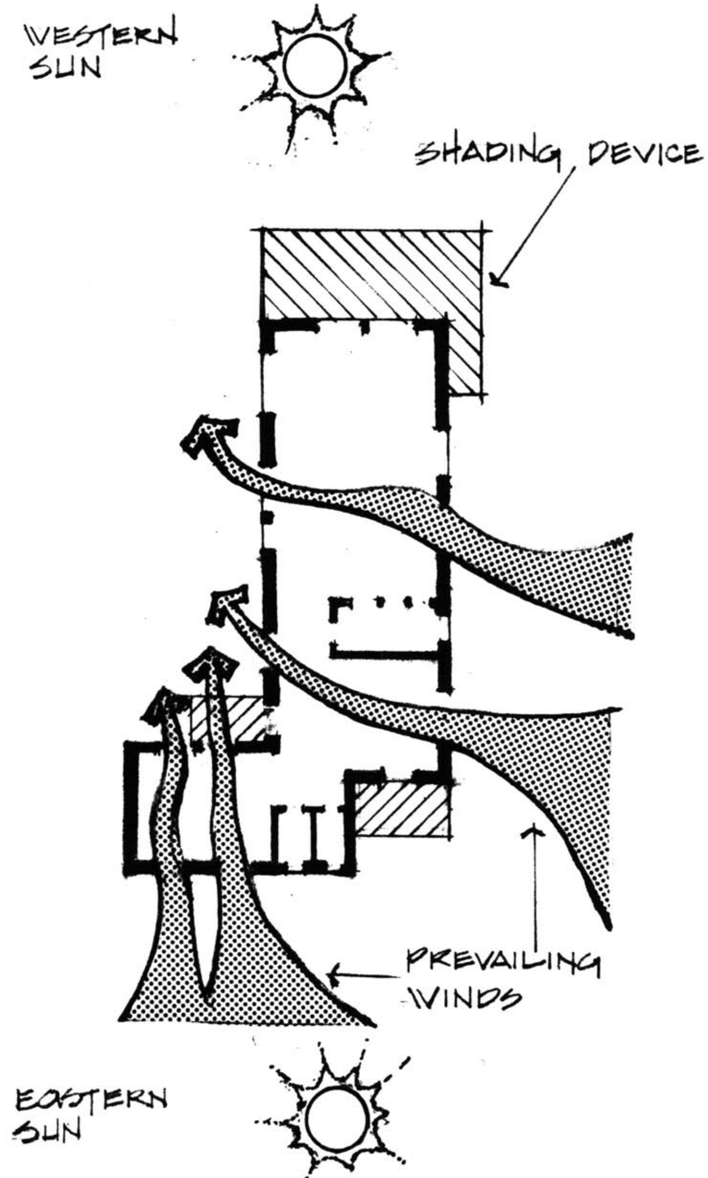
Without accurate wind data for this area of Duckenfield, detailed system performance and cost/benefit analysis was impossible. However, test data from a University of West Indies carried out a wind study in the nearby Morant Point and results of informal estimating on the site indicate that small scale wind generators -while not strong- would be adequate for electricity supply to the office facility. The simple pay-back financial analysis performed by Prof. Chen indicates that approximately an 11 year pay back period can be expected.

OFFICE DESIGN

The design of the R.C.D.C. office building involved blending programatic requirements with the physical design criteria/objectives set out earlier in the chapter. The following gives a brief description and explanation of the design decisions.

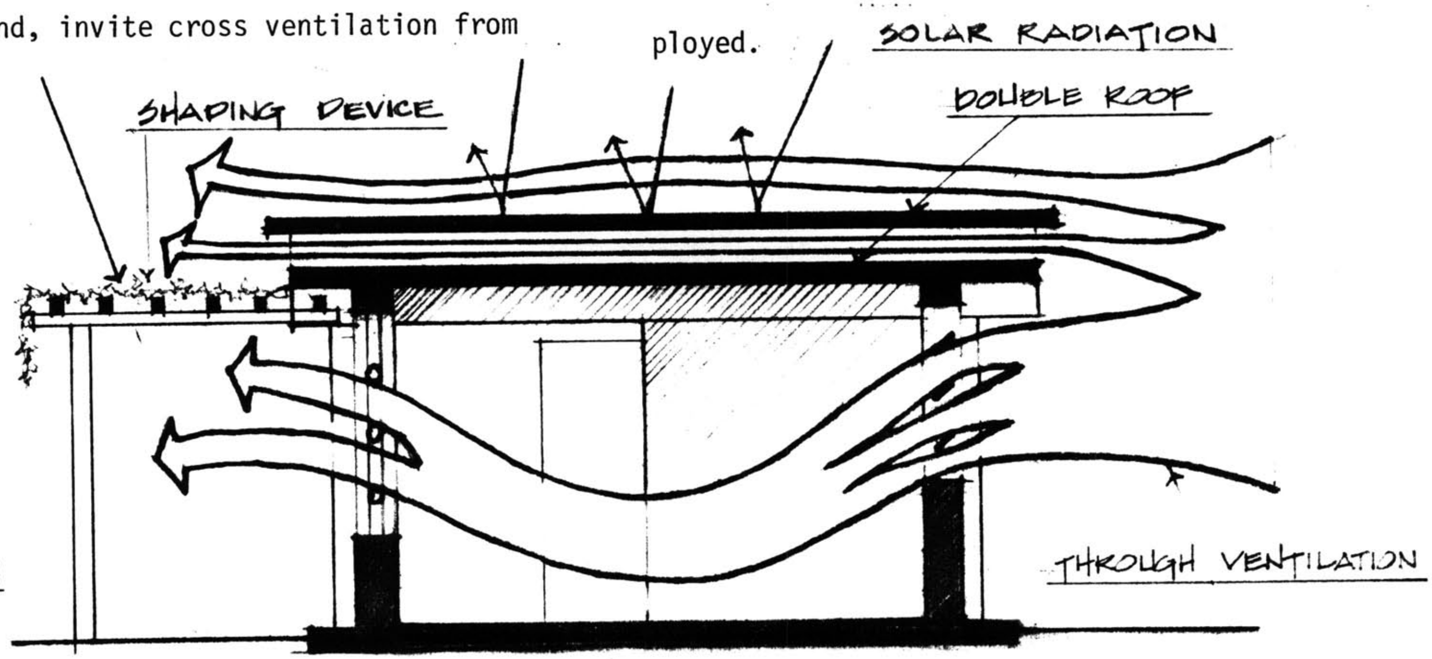
The development of the building plan exemplified this 'blending' process. Formal climate responses were considered in light of program requirements which in turn were assessed for compliance with the established growth direction.

In order to provide comfortable (thermal concitions within the building through natural, nonmechanical means, direct solar penetration had to be minimized while cross ventalization maximized.

