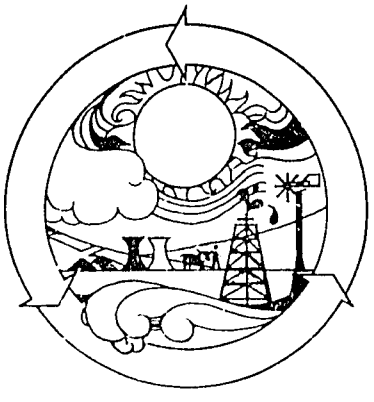
PN-AAL-347

Energy for Rural Development
Program Report PR-80-8



CASE HISTORIES OF ENERGY PROJECTS FOR RURAL DEVELOPMENT

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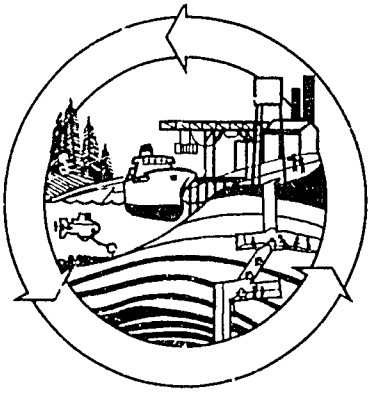
energy
systems

September 1980



CASE HISTORIES OF ENERGY PROJECTS

FOR RURAL DEVELOPMENT

by

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prepared for

SUMMARY OF 18-MONTH ACCOMPLISHMENTS

ENERGY FOR RURAL DEVELOPMENT GRANT

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NOTE: Cases 1 through 5 are completed, edited, and manuscript typed for Pergamon Press, Inc. (See Preface).

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PREFACE

Development to increase economic growth and improve the quality of life has been a major objective of all countries over the last three decades. The pace of development, however, has not always been matched by the ability to manage the process itself. Both developing and developed countries have experienced a lack of project-oriented managers who can provide unified control of development projects for all sectors of the economy and society. This problem has been especially critical in rural areas where shortages of skilled manpower are compounded by inadequate infrastructure, including reliable energy sources.

In response to the need for more effective planning and management of development projects, the East-West Center has worked to create a new conceptual framework for planning development projects and a curriculum for training project managers that uses this analytical tool. The Integrated Project Planning and Management Cycle (IPPMC) is a dynamic approach to management which examines the entire range of a project's activities, from policy formulation through completion, as an integrated process.

The IPPMC is the basis for a prototype curriculum package for project managers that was developed by the East-West Center, in cooperation with over fifty organizations in fifteen countries, during the years 1972 to 1977. The basic instructional tool of the prototype curriculum is a series of case histories analyzing real-life development projects within the mold of the IPPMC. Each case describes the entire history of a project, from identification through completion, with final evaluation of the project's success or failure providing the feedback necessary to sharpen and refine policy guidelines.

A total of 32 case histories of development projects from all sectors of the economy and society have been researched and written over the past two

years with a major grant from the Exxon Education Foundation. Partial support for this particular manuscript was provided by the grant from the U.S. Agency for International Development to the East-West Resource Systems Institute to undertake a major study concerned with "Energy for Rural Development."

Since all developing societies require energy to make their economic and social plans a reality, it was decided to include in the total number of case histories 13 cases of energy projects covering geothermal, biomass, and small hydroelectric projects for rural development. This decision was based on the fact that new alternative energy sources are needed for agriculture, communication, transportation, food processing, manufacturing, rural households, and other vital development activities. Presently, the energy needs of most nations throughout the world, developed and developing, are to a large degree being met with imported oil from outside sources. The impact of current world prices for oil is resulting in extremely severe economic and social disruptions. It is therefore vital to the future of mankind that available indigenous resources be utilized to meet energy needs in order to reduce dependence on imported oil.

For the purposes of the AID Grant on "Energy for Rural Development," it is felt that 5 of these cases are directly related to the objectives of the grant. These cases cover biomass and small hydroelectric projects in the Philippines, Fiji, China, and New Zealand. These 5 cases have been packaged in manuscript form as Sections 2 through 6 of this manuscript. The Introduction provides brief background materials on the concept and applications of biomass energy projects and small hydroelectric projects for rural development. It concludes with a discussion of the Integrated Project Planning and Management Cycle (IPPMC). The concluding section analyzes and evaluates each of the 5 case histories with respect to policy issues and research issues.

The five case histories contained in this manuscript have been accepted for publication by Pergamon Press, Inc. of Elmsford, New York.

INTRODUCTION

Energy is one of the most basic inputs to the development process. Recent global events have focused attention dramatically on appropriate ways of assessing and meeting the energy needs of all oil-importing nations, with increasing concern for island nations and rural areas in developing nations. Many of the Pacific nations and rural areas in Asia possess the means to reduce their dependence on imported oil, and over time they could become largely self-sufficient in energy requirements. There are available indigenous resources which could be utilized to meet energy needs. These include: geothermal, biomass, water power, solar, and wind. It is possible that these sources can be developed to meet much of the energy requirements, especially with a proper mix of indigenous renewable energy resources. This section will examine and discuss the potential of biomass fuels and small hydro power plants. It concludes with a discussion of the Integrated Project Planning and Management Cycle (IPPMC), the conceptual framework for researching and writing each of the case histories of energy projects.

Biomass Energy

From biomass--plant matter available for processing into food, fiber, and chemical products--comes mankind's oldest and most fundamental source of renewable energy. Until the use of fossil fuels became widespread, biomass in the form of wood was the main energy source for most countries of the world; for some it remains the only source. In the broadest terms, however, biomass resources for energy include not only wood but microbes, plants, animals, animal and vegetable oils, and organic wastes.

Figure I.1 shows how the natural forces of photosynthesis work in plant systems to produce biomass energy. Photosynthesis is the biological process by which plants and algae convert sunlight, water, and carbon dioxide into

carbohydrates and oxygen. These carbohydrates are then used as energy sources and raw materials for all other synthetic reactions in the plant. When the plants are harvested (or the organic wastes are processed), the solar energy which has been stored can be converted to a variety of biomass fuels: solids such as wood and charcoal, liquids such as oils and alcohols, gases such as methane and hydrogen, or electricity. The exploitation of these photosynthetic by-products represents a long-established technology for energy conversion and storage.

The production of a biomass fuel once photosynthesis has taken place can be summarized generally as follows (see Figure I.1): a plant system, whether crops, forests, exotic species, or an energy farm, is harvested, producing a wide range of biomass resources, including crop and forest residues, energy crops, animal and urban wastes. These resources may then be pretreated in several ways, including drying, separation, hydrolysis, densification, and pelletization; ideally, in an integrated management system some type of biomass energy can itself be used as the processing energy. At a center producing ethanol from sugarcane, for example, part of the refuse can be converted into bagasse to fuel the ethanol production process.

The conversion process that turns a biomass resource into a fuel can be either biological or thermochemical. Besides fuels, biomass resources produce electricity in the form of steam and chemicals such as feedstocks and fertilizers. All these products have diverse domestic, commercial, industrial, and transport uses. With proper management, a number of by-products of the conversion process, such as fertilizers made of compost from bagasse or sludge from biogas digesters, can be recycled into the plant system, recharging the land and creating a closed energy cycle.