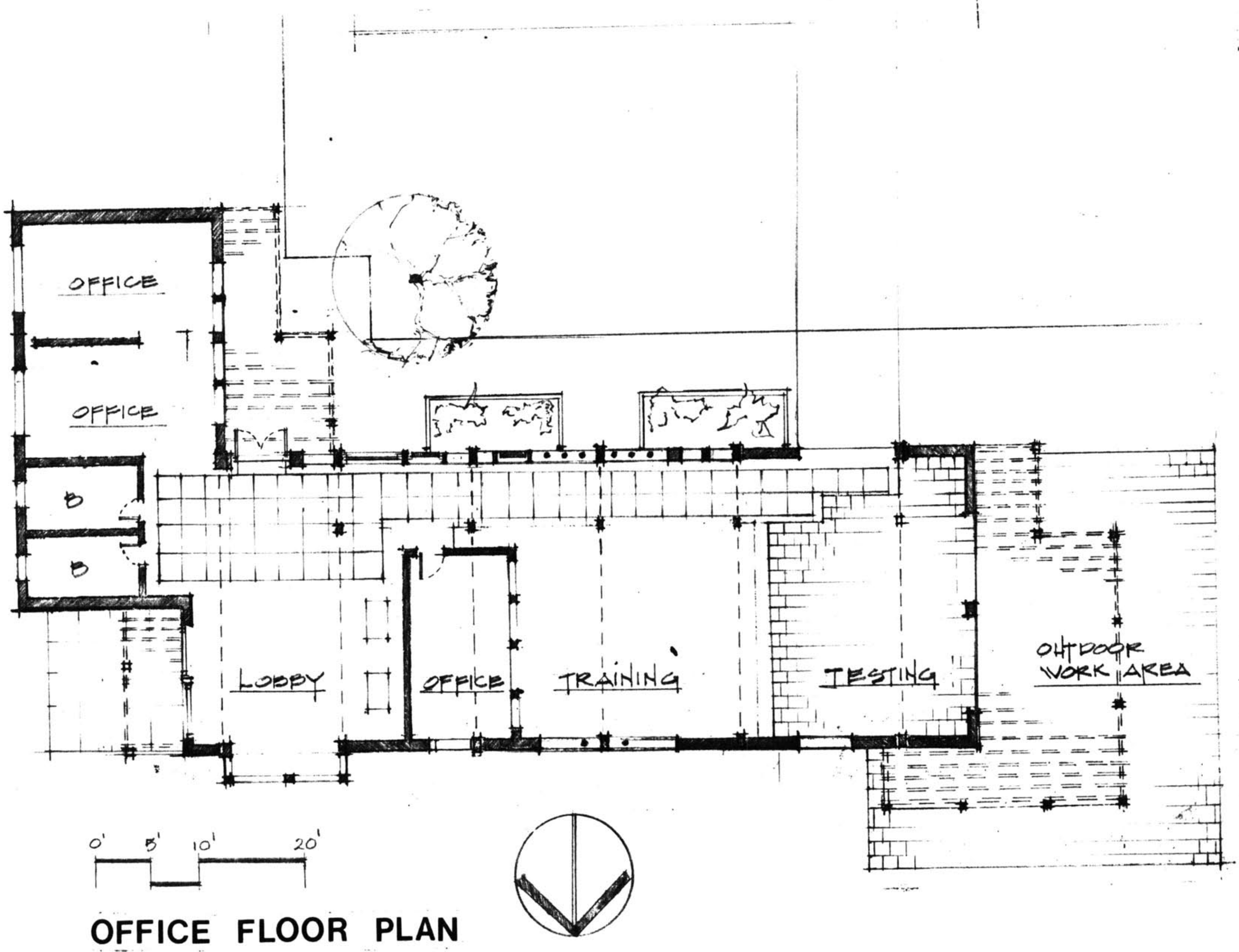


Building Response To Climate

This was achieved by reducing the dimensions of the eastern and western-building evaluations to expose as little of the building as possible to the intense, low angle morning/eastern and afternoon/western solar penetration. Shading devices were also massed heavily on these ends to increase shading/cooling. The long northern and southern elevations on the other hand, invite cross ventilation from northeasterly and southeasterly breezes. (See <u>Building Response To Climate</u>, pg. 63) In addition, a double roof system with long over hangs was employed to minimize heat gain from the high, intense, mid-day sun and to shade the highly fenestrated north and south walls. (See <u>Diagramatic Section</u> below) Because Duckenfield experiences moderate rainfall, a flat roof system could be employed.



DIAGRAMATIC
SECTION



OFFICE FLOOR PLAN

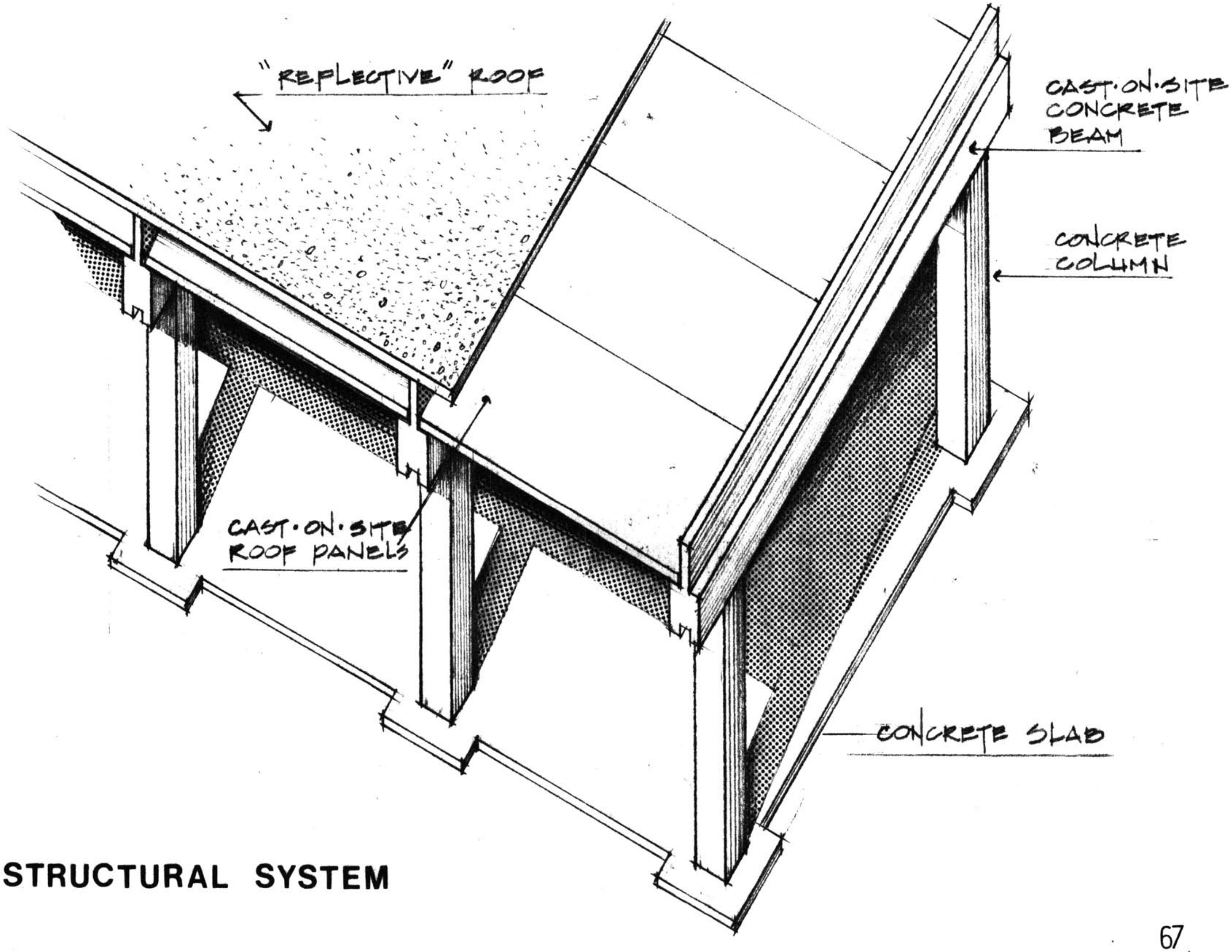
The programmatic and growth requirements integrated easily with these formal climatic responses. By clustering the administrative offices around the entrance lobby area, a formal and programatic "hub" was formed off of which the flexible training/research/testing spaces could extend linearly towards the west affording uninterrupted cross ventilation and establishing a strong westerly growth direction. Training and manufacturing activities could easily filter outdoors onto the adjacent outdoor work area. (see Floor Plan pg. 65)

The proposed construction system was designed to 1) respond to the microclimate 2) promote the use of local building materials and craftsmanship and 3) facilitate necessary expansion and growth of the facility.

As part of the R.C.D.C.'s research activities, the possible ways in which local materials and craftmanship could be incorporated into local construction methods to promote employment and lower construction costs, should be investigated. For the purposes of this design proposal however, the assumption was made that local materials and craftsmanship could be tapped feasibly.

The proposed construction system basically provided a concrete post and beam framework with a light weight, hollow core concrete slab double roof, the components of which could be cast on the site and assembled on a slab-on-grade/spread footing foundation by local workers. (see Structural System pg. 67)

As expansion needs arose, the foundation could be extended, and more components could be manufactured on the site and assembled.