Although it is difficult to quantify the amount of biomass presently used in, for example, developing countries, estimates indicate that the amount of

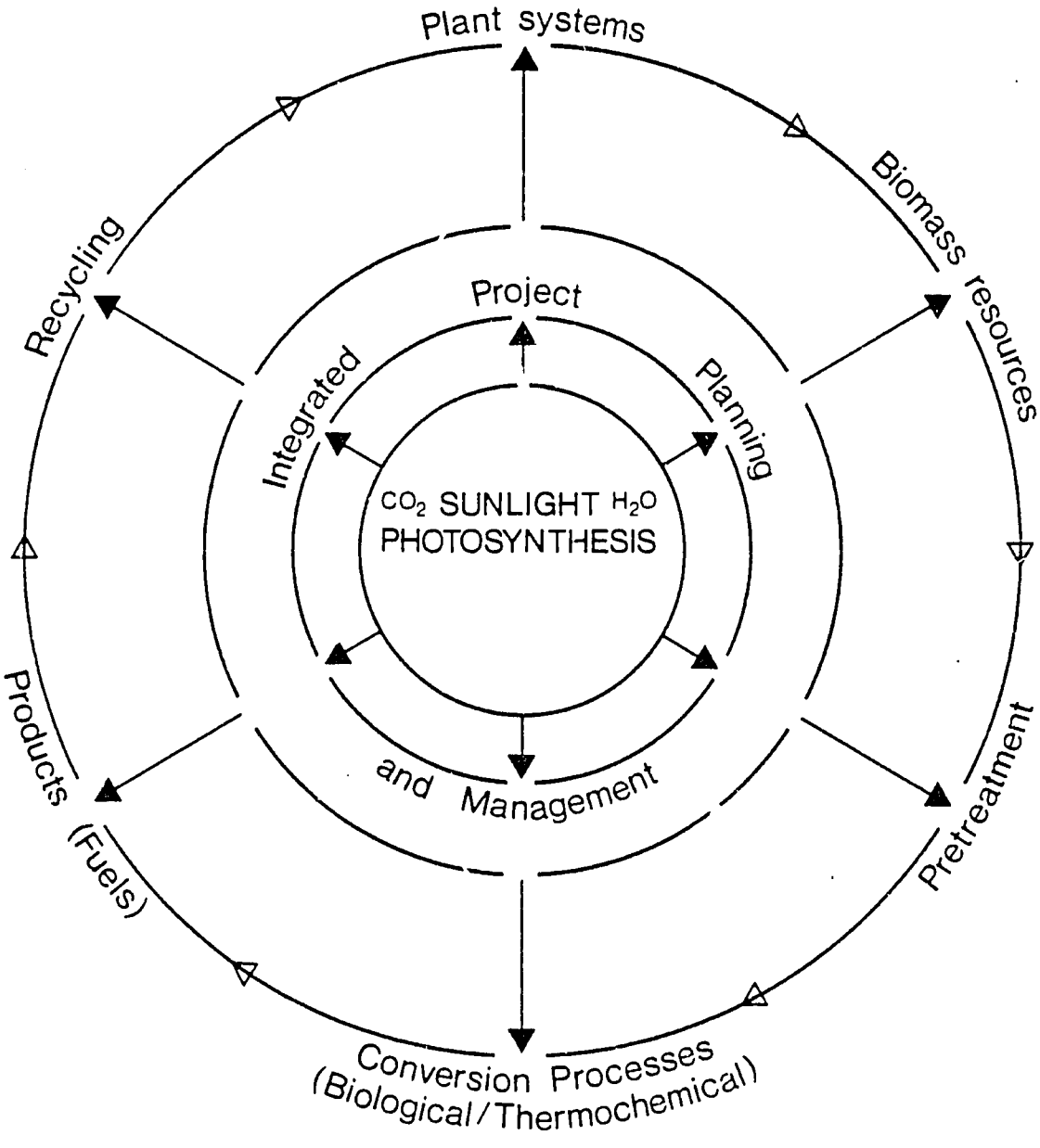


Figure I.1. Biomass energy production process.

biomass energy consumed annually is probably equal to the amount of energy moving annually in the international oil market.[1] Clearly, on a global scale, many rural areas have continued an unbroken tradition of using wood, vegetable matter, or dung as a primary energy source for domestic and village use. Ironically, rising petroleum costs and the supply restrictions of the late twentieth century are forcing the more technologically advanced nations to return to biomass and other renewable energy sources as alternatives to once abundant and inexpensive fossil fuels.

Until recently, however, science has paid little attention to biomass conversion technologies. The reasons for this are manifold: first and foremost, with cheap supplies of fossil fuels there was little incentive to explore renewable resources of any sort. Second, biomass fuels (often referred to as biofuels) are in many ways more difficult to study than their fossil fuel counterparts. While it is easy to determine the energy content of oil, or even obtain reliable values for the various grades of coal, it can be difficult to obtain similar values for raw biomass resources. The complexity of the subject matter is largely due to the interrelationships of the dynamics of biology, photosynthesis, ecosystems, and bioconversion methods.

Third, biomass is considered to be an "inconvenient" material to process industrially. It is not as easy to handle as fossil fuel materials; it tends to be highly nonstandardized in shape and density and is frequently bulky; and it often requires tedious collection methods and pretreatment such as drying, chipping, pelletizing, and other transformations. Finally, biomass energy resources require flexible management if they are to be reliable. Whereas the rate of extraction of coal or oil is fairly simply fixed by policy and technology, biomass resources--like any other agri- or silvicultural resources--are subject to the vagaries of weather, pests, and disease.

Despite these limitations, there is little doubt that biomass fuels will become increasingly attractive in the future. The most important factor in the reconnaissance of biomass research is, of course, the skyrocketing price and foreseeable depletion of oil. As biomass is a form of solar energy, its aspect of renewability makes it an appealing prospect. Here it should be noted that estimates of current biomass use, as quoted earlier, tend to mask some of the major factors involved--most important of which is the efficiency of energy use in the developing countries. For example, because of lack of capital and information, much of the biomass presently burned is used in combustion equipment whose form has remained unchanged for hundreds of years. It is therefore likely that, on the average, less than 15 percent of the energy in biomass fuel goes into useful work. With the application of appropriate technologies, this efficiency could probably be doubled.

The development of a diversity of technologies can offset some of the difficulties involved in biomass processing. Unlike the fossil fuel industries, which tend to be similar in structure and management from place to place, biomass energy systems may possess the flexibility to be either high or low technology, capital or labor intensive, and large- or small-scale in management and organization. With certain important limitations and modifications, therefore, biomass conversion does represent a flexible and widely available solution to the severe problems of dependence on imported fossil fuels.

Small Hydro Power Systems

The first source of mechanical power was that derived from flowing water, either falling directly upon paddles attached to a wheel or filling buckets attached to a wheel. The origin of these devices, known as waterwheels, can be traced to ancient Egypt, China, and Persia. History shows that waterwheels took over many tasks such as raising water for irrigation purposes and water

supply, as well as grinding grain for flour. As the demands for power increased, larger waterwheels were built. By the middle of the 19th century, the revolutionary development of the water turbine by Fourneyron in France began to replace the waterwheel.

History further records that water is the only renewable energy source that has been exploited by man on a large scale and that has a well-developed technological base to support its continued exploitation. Indeed, hydropower is a form of nondepleting, self-replenishing energy, and is also the most efficient and least polluting form of power. To date, it is the only practical means to store electrical power by means of pumped storage for use at a later time.

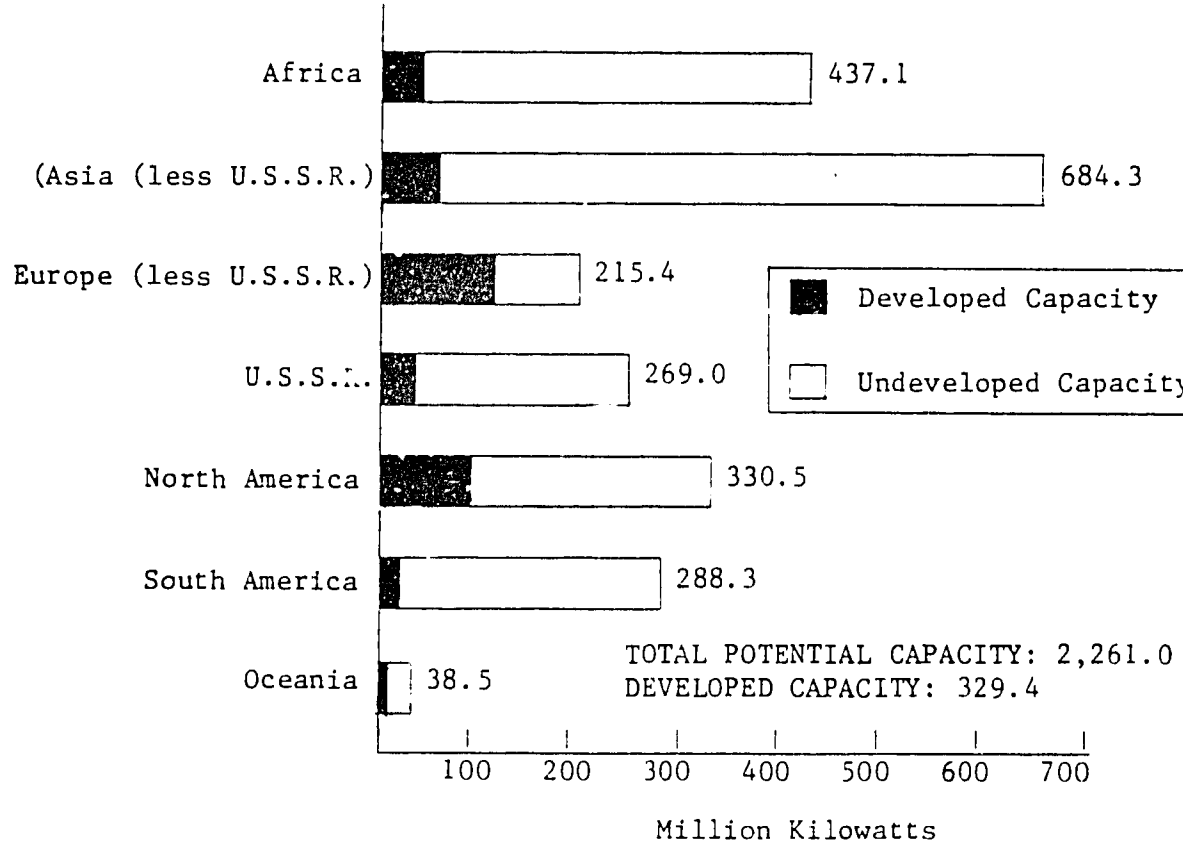
The waterwheel and the small hydroelectric turbine may be seen as the springboard from which hydraulically endowed areas were transformed from handcraft to machine-based economics. Consequently, the history of small-scale hydroelectric development can provide sound suggestions for helping rural areas of both developed and developing countries achieve an improved standard of life, both for themselves and for other regions of their countries. Ideally, a small hydro system should serve several purposes in addition to power, such as water supply, flood control, and irrigation.

Small hydro power plants offer several advantages. The facilities are small and can be aesthetically acceptable. In addition, the effects upon stream ecology are minor compared to larger hydro facilities. Small dams may in fact enhance the streams by maintaining water depths sufficient to support aquatic life. Finally, technology for hydro power plants is well established. The required components are available throughout private industry. This could speed formation of an industrial base with potential for mass production and capacity to develop substantial small hydro resources.

Utilization and Potential of Hydropower Every region of the world has a certain level of hydroelectric power potential, and in some cases, the potential is very significant. Total worldwide water power resource potential is 2.3 million megawatts, of which approximately 300,000 or slightly more than one-tenth is developed. As can be seen from Table I-1, the bulk of this potential is in Asia, followed by Africa and North America. Resources in Latin America are also significant.

Table I.1

REGIONAL HYDROELECTRIC POTENTIAL



Source: U.S. Department of the Interior, Energy Perspectives, February 1975.

While these figures seem impressive, they are somewhat unrealistic, since to tap into that amount would mean flooding rich natural ecosystems and/or fertile and cultivated farmlands. This is especially true of large-scale water power projects, so for many developing nations, small-scale hydroelectric schemes are more feasible. Even according to the most conservative estimates, if the world's vast assortment of small hydroelectric sites are taken into consideration, then the current 340,000 megawatt capacity is boosted to over 1 million.[2]

In summary, world resources are abundant and available. Previous efforts to harness large river systems for large-scale hydroelectric power will undoubtedly continue, but for many developing nations, small- and medium-scale schemes will probably receive equal priority. They are less disruptive environmentally and socially, and lend themselves to multipurpose uses. Rural development efforts, especially in the area of increasing agricultural production, will in all likelihood be linked closely with the future of small-scale hydroelectric power.

Small Hydro Systems. We will define a small hydroelectric system as one with a developmental potential of 15 megawatts (MW) or less. There is no universal definition for small (or micro) water power stations. The Department of Energy in the United States uses 15 MW as the upper limit for small hydro sites. This upper limit will vary from as much as 50 MW* in New Zealand to 5 MW in the Philippines. In terms of developable or rated head (the difference between head water and tail water elevations--see Figure I.2), the upper limit is normally considered to be approximately 65 feet (20 meters). The power generated, however, is related to both rated head and the rate of flow of the water.

With increasing attention devoted to this field because of rapidly changing economic patterns, it will be of interest to examine and discuss the major components of the small hydro system. These components normally include: (1) a dam to create the elevation difference (head); (2) a penstock to convey water to the

*There is no definition of small hydros in New Zealand. Fifty MW is the upper limit for local government hydros.