STRUCTURAL SYSTEM

With ventilation providing the only natural cooling, "Open Screen" enclosures that utilize local materials such as bamboo, rammed earth blocks and hand crafted panels were designed. Not only does this approach promote thermal comfort, but also provides beautifully articulated elevations and a handsome overall design compositon that utilizes inexpensive local materials and çelebrates the local Jamaican culture. (see Partial Elevation pg. 68)

PARTIAL ELEVATION

SMITHFIELD

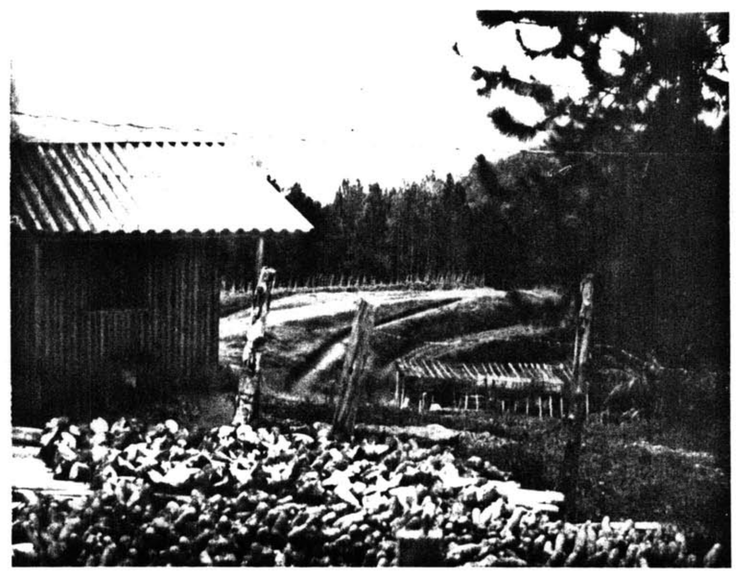

Montego Bay
The Cockpit Country
Spanish Town
KINGSTON
Blue Mountains
Port Antonio
JAMAICA
1:1,250,000

SMITHFIELD

Contrasted to Duckenfield, Smithfield represents what can be done in a community whose agricultural base is smoewhat restricted (by terrain) and whose energy resources are generally less abundant.

GEOGRAPHICAL/SOCIAL-ECONOMIC OVERVIEW:

Smithfield, a section within the community of Cascade, is located in Hanover Parish in the northwestern section of Jamaica. Most of Smithfield's 86 mountainous acres are part of a Ministry of Agriculture Demonstration and Training



Center, which was established to introduce soil conservation farming techniques to teh area. Approximately 36% of the land slopes at 20° or more.[17]

With a population of approximately 1,000 farmers, approximately 600 are legal, small hill farm tenants while the remainder are long term squatters.

The main cash crop of the area is Yam, yielding approximately 12 tons/acre.[18] While it is not an export crop, its domestic markets are extensive. Approximately 48 acres of Banana and 14 acres of plantain are also grown but are strictly distributed to local markets. Scattered cases of cocoa, begetables and potato growing can also be found but almost always for home consumption.

Greater Cascade is one of Jamaica's district centers with a population of approximately 9,000. Most civic buildings such as school (two), health care center, Post Office etc. are located in or near the 'town square.' Again most of the population is small farmers that trade in regional and local markets, such as Lucea and Montego Bay.

COMMUNITY ENERGY ASSESSMENT:

Again, as in Duckenfield, a modest surveying process was used to gather infromation on the community's energy supply and consumption/demand.

An initial interview with the local Ministry of agriculture extension officer provided an overview of the community's productive activities, major institutions and its basic energy flows. A second series of interviews with several farmers and local community leader provided more detailed information on production and energy use.

Unlike Duckenfield, Smithfield has no large export oriented agri-industry. Most of the growing is done on privately owned 5 to 7 acre farms.[19] Farm energy consumption is therefore relatively small and dispersed and centeres mostly on petroleum based fertilizer and yan head drying. Presently, the yam heads are simply left on the ground exposed to the sun to dry in a cleared section of the field used as seed for the next crop. Because of relatively high levels of rainfall and exposure to the ground, variable percentages of the Yam head are lost to insect infestation and moisture rot.

Residential energy supply is mostly from kerosene, for lighting and wood for cooking. Very few residences have electricity.

The Smithfield Demonstration and Training Center is the largest single energy consumer in the Smithfield community. As a regional agricultural training center, a sizable office and dorms - to house visiting trainees- have been build, forming the main compound. Lights, hot water, and kitchen appliances (range, freezer, refrigerator, etc.) are the main sources of energy demand.

COMMUNITY DEVELOPMENT/RENEWABLE ENERGY DEVELOPMENT STRATEGY:

Because of the highly decentralized nature of Smithfield's energy demand and its unique position as a regional training/education center, the primary focus on the strategy was to integrate energy training and education into this existing training program.

The R.C.D.C. was proposed to be located

adjacent to the Demonstration Center replacing as many of the Center's present petroleum based energy systems with renewable systesm as possible. The primary programatic focus R.C.D.C. would be on training farmers to incorporate renewable energy systems into their present farming practices.

SMITHFIELD R.C.D.C. DESIGN

The three step design process used in the DUceknfield study - program development, detailing of design criteria, and decision making - are duplicated here in abbreviated form.

R.C.D.C. Program Development:

Based on the COmmunity Development strategy, the following componants were included in the Center program.

A Renewable Energy Systems

A Renewable Systems

- Solar Hot Water Systems:

  for heating the water supply of the existing Demonstration Project office and the new

- R.C.D.C. office facility.

  Wind Generator

  to supply electricity to the R.C.D.C. office

- Methane Generators

  The R.C.D.C. would assist in the construction of small generators on a farm by farm basis to supply methane gas using crop wastes and manures for farm and residential uses.

- Solar Yam Head Dryer

  To supply a low cost system for drying yam head in a controlled environment to prevent moisture rot and insect infection

B. The Office Building

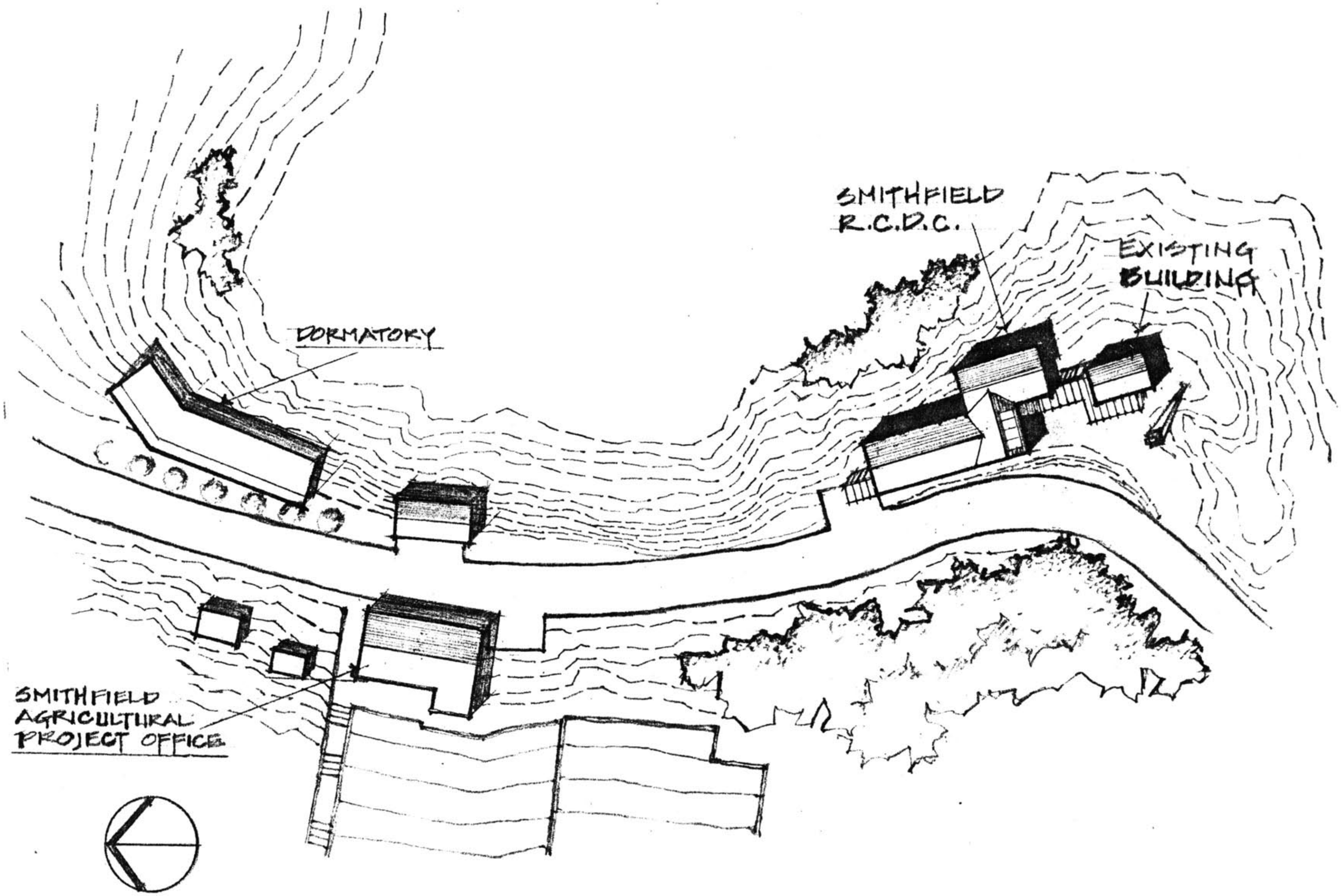
Provide Centrally located office space for the R.C.D.C. manager