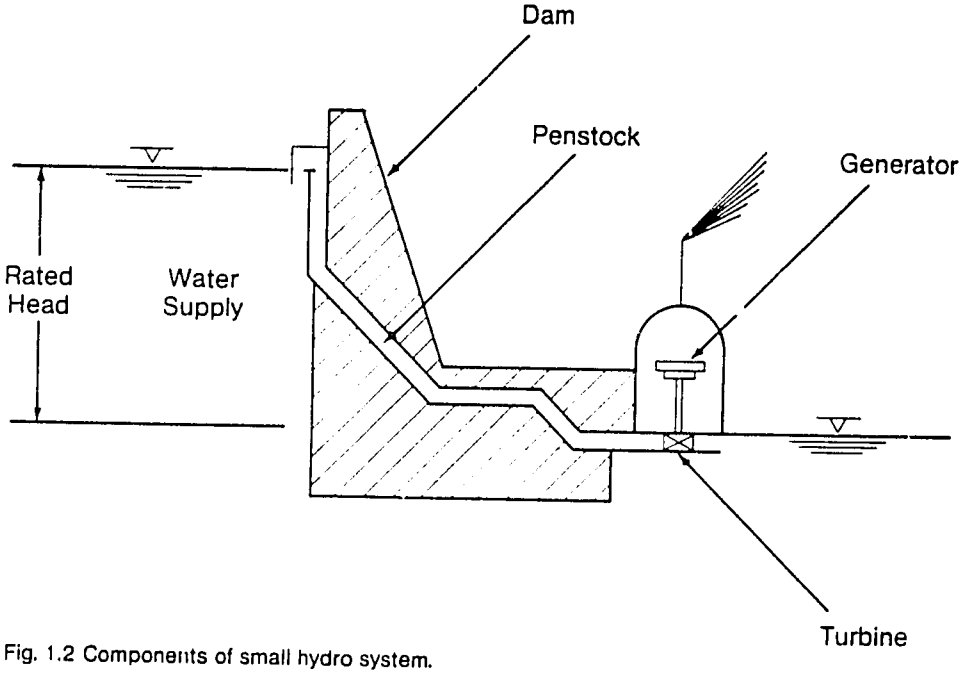


Fig. 1.2 Components of small hydro system.

turbine(s): (3) the turbine and its discharge piping; (4) the electrical generator; and (5) connection between the turbine and the generator. Figure I.2 shows a typical layout for a small hydro system. There are examples of small-scale systems where the drop in elevation from the water source to the turbine is sufficiently great that a canal system can be utilized (Case 4). However, a dam is more effective in controlling stream flow as well as providing water supply systems.

Dams are classified as low or high, storage or run-of-river, with concrete, earth, or timber construction. Penstocks are usually made of steel and can be installed above or below ground. The hub of the system is the powerhouse which contains the turbines and generators. There are two basic types of turbines, impulse and reaction. An example of an impulse turbine is a Pelton wheel--water under high pressure is directed against a series of cups attached to a shaft. In reaction turbines, water flows directly through the turbine, exerting pressure on angled blades or vanes.

The major expenditure for small hydro power development is the initial capital investment, including costs for the main structures and generating machinery. Operational and maintenance costs for small hydro facilities have proven very low, and once completed, the plant's costs are largely unaffected by inflation.

A recent development that will improve the economics of small-scale hydro development is the introduction of standardized, pre-engineered low-head turbines. These turbines have a maximum output of 6 MW and cost about one-half as much as custom-designed turbines. Packaged hydroelectric units are also available off-the-shelf, and include fixed blades and a direct connection to the electric generator, doing away with the inconvenience, expense, and reduced efficiencies of using belts or gears.

For the most part, small hydro systems have more applications than just that of producing power. For example, many hydroelectric plants in the United States utilize water from federally owned reservoirs originally constructed for flood control and irrigation. In California, for example, irrigation reservoirs constructed in the 1960s are being retrofitted with intake tunnels and rebuilt Francis turbines to generate electricity. In addition, irrigation canals with drops as low as 15 feet (4.6 m) are being reconstructed to generate electricity with the use of small-scale hydroelectric equipment. These examples represent projects where agricultural activities were the primary purpose (irrigation, flood control) and electricity generation an auxiliary outcome.

The demand for water by farms has continued to grow as Japan grows economically. One result has been the utilization of water resources for the integrated development of river basins, including the construction of multipurpose, small-scale hydroelectric stations. Fossil fuel costs are especially high for Japan and this has necessitated a reappraisal of medium- and small-scale hydroelectric projects, especially for remote rural areas, and always linked directly to agricultural production. A study conducted by the Agency of Natural Resources and Energy (a division of MITI) recommended that small-scale hydroelectric stations be utilized for rural development as follows:

1. Household electrification in agricultural, rural sectors.
2. Electric generating facilities for fishponds and aquaculture in general.
3. Rural electrification for livestock and animal husbandry in general.
4. Electricity generation in general for agriculture and agro-based industries.

The primary emphasis for developing small-scale hydroelectric stations in China is to support the development of agriculture by supplying energy for such agricultural inputs as fertilizer, cement plants, irrigation schemes, etc. An example from one county (Linxian) specifies that investment plans focus first on

continued electricity generation, second on coal extraction, third on construction and operation of fertilizer plants, and fourth on agricultural machinery production, all of which depend on energy generated primarily by the numerous small- and medium-scale hydroelectric stations in the country. With respect to electricity distribution from the hydroelectric plants, first priority is for agriculture-related machinery and industry; second priority is to power irrigation and pumping stations; third priority is for household consumption. In addition, small-scale hydroelectric stations in China are generally used to power machinery for the production of agricultural machinery spare parts, to power grain and cotton processing plants, and for pumping stations for reservoirs and irrigation.

In summary, it seems obvious that biomass and small hydro projects, with their increasingly important role in world energy development, demand a systematic planning and management approach that can handle their special requirements without sacrificing overall flexibility. The projects described in this manuscript, though independently conceived, have been analyzed within a single conceptual framework--that of the integrated project cycle. The unifying guidelines that follow allow us to compare and contrast biomass and small hydro projects of varying size and scope in different regions of the world.

The Integrated Project Planning and Management Cycle (IPPMC)

Each of the projects is written as a case history in the framework of the integrated project planning and management cycle (IPPMC).[3] The IPPMC is a conceptual tool for observing and analyzing the unifying process that constitutes the life of a development project (Figure I.3). This integrated framework has been developed to clarify the major phases and tasks that constitute the entire spectrum of a given project from planning through implementation, evaluation, and refinement, with policy as the controlling influence.

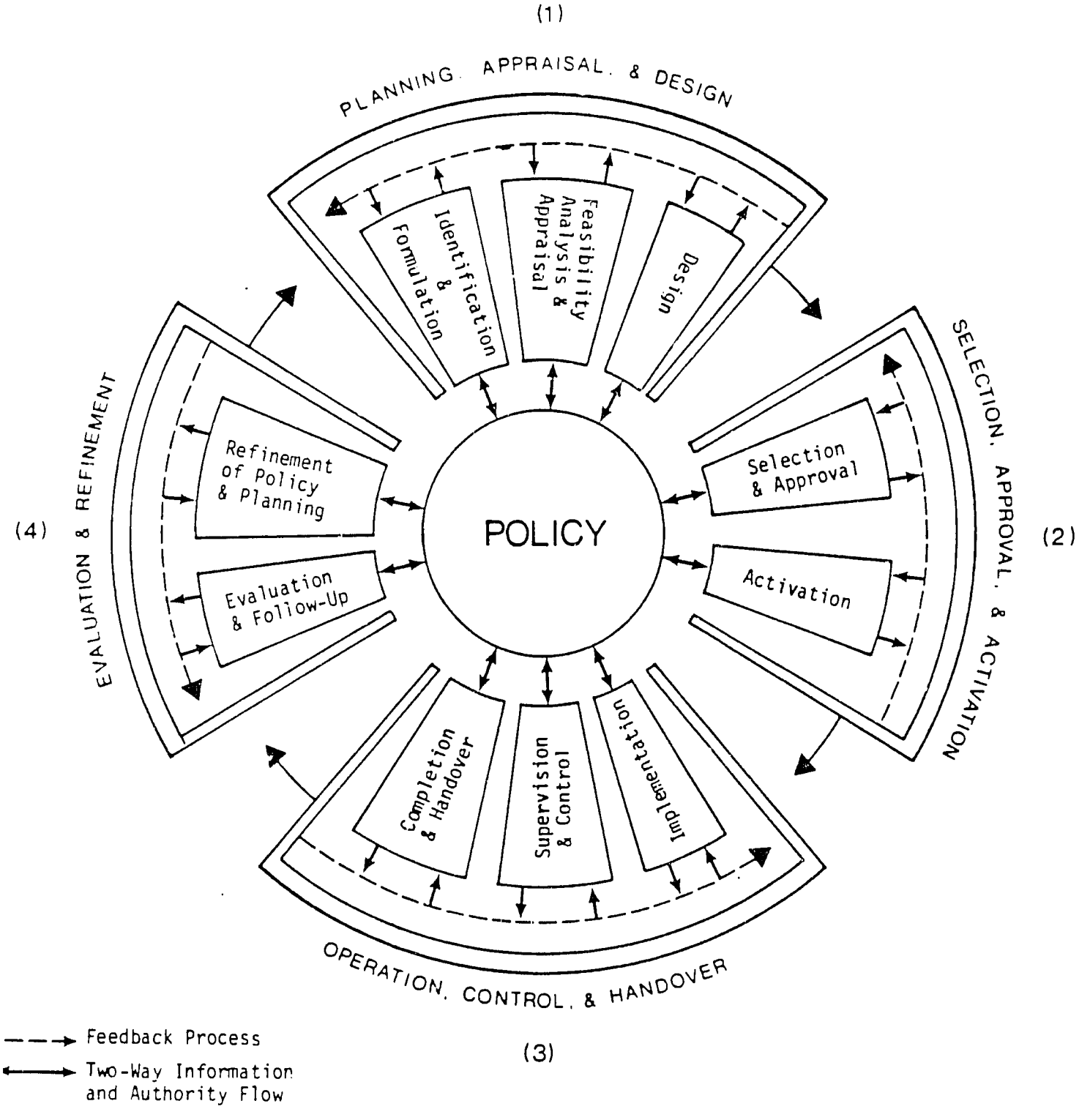


FIGURE I.3 Integrated Project Planning & Management Cycle:

The Four Phases

Source: East-West Center, Honolulu, Hawaii.

The following brief discussion of the IPPMC will provide an understanding of the organizational framework within which each of the biomass and small hydro case histories were researched and written. The IPPMC may be divided into four major phases: (1) planning, appraisal, and design; (2) selection, approval, and activation; (3) operation, control, and handover; and (4) evaluation and refinement. Specific tasks may be further identified within these four phases.

Figure I.3 illustrates the relationships among the phases of the project cycle, the tasks within each of the phases, and the overall dependency on central policy issues. It must be emphasized that the project cycle is an ideal model; not every project will conform exactly to it. The tasks of the cycle, furthermore, are not necessarily sequential--they may take place at the same time or in a different order--nor are all of them necessarily required. For example, the leader of a country might decide that a biomass or small hydro scheme is needed. He decides to have it built and instructs his subordinates accordingly, thereby bypassing the first two tasks in Phase 1 of the cycle. A continual feedback and dependency relationship does exist among the tasks, however. Each task is dependent upon and is influenced by the others.

There is a two-way flow of information between those responsible for policy and those responsible for managing each of the project tasks. This feedback to policy makers and management's response is an important part of the integrated project cycle. Decisions on project implementation, though in the hands of the manager on a day-to-day basis, are closely linked to the policy framework in which the project operates. Thus, all tasks within the four phases of the IPPMC are tied together by policies emanating from the various authorities concerned with the projects.

The IPPMC framework emphasizes the interdependent and cyclical nature of projects. However, because each task within the four phases of the cycle

is distinct and must be examined as an individual entity proceeding in an orderly time sequence, the cycle must also reflect this linear progression.

Some projects, it should be noted, may not proceed beyond the first phase. After the tasks within the planning, appraisal, and design phase have been completed, the information fed back to policy makers may lead to a decision to scrap the project. In certain cases, however, for economic, technical, or other reasons, it may not be desirable to stop a project once the first phase has been completed.

With this overview of the integrated project planning and management cycle, each of the four phases and their tasks can be examined in turn.

Phase 1: Planning, Appraisal, and Design. The first phase of the project is planning, appraisal, and design. There are three basic tasks in this phase: (1) the identification and formulation, (2) feasibility analysis and appraisal, and (3) design of the project. The first joint task, identification and formulation, involves the actual conception or identification of a project, which may occur in several ways. Basic needs within a country will induce the implementation of projects to satisfy these needs. The planning process often identifies project possibilities for each sector in society.

The major source of projects in developing countries, however, will be the existing departments or ministries, including central planning agencies. Projects may be identified by political parties or government officials. In this case, the motivation to undertake a project may be political, such as an attempt to gain the support of particular constituents. In some countries, private entrepreneurs or multinational corporations will identify projects that meet the criteria established by government.

International agencies have their own procedures for identifying projects. The identification of projects, then, is a process that must take into account

various needs, preconditions, and policies if the project idea is to proceed to operational reality.

After a project has been identified, its parameters must be defined. This is part of the formulation task. The formulation of a project involves developing a statement in broad terms which shows the objectives and outputs of the project and also provides an estimate of the various resources required to achieve the project's objectives.

The second set of tasks in the first phase, feasibility analysis and appraisal, are critical ones which in effect involve two distinct operations. A prerequisite of this set of tasks is the development of preliminary designs for the project. The early designs must be detailed enough so that cost estimates and decisions on various aspects of the project can be made.

Feasibility analysis is the process of determining if the project can be implemented. Appraisal is the evaluation of the overall ability of the project to succeed. Projects will proceed to the feasibility stage only if decision makers find them desirable.

While the feasibility analysis and appraisal are being conducted, several critical decisions need to be made. These decisions will determine first, if the project is capable of achieving its objective within the limits imposed by decision makers and second, whether it will proceed. Preliminary estimates of the resources required, and basic decisions about size, location, technology, and administrative needs must be made.

Feasibility and appraisal should be approached systematically and deliberately: time spent in researching the feasibility of a project is usually time well spent. Moreover, the findings at this point of the project's life will be useful during other phases of the project, particularly in Phase 3.

Determining project feasibility depends on the accuracy of the information

received. Even though the final detailed design of the project can be undertaken only after approval has been given, the preliminary designs form the base upon which future decisions will rest. Most developing countries have to contend with a shortage of both design and research and development capabilities. The result may be a lack of attention to critical aspects of the project. When decisions have been made on the overall project concept, its dimensions and parameters, it is then possible to determine the feasibility of the project in the terms required by the policy makers and the funding agents.