Research/Testing:

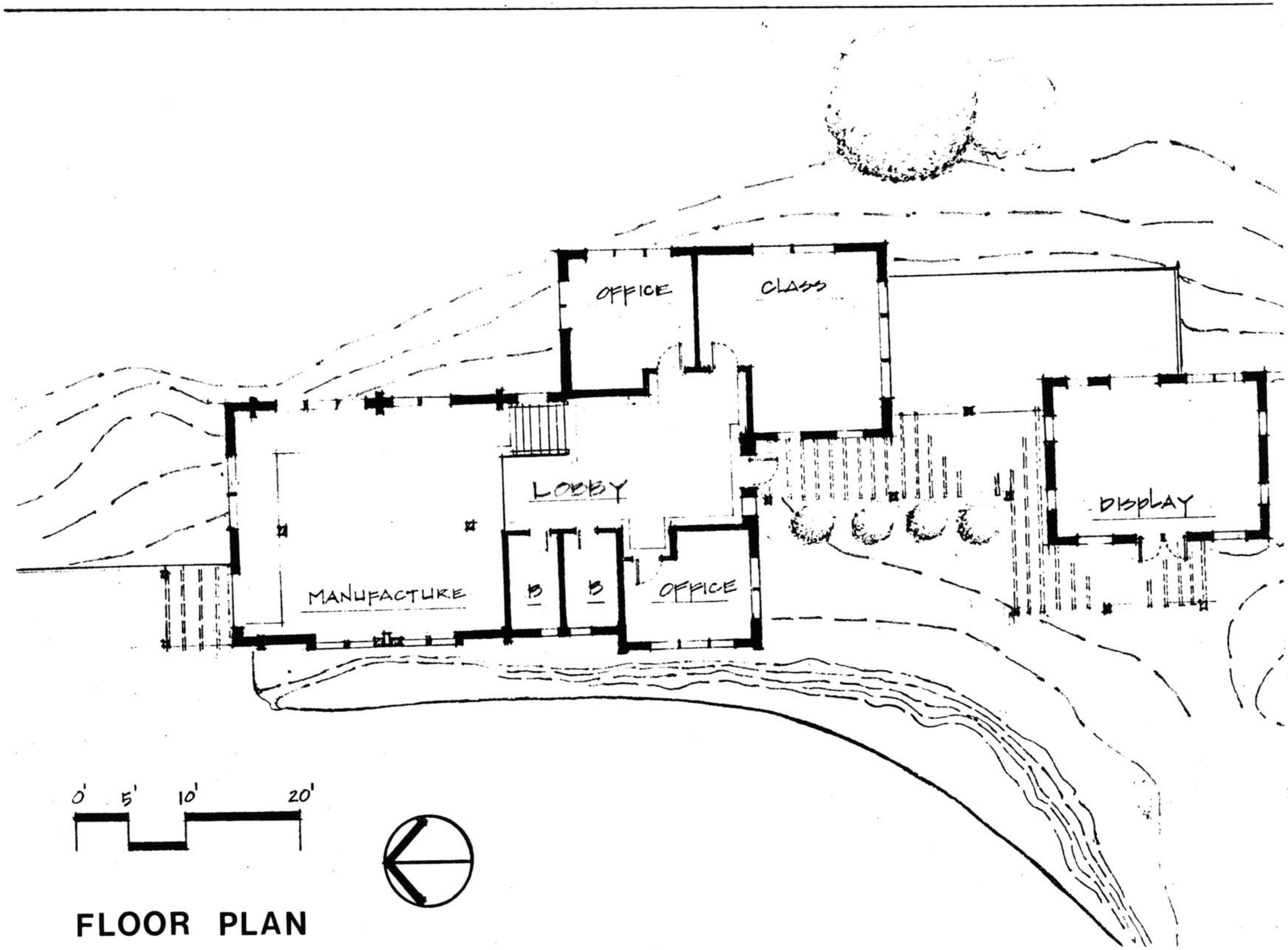
- Provide expandable space for research and testing of local technologies such as the local technologies such as the solar drier and methane generators.

- Training/Public Education

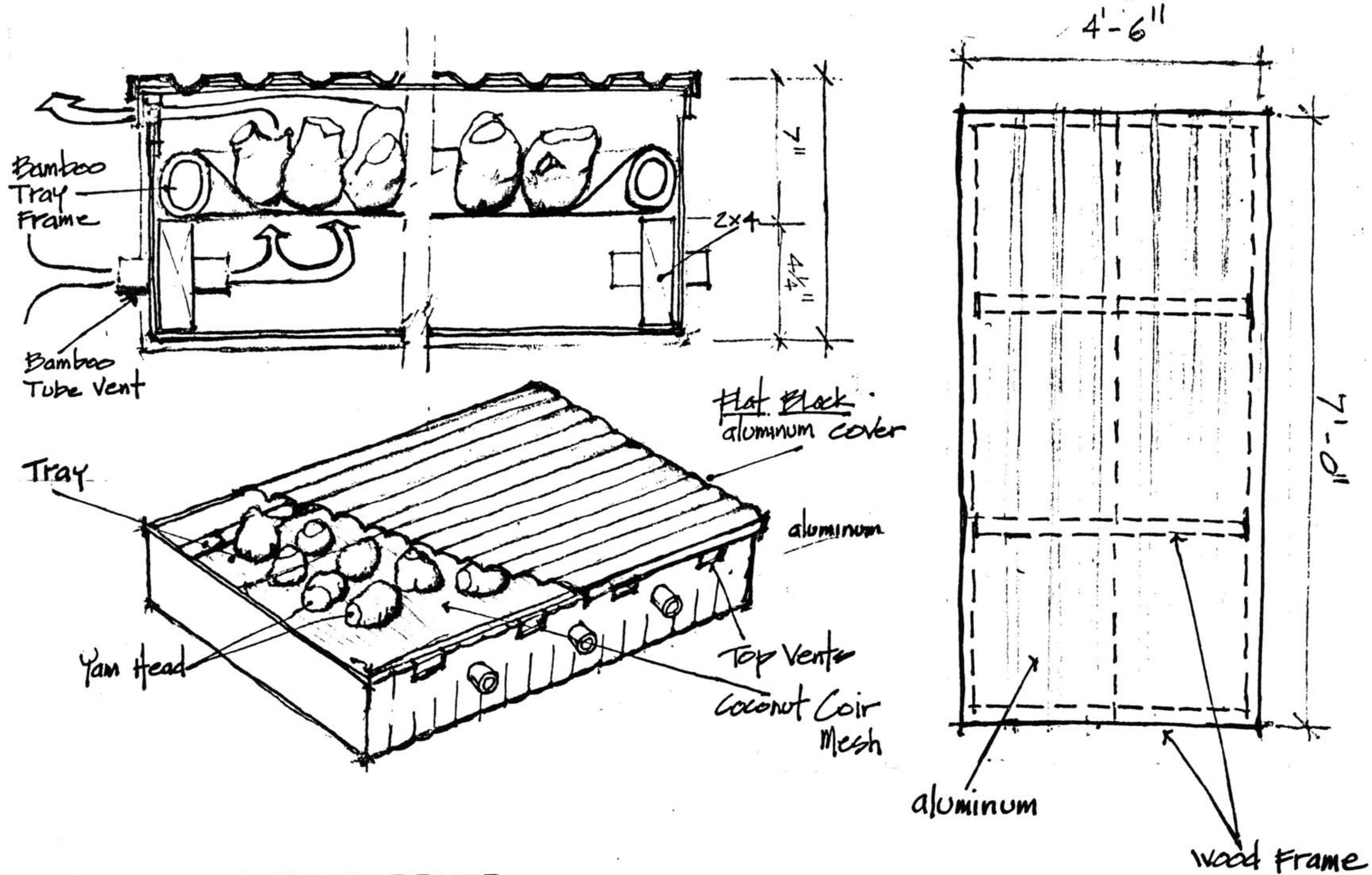
  Provide flexable space for variable sized classroom teaching, open lecturing and training.