Some projects may require a pilot study as part of the feasibility process. Pilot studies provide data to enable more meaningful decisions to be made about larger projects. The appraisal process may require a comparative study to determine the merits of one project over another. Although the project identified may be feasible to implement, a comparative study determines whether resources are best used in the project or in some other form.

Many governments and international agencies have imposed rigid procedures to be followed when their funds are required. While actual details vary from project to project and from organization to organization, a trend over recent years is for more sophisticated and more systematic project-related studies. For example, to receive a recommendation from the United Nations Development Program (UNDP) for industrial projects, prospective borrowers must undertake market analyses that provide overall national trends in production, foreign trade, consumption, consumer prices, together with details about output type and use, cost of production, and estimated sales. Other agencies have brought in new dimensions to their studies, such as the impact of projects on the social and cultural life of the community, as well as the environmental and ecological impact of the project.

Numerous components of the project can be dealt with in the feasibility report. Studies can relate to the feasibility of the technical, economic, commercial, financial, administrative/managerial, and organizational aspects of the project. Additional political, social, environmental, and cultural factors that affect the project may also be included. Various technical alternatives must also be studied to ensure the suggested approach fulfills project requirements.

Economic studies examine the overall sector into which the project falls and consider how the project fits into the broader sector and the national planning framework. Related to economic feasibility studies, commercial studies may be necessary to determine the overall competitive nature of the proposed project. They will examine the market demands for the output of the project, consider the costs of production, and look at all aspects of the project to determine if it is a viable proposition.

Financial studies determine how much capital is required to complete the project. These studies determine whether the project can sustain its financial obligations, have adequate working capital, and generate enough funds to ensure adequate cash flow to keep the project operational.

Administrative/managerial studies determine the adequacy of procedures to control and direct the project. Studies in this area are not always undertaken, even though all projects would benefit from them. Their objective is to determine whether a project that is economically, financially, and commercially sound can be properly implemented by available manaterial and administrative procedures. Many countries suffer from a lack of management and administrative capacity to direct projects. Related to this problem is a lack of ability to ensure that a project can be administered effectively within an appropriate agency or organization. Because administration of a project differs from normal departmental procedures, a careful assessment of

the operational methods of existing units is necessary to ensure that a project's unique features can be catered to. Even though a project may be conceived and sponsored by an existing department, the department itself may not be the appropriate body to administer it. This is especially the case when the involvement of a wide group of outside personnel and agencies is necessary, since existing departmental procedures are often unable to provide the necessary flexibility.

Once the feasibility studies have been completed, a meaningful appraisal of the project is possible. Policy and decision makers and lending institutions may carry out the appraisal. They satisfy themselves that the project meets the conditions that enable it to proceed. Their concern is to determine whether or not the project is the best means of reaching the objectives they have set. They may review the project itself and alternative means of reaching the objective.

Potential lending institutions may undertake their appraisal with a healthy skepticism toward all phases of the project. They attempt to determine whether or not the project is intrinsically sound and whether or not all the circumstances that surround it are viable.

The last task within this phase of the integrated project cycle is design. As mentioned earlier, preliminary design criteria must be established before the project feasibility and appraisal task begins. Once it has been determined that the project will continue, the design task proceeds. Design is a critical function. It establishes the basic programs, allocates responsibilities, determines activities and resources, and sets down in operational form the areas of priority and functions to be carried out. All inputs relating to projects, including personnel, skills, technical input, and so on, must be determined at this point. Environmental factors, social criteria, technological requirements, and procedures must be assessed and included.

The design task also includes the preparation of blueprints and specifications for construction, facilities, and equipment. Operating plans and work schedules are prepared and brought together in a formal implementation plan; contingency plans may also be prepared. Designers must bring together the views of policy and decision makers and technical experts in such a way that the design reflects the inputs of all those contributing to the project.

Phase 2: Selection, Approval, and Activation. This phase of the project has two major tasks: (1) selection and approval, and (2) activation. Project selection takes place after the project has been accepted by policy makers and funding organizations as meeting the feasibility criteria. At this point, the design function, including the formal implementation plan, has been completed. The project will be well defined, with key elements identified and the inputs clearly identified. The selection of one project for implementation over another is made on the basis of several criteria. Policy makers consider the overall feasibility of the project and the priority of the project area. If a project fulfills a major need or contributes to national or sector goals and is politically desirable, it may be selected for implementation over a competing project that is not politically important. Funding agencies, however, have a variety of techniques for determining whether resources will be allocated to a particular project. These techniques may range from cost-benefit to other complex forms of analysis. The overall requirement, however, is that the policy makers and the funding agency conclude that the project itself has a priority claim for resources required for the project. Therefore, the selection process is normally a competitive one.

The selection of a project for implementation requires negotiations to be undertaken to obtain formal approval from national authorities, funding agencies, and others contributing to the project. This requires the finalization of funding proposals, agreements, contract documents, including tenders

and other contracts and the introduction by government or some other organization of appropriate regulations.

Activation of the program involves the coordination and allocation of resources to make the project operational. Activation is a complex process in which the project manager has to bring together an appropriate project team which may include professionals, technicians, and resource personnel. Other contributions to the project may come from other groups, such as outside consultants, contractors, suppliers, and policy makers in other agencies. The outside inputs must be coordinated with the work of the project team. Responsibility and authority for executing the project must be assigned at this point. This will include the granting of authority to make decisions in areas relating to personnel, legal, financial, organizational, procurement, and administration matters.

The activation task must ensure that planning for all phases is undertaken so that delays in vital inputs do not occur. Organizational and administrative procedures, together with feedback and response to policy makers' decisions, will have an important bearing on implementation. Concern for detail and proper planning during activation can save a great deal of time and resources during later phases of the project. At this point, the actual work of the project is about to begin.

Phase 3: Operation, Control, and Handover. Looking at the development project from the outside, the uninitiated observer might mistake this most visible phase for the entire project itself. As has been indicated, Phase 3 in fact makes up only a small part of the integrated project cycle. This phase of the project has three sets of tasks: (1) implementation, (2) supervision, and (3) completion and handover.

Implementation involves the allocation of tasks to groups within the project organization. Implementation of the project will be based on procedures

set down during the two earlier phases. At this point, a final review of the project design and timetable will be undertaken, and any necessary changes or adjustments will be included. Decisions about the procurement of equipment, resources, and manpower also need to be made. Schedules and time frames need to be established, efficient feedback, communication, and other management information systems must be set up. The responsibility for implementation falls within the jurisdiction of the project manager. The project manager will need to work with policy makers, authorities, and organizations related to the project as well as with policy makers controlling the project. His task is a complex one, requiring him to steer the project through many obstacles.

The second set of tasks in Phase 3 is supervision and control. Supervision and control procedures must be activated to provide feedback to both the policy makers and the project manager. Control procedures must identify and isolate problem areas; the limited time span of a project means that fast action is necessary if costly delays are to be avoided. At this point, specific management tools, such as the critical path method (CPM), the program review and evaluation techniques (PERT), and other forms of network analysis are particularly useful. These control and supervision techniques break down a project into detailed activities and establish the interrelationships between and among the various activities. This allows the project manager to organize the project into manageable components, to coordinate all activities, and to set a time-sequence schedule for project implementation. Although using such techniques means spending more time prior to implementation, it is time well spent. Not only will these techniques give the project internal coherence, but they will also save implementation time by isolating any problems to the appropriate project component.

In addition to internal control, those providing funding for projects will maintain an independent monitoring and control system for the project.

The project manager will therefore have to meet control criteria established by either the government or another controlling agency, or perhaps by the funding institution. This may involve using specified procedures, such as international competitive bidding, for supply contracts. Formal procedures are established by many international organizations for the procurement and control of resources.

Whatever supervision and control techniques are used, they must take into account the changing patterns that occur during the life of the project. These may include changes within the policy and political structures, difficulties with procurement, and poor performances by project team members and contractors. In many cases, the overall project design will need to be reviewed. Many technicians are involved in the supervision and control processes, and adequate information flow in all directions--from the project manager and from those within his organization assigned with special responsibilities--is essential if these procedures are to be effective. As part of supervision and control, any problems relating to environmental factors must also be identified and appropriate action taken.

Control procedures are useful only if action is taken to correct any deviation. It should also be noted that both personnel and input patterns change naturally as the project proceeds through its four phases. As work on some tasks is completed, other personnel, experts, and contractors move in to begin new tasks. Personnel must adjust to their new environment, and procedures need to be reviewed and updated to meet the changing situation.

Project <u>completion</u> prepares the project for phasing out and <u>handover</u> to another form of administration. These are the third tasks of this phase. Project completion consists of scaling down and dismantling the project organization. It also involves the transfer of project personnel to other

areas of operation. Assets and other facilities, including equipment and technology, may not be required by the operational project. Provision for their transference must be made, since it is not always possible to have an automatic transition from the development to the operational stage.

The process of completion may take place over a considerable period. As various parts of a project are completed, however, they may be taken over by a new organization, and handover may therefore be accomplished in a piecemeal manner. It is essential that development resource linkages between scaled-down projects and those projects in the elementary stages of implementation be planned systematically to ensure optimal use of limited project resources, particularly in the context of broader development programs. The new project, when operational, will have an effect on other aspects within the sector. As the project becomes operational, the new controlling organization must have the skills, personnel, and technical backup required. Key personnel working in the development stage will often transfer over to the new controlling organization.

In cases where technical, financial, political, or other factors prevent projects from being completed according to the original terms, handover and termination procedures may have to be implemented at an earlier stage. This may involve considerable loss as far as the project is concerned. In this situation, the objective should be to liquidate the project in a way that will obtain the most benefit.

As a project nears completion, special reporting systems should be set up so that full information relating to the project is available. Completion reports will be prepared for various authorities, including funding organizations and policy makers.

The actual handover of the operation of the project involves finalization of contracts, termination of loan facilities, and so on. Handover also includes

the transfer of the project activity and resources to the new administration. This is a critical task. While the development of the project can be viewed initially as a creative phase, once the project is completed, it must be viewed as a long-term operational program.

Phase 4: Evaluation and Refinement. The final phase of the project is the evaluation and refinement of policy and planning factors. The first task is evaluation and follow-up. While it is possible to evaluate project results immediately, actual benefits--both ancitipated and unanticipated--together with side effects, may not become apparent until the project has been operating for some time. Evaluation thus needs to cover several time periods. Evaluation normally includes a retrospective examination of the project in attaining its intended goals within the framework of both the timetable and the budget. However, experience clearly demonstrates that it is necessary to consider evaluation as an ongoing process integrated with each phase of the IPPMC. For example, evaluation procedures must be designed to analyze and propose solutions to problems that may arise during the tasks of activation, implementation, supervision, and control. Ongoing evaluation, which includes retrospective evaluation, should result in a careful documentation of experiences which can provide both insights and lessons for improving project planning and project management in the future.

Evaluation of a project can take several forms. These include evaluation by those responsible for implementing the project and by others with an interest in the project, including funding organizations and contractors. Those funding the project will undertake a thorough investigation of its financial aspects, including an effectiveness study of goal attainment. The agency responsible for the project will be concerned with determining whether goals have been attained and whether the expected impact on a sector or on national development will be achieved. The studies should also consider, in addition to impact on

the target group, the impact of the project on the political, social, cultural, and environmental factors relating to the project. An exhaustive evaluation of each phase to determine its contribution to the project in regard to budget, timetable, and other factors is most desirable. In most cases, however, the project as a whole is evaluated with little effort made to analyze each phase or each task separately.

International agencies, such as the World Bank and the United Nations, have their own procedures for evaluating projects. These may be useful to policy makers, since they provide the opportunity for comparative analysis with similar projects.

Related to and often arising from the evaluation of a project is the need for project follow-up. Follow-up activities may vary from determining how unmet needs can be satisfied to action on project tasks not properly fulfilled. The piggyback or follow-up projects mentioned earlier may come into play at this point. For a project to achieve its full objective, smaller or related projects may need to be implemented almost immediately. There is then a clear need to relate follow-up action closely to evaluation of projects. Follow-up action is one aspect of the project manager's role which could involve considerably more commitment than he initially envisages. If follow-up action means the difference between the project's being fully operational or not, then it is a wise investment to undertake these activities as quickly as possible. Aspects arising from the follow-up procedures may be useful in the future. If the project is successful, guidelines can be set down for the project to be repeated in another setting.

The second and last task is <u>refinement</u> of policy and planning. Policy makers and managers will need to refine their procedures in the light of each completed project. Experiences and lessons learned should be the foundation

on which planning and policy tasks are reviewed. As the essential controlling force, policy procedures must be continually updated to meet challenges in the future. Planning must also be able to meet any new demands or new situations. Refinement of these procedures is an important contribution that the project can make to future development programs.

The IPPMC is a flexible model for all phases of a project from conception through completion. The cohesive force unifying all the phases and tasks of the IPPMC is the power and authority relationship vested in various policy makers, ranging from top government and political decision makers to those in charge of one aspect of the project. The project manager, the staff, and those contributing to the project as consultants or contractors are bound by and exist within the framework of policy decisions. Analysis of these changing relationships through the IPPMC model can provide a comprehensive overview of a development project. It is also useful for policy makers in providing guidelines for addressing policy issues as a basis for more viable policy formulation and related decision making.

It is significant to note that the IPPMC conceptual framework was developed as the basis for a new and dynamic approach to planning and management because of past experience with the problems of poor planning and management resulting in a waste of enormous human and capital resources in development projects from all sectors. The viability and effectiveness of the IPPMC in designing and implementing new curriculum materials for educating and training project planners and project managers have been established. This is of particular importance today as we devote increasing attention and resources to research and development of alternative energy sources to come to grips with the severe economic and social dislocations that directly result from the extraordinarily high prices of imported oil. There is an outstanding need, however, to provide

adequate planning and management if we are to optimize the research, development, and implementation of biomass and small hydro energy projects.

NOTES

1. Arjun Makhijani and Alan Poole, Energy and Agriculture in the Third World (Cambridge: Ballinger Publishing Company, 1975).
2. Denis Hayes, Rays of Hope (New York: WW Norton & Co. Inc., 1977), p. 80.
3. For further reading about the IPPMC model, see Louis J. Goodman and Ralph Ngatata Love, eds., Project Planning and Management: An Integrated Approach (New York: Pergamon Press, 1980).