DORMATORY
SMITHFIELD
R.C.D.C.
EXISTING
BUILDING
SMITHFIELD
AGRICULTURAL
PROJECT OFFICE

SITE PLAN



FLOOR PLAN



SOLAR YAM HEAD DRYER

CHAPTER 4

DESIGN GUIDELINES

This thesis has explored a way in which the rich renewable energy resources found in each of Jamaica's rural communities can be tapped and organized to form a base for environmentally sound, overall community development. The first section reviewed Jamaica's current plans for both energy and rural community development and offered general suggestions as to how to achieve the necessary integration of the two plans - keeping long range implementation in mind. The Duckenfield and Smithfield case studies attempted to give a more detailed look at how these ideas could actually take form; how the proposed Rural Community Development Centers could be designed to economically respond to energy, educational and agricultural/productive needs.

The following concluding section offers a set of general design guidelines and - in line with the exploratory nature of this thesis - suggests several "next steps" that could be taken in further pursuing this proposal.

DESIGN GUIDELINES

The following guidelines were developed by combining the design lessons learned from the Duckenfield and Smithfield case studies with the results of several earlier climate response such as Victor Olgay's Design with Climate. As with all guidelines, they should not be mistakenly interpreted as being definitive perscriptions - because each site will bring different conditions - but rather as an informational framework out of which responses to varying conditions can be shaped.

A. Climate Response

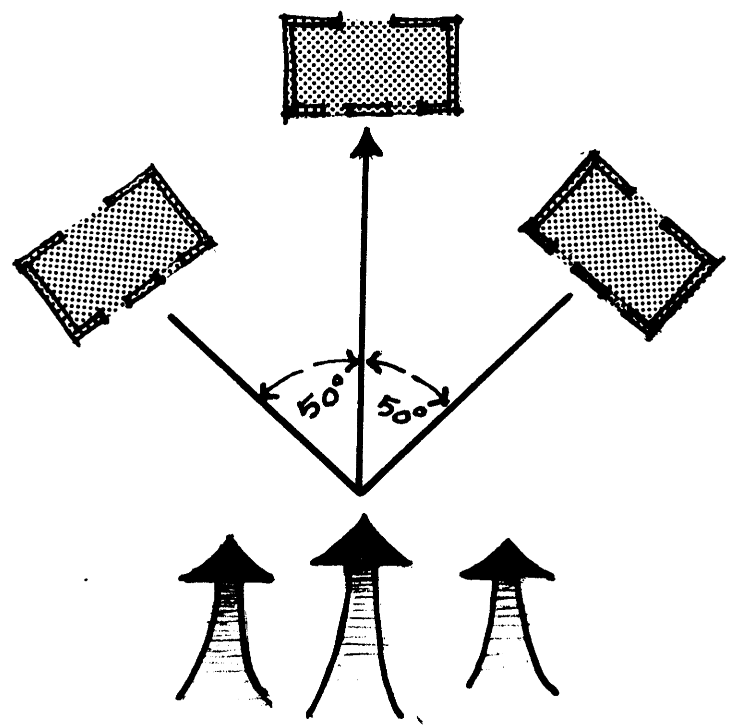
Jamaica's climate - like most hot and humid climates - is generally characterized by "high ambient temperatures, high humidity, small diurnal and annual variations of temperature, and little seasonal variation."[17] But because of its marine location (subject to trade winds) and mountainous terrain, rainfall, wind and other microclimate factors can vary dramatically from one location to the next.

The main comfort requirements in Hot-humid regions are 1) Continuous Ventilation to increase the efficiency of sweat evaporation 2) Reduction of Solar Radiation gain.

B. Building Orientation and Configuration

The building's orientation and configuration should provide the optimal conditions for maximum ventilation and minimum solar penetration.

Orientation may be within 50° of either side of the predominant wind direction and still be effective.[18]



BUILDING ORIENTATION

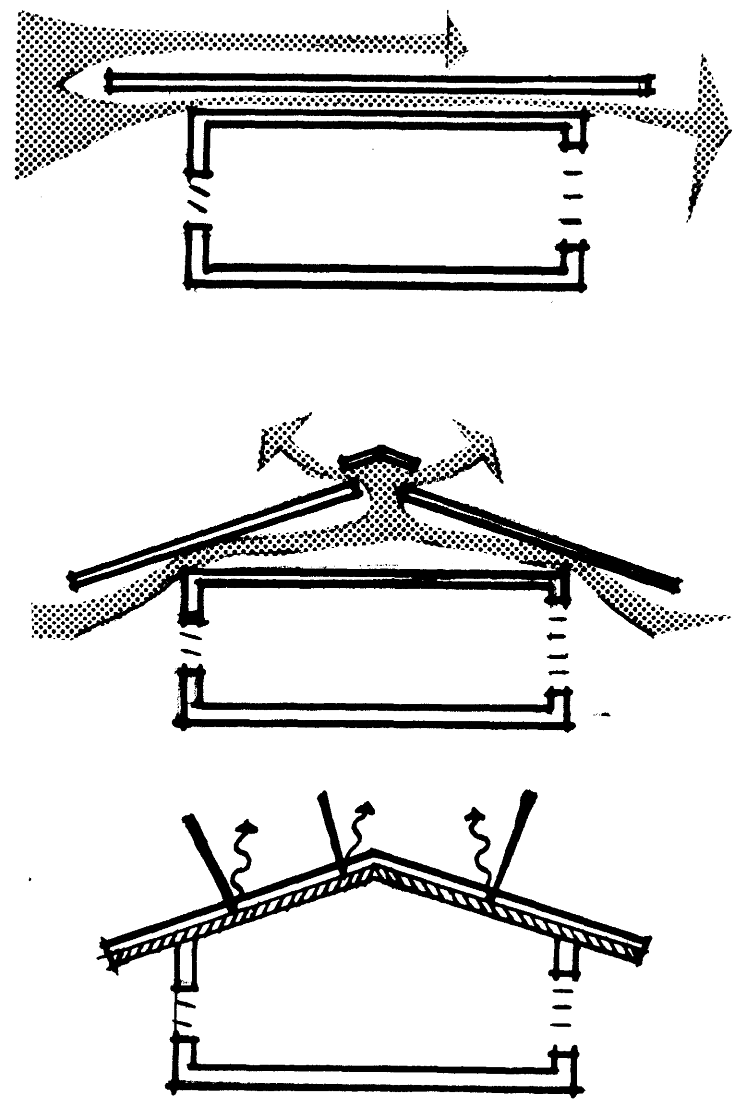
To the extent possible, the building should be configured longest along the east-west axis with the smallest building elevations facing east and west where the most sever solar penetration occurs.

As the case studeis demonstrated achieving the optimal orientation and configuration of the building for climate response is not always simple. In the Duckenfield case, these conditions were achieved very easily; the siet was an open field. Smithfield however, presented the opposite situation The site was a long, narrow strip of land along the ridge of a hill. Optimal conditions were impossible given the severe limit on buildable land, therefore, creative auxiliary mechanisms for naturally tempering the extremes of the climate had to be employed.

C. Roofs

Light weight, low thermal capacity roofs of light color perform best in this climate. The lower the thermal capacity, the lower the amount of heat that will be stored in the roof material and reradiated throughout the day. The lighter the roof color, the higher its reflectance and again, the lower the heat gain.

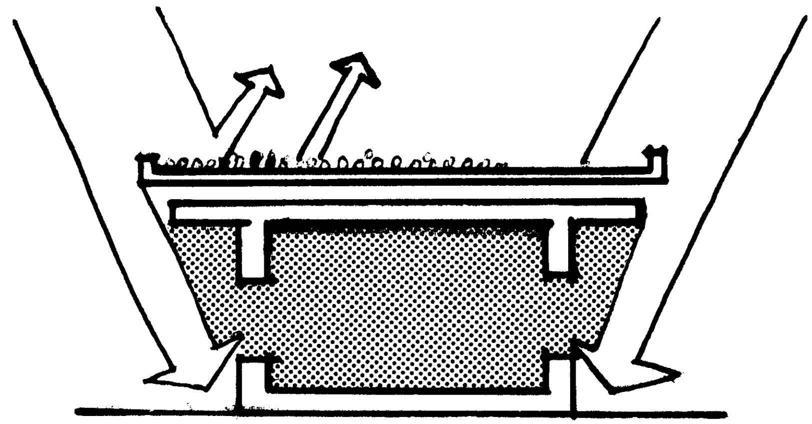
In areas of low to moderate rainfall like Duckenfield, a flat double roof with a ventilated cavity is an excellent solution. In heavt rainfall areas such as Smithfield, a pitched double roof with a ventilated attic is best. Both of these solutions obviously have higher material costs. Therefore, a lightweight, light colored roof insulated from below is usually a lower cost alternative.

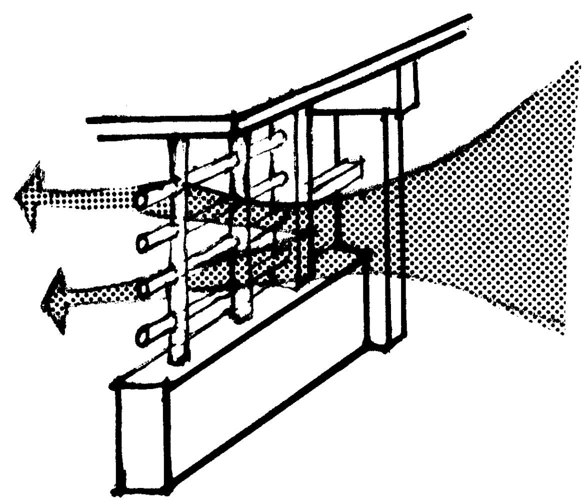


REDUCING ROOF HEAT GAIN

D. Fenestration

Because of high year round ventilation needs, the customary distinction between walls and openings should disappear. Any type of "screen" that freely admits air flow and protects interior spaces from the sun is appropriate. As the case studies demonstrated, this provides opportunities for creative use of light weight, local materials and local craftsmanship. Roll-back openings walls are practical. Revovable shutters are desirable for hurricane protection. Long over hangs protect large wall openings from the sun and rain.





SHADING AND VENTILATION

E. Building Materials

Whereever possible, light thermal capacity "breathing" materials should be used. Thermal lag may cause a small amount of night reradiation of heat and heavy morning moisture condensation.

F. Frameworks

In any abstract or material structure, frameworks provide a basic set of "decisions" upon which later "decisions" can be made.

The Rural Community Development Center can be seen as a frameworks - a set of programatic decisions that allows for later decisions to be made and changes to occur over time. Consistent with this, the center construction method should be based on providing a structural frameworks - columns, beams, and a roof - that will allow for material input from other "craftsmen" in the community and allow for easy expansion over time. By so doing, more local is employed and opportunities for integrating elements of the local material culture are maximized.

CONCLUSION

WHERE TO GO FROM HERE

One of the central purposes of a reconnasance study of this type is to gain insights into how the next, more detailed set of activities can yield the best results. The following comments and suggestions are forwarded in the spirit - emerging from a retrospective of both the results of the study and the process employed to complete it.

CLIMATE DATA

The key to any future broad based, energy related program in Jamaica is the ready availability of local weather data. As was mentioned in chapter this became the primary criteria forselecting the case study communities used in this project because all energy systems testing (cost/benefit and technical performance) is based on accurate weather data. As it was, the unavailability of wind data for both Duckenfield and Smithfield stymied accurate feasibility analysis of wind generation for both communities. Consistent insolation rates for the entire island had to be assumed because testing had only been performed at the two national airports.

Despite the tremendous cooperativeness of the National Meterological Center, no rural community development program, based on renewal energy development can be thoroughly planned, much less successfully implemented, without up to date, community based weather data. Top priority therefore, should be placed on setting up a board network of testing facilities nation wide.

PROPOSAL COST/BENEFIT

An effort was made in this study to provide a very basic financial analysis of the main renewable energy systems employed in each case studv communitv. This was consistant with the exploratorv nature of the thesis in that the aim of the analysis was to simply indicate the price range of the "low cost" systems proposed. In the Duckenfield study, this entailed a cost/pay-back assessment of the biogas system and in Smithfield, a simple cost estimation of the proposed crop dryers.

A far more detailed cost'benefit analysis of the community development plan in general and the R.C.D.C. in particular, would be an essential next step. Clear definitions of what community development is - whether it is simply the economic growth of local industry, or an increase in per capita income, etc., will have to be set.

The local/regional energy sector analysis proposed in chapter will provide necessary information on energy flows and related expenditures. This will comprise part of the data based upon which the assessment of forward and backward economic linkages associated with overall community development and R.C.D.C. activities can be carried out.

SYSTEMS TESTING

The technical state of the art for energy systems is advancing daily, due to the tremendous increase internationally in research on renewable energy sources. As Jamaica's efforts to apply a wide range of renewable systems becomes more broad based, the need for system testing is going to intensify.

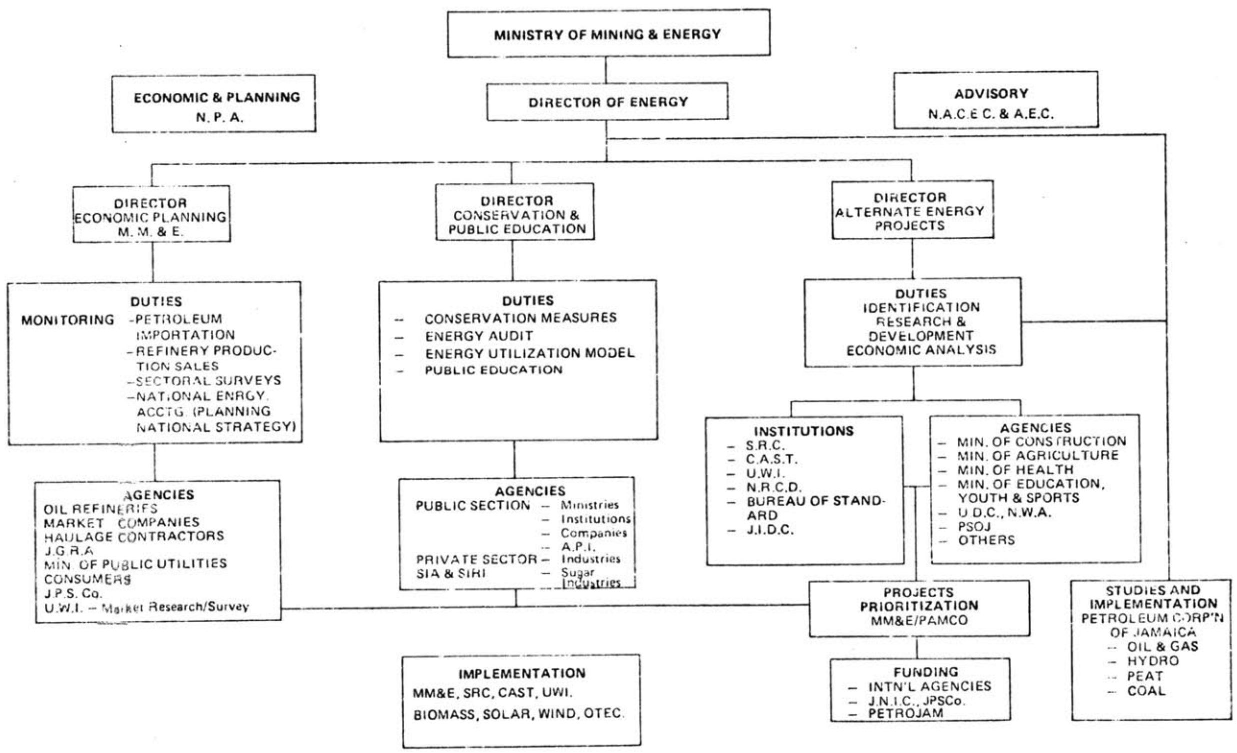
In both the Duckenfield and Smithfield

proposals varying degrees of systems testing would be required in the next stage of program development. The Mona Rehab Biogas Project-directed by the Scientific Research Council-would be a logical source of detailed information and actual system testing for the proposal Duckenfield bio-gas system. The Smithfield crop dryer would require even more intense performance testing-given its unorthodox construction and direct application to agricultural production. Again, the Scientific Research Council might provide the necessary research and test.

APPENDICIES

APPENDIX 1

ORGANIZATIONAL CHART
MINISTRY OF MINING AND ENERGY



API – Agency for Public Information
CAST – College of Arts, Science & Technology
JGRA – Jamaica Gasolene Retailers Association
JIDC – Jamaica Industrial Development Corporation
JNIC – Jamaica National Investment Co.
JPSCo – Jamaica Public Service Co.
NACEC – National Advisory Committee on Energy Conservation

NPA – National Planning Agency
NRCD – Natural Resources Conservation Department
NWA – National Water Authority
MME – Ministry of Mining & Energy
PAMCo – Projects Analysis & Monitoring Co.

PETROJAM – Petroleum Company of Jamaica
PSOJ – Private Sector Organisation of Jamaica
SIA – Sugar Industry Authority
SIRI – Sugar Industry Research Institute
SRC – Scientific Research Council
UDC – Urban Development Corporation
UWI – University of the West Indies

APPENDIX 2

BANGLADESH NATIONAL ENERGY USE SUMMARY

Sector	Conventional Energy Sources: Conventional Fuels Btu x 10^{12}	Conventional Energy Sources: Electric Power kWh x 10^{6}	Traditional Fuels Btu x 10^{12}
Agricultural production (including fisheries)	1.35	6.7	--
Agricultural processing (excluding textiles)	2.04	80.3	39.3
Textiles (including jute processing/baling)	1.82	383.3	.4
Industry (excluding power and fertilizer)	9.51	167.51	.2
Fertilizer	4.69	1.0	--
Services (including transport and construction)	12.56	15.7	1.07
Electric power	13.88	a	--
Commercial	2.91	31.5	--
Domestic	13.65	166.0	164.00[b]
Losses	1.63	410.6	--
Total	63.9[c]	1,262.7	205.0

Source: LDC Energy Planning: A Study of Bangladesh

APPENDIX 3

DUCKENFIELD BIO-GAS (METHANE) GENERATOR

APPENDIX 3A

BIO-GAS SUPPLY AND DEMAND

Quantity of Bio-Waste Materials

Waste Bananas:

10/tons/week/boxing plant[1]

Animal manures:

Animal	Urine Portion lb.(wet)/day	Fecal Portion lb. (wet)/day	No. of Animals	Total Manure Weight[2]
Pig (over 160 lbs.)	4.0	7.5	15	112.5 lb./day
Chickens (3.5 lbs.)		.3	106	50 lb./day

1. This is an estimate made by a Banana Co. of Jamaica boxing plant manager and confirmed by a private banana company ower.

2. From Other Homes and Garbage, p. 195.

Total BTU content of bio-gas =

$$4{,}625.6\ FT^3/day \times 1000\ {}^{BTU}/{}_{FT^3}\ gas$$

$$= 4{,}625{,}600\ BTU/day$$

<u>Area Bio-Gas Demand</u>:

● Secondary School

General Gas Demand = 100 lb. propane/2 months[1] @

$$\frac{2.18\ mm\ BTU}{100\ lbs.}$$

= 2.18 mm BTU/2 months

= 36,333. BTU/day

<u>School Gas Demand for Hot Water Heating</u>

Hot water demand = 4 gallons/person x 1,350 person/day

= 5,400 gals./day

* 1 BTU heats 1 lb. of water 1°F

Total BTU/day = Total gals./day x Δt x 11.3 lb./gal.

5,400 gals./day x 35°F x 11.3 lb./gal. = 2,135,700 BTU/day

[1]General gas demand figure quoted by the school principal during an interview.

Gas from Banana Waste:

In general: 1 lb. dry banana $\rightarrow$ 5 FT^3 CH^4[1]

$$\text{Methane } \frac{(FT^3) \text{ from total banana waste}}{\text{week}} = \frac{10 \text{ ton(wet)}}{7 \text{ days}} \left(0.2 \frac{\text{dry}}{\text{wet}}\right)$$

$$\left(0.75 \frac{\text{ton Cellulose}}{\text{ton banana}}\right) \left(\frac{2{,}000 \text{ lb.}}{\text{ton}}\right) \left(\frac{5 \text{ FT}^3 \text{ CH}^4}{\text{lb.}}\right)$$

$$= \frac{10 \text{ ton}}{\text{week}} \times 1500$$

$$= \frac{15 \times 10^3 \text{ FT}^3 \text{ CH}^4}{\text{week}}$$

$= 2{,}142.8$ FT^3/day per boxing plant
x2 boxing plants

$= 4{,}285.6$ FT^3/day

Total Volume of Bio-Gas Produced $= 4{,}285.6$ FT^3/day
\+ 253.0 FT^3/day
\+ 87.0 FT^3/day

4,625.6 FT^3/day

[1] Conversion formuli and general information on the biochemical characteristics of banana were provided by Prof. Charles Cooney of MIT's School of Nutrition and Food Science

Volume of Bio-Gas Gas Produced

Gas from Manures:

Material	% Total Solids	Bio-gas (FT^3)/lb. Total Solids
Pig Manure	13%	7 FT^3
Chicken Manure	90%	10 FT^3

Bio-gas (FT^3) = lb. of Raw Material x % T.S. x % VS
x FT^3 Gas/lb.

Pig Manure Bio-gas (FT^3) = 112.5 $lb^{(manure)}$/day x .13 T.S. x .85
x 7 FT^3/lb. T.S. = 87 FT^3/day

Chicken Manure Bio-gas(FT^3)= 50 lb./day x .90 x 56.2
x lo FT^3/ lb. T.S. = 253 FT^3

- <u>RCDC Office</u>

  Total gas demand = 25,000 FT^3/month

  = 834 FT^3/day x 1000 BTU/FT^3 gas

  = 834,000

- Teacher's Bungalow

  Total gas demand = 15,000 FT^3/month

  = 500 FT^3/day x 1000 BTU/FT^3 gas

  =500,000. BTU/day

- Residences (2 homes adjacent to school property)

  Total gas demand = 10,000 FT^3/month x 2

  = 20,000 FT^3/month

  = 666. FT^3/day x 1000 BTU/FT^3 gas

  = 666,000. BTU/day

Total Daily Bio-Gas Demand =	36,333	BTU/day
	2,135,700	
	834,000	
	500,000	
	666,000	
	4,172,033	BTU/day

Bio-Gas Supply-Demand Balance

Total Supply	4,625,600	
Total Demand	- 4,172,033	
	453,567	BTU/day

APPENDIX 3B

DIGESTER SIZING[1]

Total Weight of Feed Slurry

Raw Material		Weight lb./day
Pig Manure	=	112.5 lb./day
Chicken Manure	=	50.0 lb./day
Banana waste	=	2,857 lb./day - boxing plant x 2 boxing plants
	=	5,714 lb./day
		5,876.5 lb./day

Raw Material	% of total mixture (%A, %B, %C)	% of moisture of raw material
Pig Manure	3.7%	87%
Chicken Manure	1.6%	65%
Banana Waste	94.6%	80%

[1]From Other Homes and Garbage.

%M = Moisture content of raw material in percent, M = Moisture content of raw material as decimal fraction, Wr = Total weight of raw material, Vw = Volume of water to be added to make 8% slurry, Ww = Weight of water to be added to make 8% slurry, Vsl = Total volume of slurry, Wsl = Total weight of slurry, VSa = Volitile Solids of Material A, Wa = Weight of Raw A, Ma = Moisture Content of A

Percent Moisture of Mixture (%M mix)

$$\%M\ mix = \frac{\%A \times \%\ Ma}{100} + \frac{\%B \times \%Mb}{100} + \frac{\%C \times Mc}{100}$$

$$\%M\ mix = \frac{3.7 \times 87}{100} + \frac{1.6 \times 65}{100} + \frac{94.6 \times 80\%}{100}$$

$$= 3.219 + 1.04 + 75.68$$

$$= 79.9\%$$

Volume of Water (Vw) to be Added (for 8% Slurry)

$$Vw = \frac{Ww}{62.3}$$

$$= 0.1845\ Wr - 0.2\ WrM$$

$$= 0.1845 \times 5{,}876.5\ lb./day - (0.2 \times 5{,}876.5\ lb./day \times .799)$$

$$= 1{,}084 - 939.$$

$$= 145.0\ FT^3\ water/day$$

Volume of 8% Slurry

$Vsl = \frac{Wsl}{65}$ (use 65 pound's per cubic foot as an average density of the 8% slurry)

$= 0.192 \; Wr \times (1-m)$

$= 0.192 \times 5{,}876.5$ lb./day $\times (1-.799)$

$= 226.7 \; FT^3$/day slurry

Calculating Detention Time

COD = Chemical Oxygen Demand

% and moisture content of volitile solids:

$VSa = Wa \times (1-Ma) \times \frac{\% \; Vsa}{100}$

Pig Manure:

$VSa = 112.5$ lb./day $\times (1-.87) \times \frac{85}{100} = 12.43$ lb./day

Chicken:

$VSa = 50$ lb. $\times (1-.65) \times \frac{65}{100} = 11.3$ lb./day

Banana:

$VSa = 5{,}714 \times (1-.80) \times \frac{88}{100} = 1{,}005.$ lb./day

VS Total = 1,028.7 lb./day

Concentration of Volitile Solids:

$$\text{VS con.} = \frac{\text{VS total}}{\text{VSl}}$$

$$= \frac{1{,}028.7 \text{ lb.}}{226.7 \text{ FT}^3}$$

$$= 4.53/\text{FT}^3$$

$$\text{COD} = 12{,}000 \times \text{VS con.}$$

$$= 12{,}000 \times 4.53$$

$$= 54{,}360$$

Solid Retention Time (SRT)

$$\frac{1}{\text{SRTm}} = [a \times k \times [1 - \left(\frac{kc}{kc + \text{COD}}\right)^{1/2}] - b$$

a=constant for bacteria production .04

$$= .04 \times 4.73 \times [1 - \left(\frac{6{,}450}{6{,}450 + 54{,}000}\right)^{1/2}] - .015$$

b=bacteria death rate .015

$$= .189 \times .67335 - .015$$

$$= .112$$

Temp. 77°F
k=4.73
kc=6,450

$$\text{SRTm} = \frac{1}{.112} = 8.90 \text{ days} \times \text{safety factor} = 2$$

$$3 \times 8.90 = 26.7 \text{ days}$$

Digester Volume (Vt)

$$Vt = VS1 \times D.T.$$

$$= 226.7\ FT^3 \times 26.7\ \text{days}$$

$$= 6{,}052.8\ FT^3$$

APPENDIX 3C

Sludge Volume

W_1 = Weight of Sludge solids produced by non-biodegradable solids

W_2 = Weight of sludge solids due to bacteria

Wr = The weight of raw materials added (lbs.)

$$W_1 = W \times [1-(0.5)\left(\frac{\%\ VS}{100}\right)]$$

$$Wr\ lbs. \times (1-m) \times [1-(0.5)\left(\frac{\%\ VS}{100}\right)$$

5,876.5 lbs. x .201 x .6 = 708.7 lbs.

The biodegradable COD:

COD = .75 VS tot.

= .75 x 1,028.7

= 771.5

Sludge solids due to bacteria:

$$W_2 = \frac{0.04 \times COD}{1+(0.015 \times DT)}$$

$$= \frac{0.04 \times 771.5}{1+(0.015 \times 26.7)}$$

$$= 1.1 \text{ lbs.}$$

Total weight of sludge solids:

$$Wss = W_1 + W_2$$

$$= 708.7 \text{ lbs.} + 1.1 \text{ lbs.}$$

$$= 709.8 \text{ lbs.}$$

* The digested sludge is approximately 10% solids by weight

The amount of total sludge = W sludge = 10 Wss

W sludge = 10 x 709.8 = 7,098.0 lbs.

$$\text{Tot. Volume of Sludge} = VSl = \frac{Wsludge}{65} = \frac{7.098}{65} = 109.2 \text{ FT}^3$$

APPENDIX 4

DUCKENFIELD BIO-GAS SYSTEM COST ANALYSIS

COSTS

Capital/Installation .... u.s.$2,000./ Methane Generator
x2 Generators = $4,000.00

Annual Costs $200.00

Gas Storage Tank $500.00

Gas Distribution System (piping) $350.00

TOTAL $5,050.00

BENEFITS

Propane Gas Savings:

R.C.D.C. Office ....Usage = 1x100 lb. tank/2 months...@ $60.00/100 lb. tank
$60 x 6 months = $360.00/yr.

School ....Usage = 1x100 lb. tank/1.5 months.@ $60.00/100 lb. tank
$60.x 8 months = $480./yr.

Residences ....Usage = 1x100 lb. tank/2.5 mths...$60.x 4.8 = $288/yr.

TOTAL $1,400.00

SLUDGE/FERTILIZER

Assume sludge/fertilzer = \$1.70/100 ft^3 sludge

Volume of sludge produced = 109. ft^3/2 days

109.ft^3 x \$.016/ft^3 = \$1.7 x 184days/yr. = \$322.00

TOTAL BENEFITS \$1,722.00

The following is a pay back analysis of the system given the costs and benefits tabulated above. Using interest rates of both 15% and 25%, a pay back period of approximately four (4) years is achieved.

```
READ B,R
PRINT "ANNUAL BENEFITS = "B
PRINT "INTEREST RATE = "R
LET Y = B
 FOR I = 1 TO 10
 LET Y = Y + X
 LET X = B / (1 + R) ^ I
 PRINT X,Y
 NEXT I
 DATA  1722.4,.05
```

ANNUAL BENEFITS = 1722.4
INTEREST RATE = .15

1497.73913	1722.4
1302.38185	3220.13913
1132.50596	4522.52098
984.787789	5655.02694
856.337207	6639.81473
744.64105	7496.15194
647.513956	8240.79299
563.055613	8888.30695
489.613577	9451.36256
425.750936	9940.97613

ANNUAL BENEFITS = 1722.4
INTEREST RATE = .25

1377.92	1722.4
1102.336	3100.32
881.8688	4202.656
705.49504	5084.5248
564.396032	5790.01984
451.516826	6354.41588
361.21346	6805.9327
288.970768	7167.14616
231.176615	7456.11693
184.941292	7687.29354

END NOTES

1. Jamaica, Ministry of Energy and Mining, National Energy Plan, 1982 (Kingston: Agency for Public Information, 1982), p. 12.

2. Ibid., p. 3.

3. Ibid., p. 11.

4. Jamaica, Urban Development Corporation, Comprehensive Rural Township Development Program, (Kingston: Urban Development Corporation, 1982).

5. Michael P. Todaro, Economic Development in the Third World, (New York: Longman Inc., 1977), p. 51.

6. Ibid.

7. Ibid., p. 57.

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