CASE 1

BIOGAS DEVELOPMENT: THE PHILIPPINES

Ernesto N. Terrado

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PROJECT BACKGROUND

The Philippine energy situation in 1976 was one of great uncertainty. The nation's overall energy needs had been projected to be twice the 1975 consumption by 1985 and six times by the year 2000. In 1975, the total commercial energy consumption was about 75 million barrels oil equivalent, 95 percent of which was provided by imported oil. Only hydro and coal accounted for the small balance.

The government agency with primary responsibility for energy at that time was the Energy Development Board (EDB), created by Presidential Decree No. 910 in March 1976 and composed of seven Cabinet members. Chairman of the Board was Geronimo Z. Velasco, who was concurrently chairman and president of the Philippine National Oil Company.

The EDB was already engaged in defining the availability and distribution of indigenous resources. The major activity was oil exploration, mainly in offshore areas. Eleven wells had been drilled the previous year by foreign companies operating under EDB's service contract system, but there had been no commercial oil discoveries.

The stimulus for structuring a more comprehensive energy development program was provided in part by an international conference, hosted by the government in September 1976, titled "Survival of Humankind: The Philippine Experiment." Under the theme of energy, officials and experts in the areas of petroleum, coal, hydro, geothermal, and nonconventional energy drafted the basic technical document which became the precursor of the country's energy program today.[1] Significantly, this occasion marked the first time that official recognition was given to the potential of solar and other nonconventional energy forms in meeting the nation's growing demand for fuel. Immediately after the conference, the author, who was then with the Philippine Atomic

Energy Commission, was asked by EDB to organize a nonconventional energy development program. A new unit, the Nonconventional Resources Division (NCRD), was created under EDB's structure, which previously had divisions only for oil, coal, and geothermal energy (see Figure 1.1).

On October 6, 1977, the Energy Development Board was abolished and the Department of Energy (DOE) created. Two new bureaus were created within this department, the Bureau of Energy Development (BED) and the Bureau of Energy Utilization (BEU). The BED's role, however, was essentially that of the old EDB, so that except for very few minor changes, the divisions and personnel of EDB remained intact as BED. NCRD retained its name but was now a division of BED. Later, in the second half of 1978, when the Philippine government shifted to the parliamentary form, all departments were converted to ministries. The Department of Energy became the Ministry of Energy (MOE). This, however, was the only change; the names of the bureaus and their component divisions remained as before. In July 1979, NCRD was spun off the BED and became a new unit under the MOE called the Center for Nonconventional Energy Development, or CNED (see Figure 1.2), an arrangement still current at the time of this writing.

To give impetus to the nonconventional energy or "noncon" program, appropriate legislation was subsequently developed and recommended by NCRD. In January 1977, Presidential Decree 1068 was promulgated, entitled "Directing the Acceleration of Research, Development and Utilization of Nonconventional Energy Resources and Vesting in the Energy Development Board Powers and Functions in Connection Therewith and for Other Purposes." The decree gave EDB the authority to integrate all existing programs in this sector and to set priorities and direction. More important, the decree directed the release of ₱10 million to fund the program initially. The bulk of the money was to be used as grants-in-aid to deserving projects. Funds were actually released in

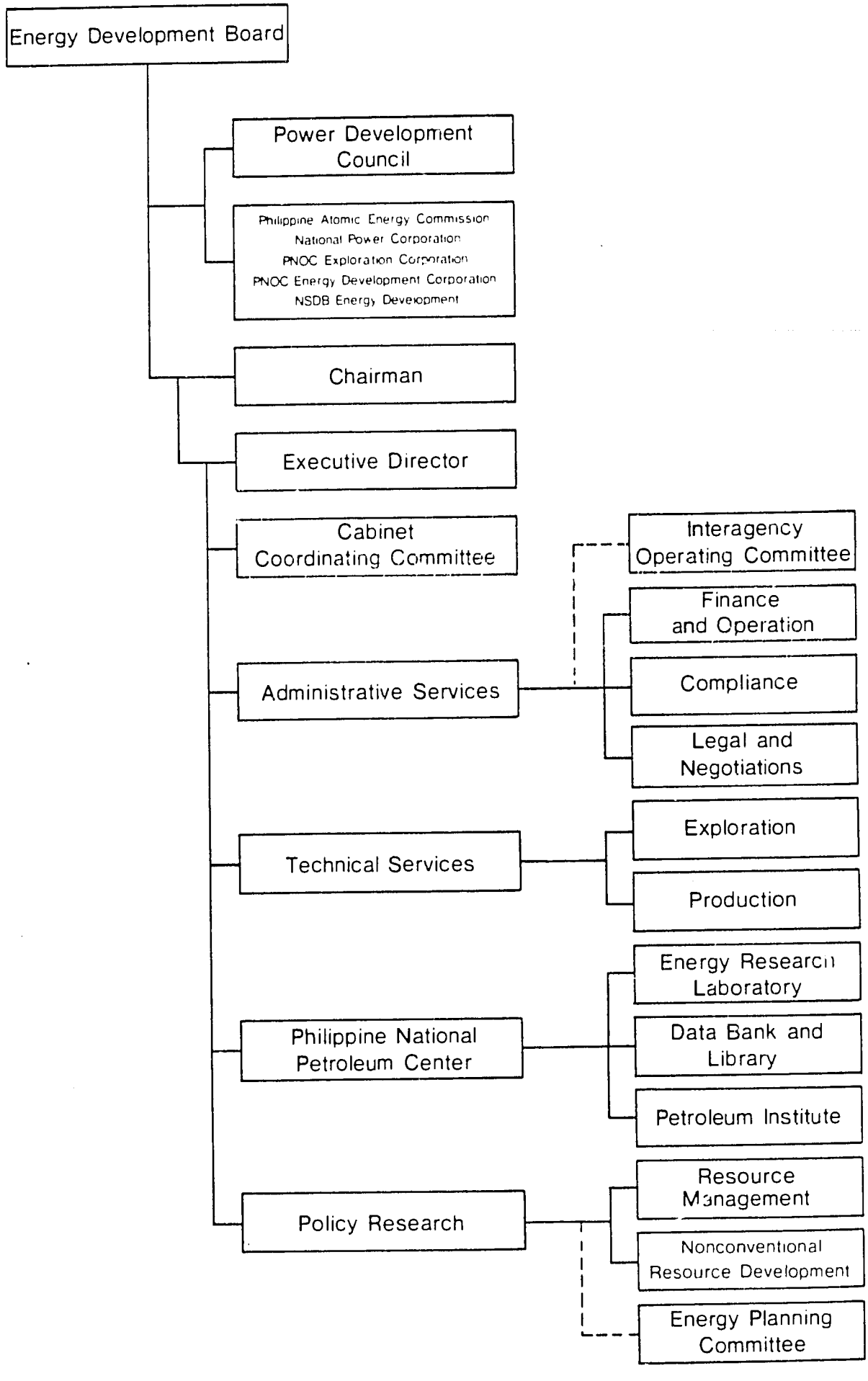


Fig. 1.1. Energy Development Board, 1977.

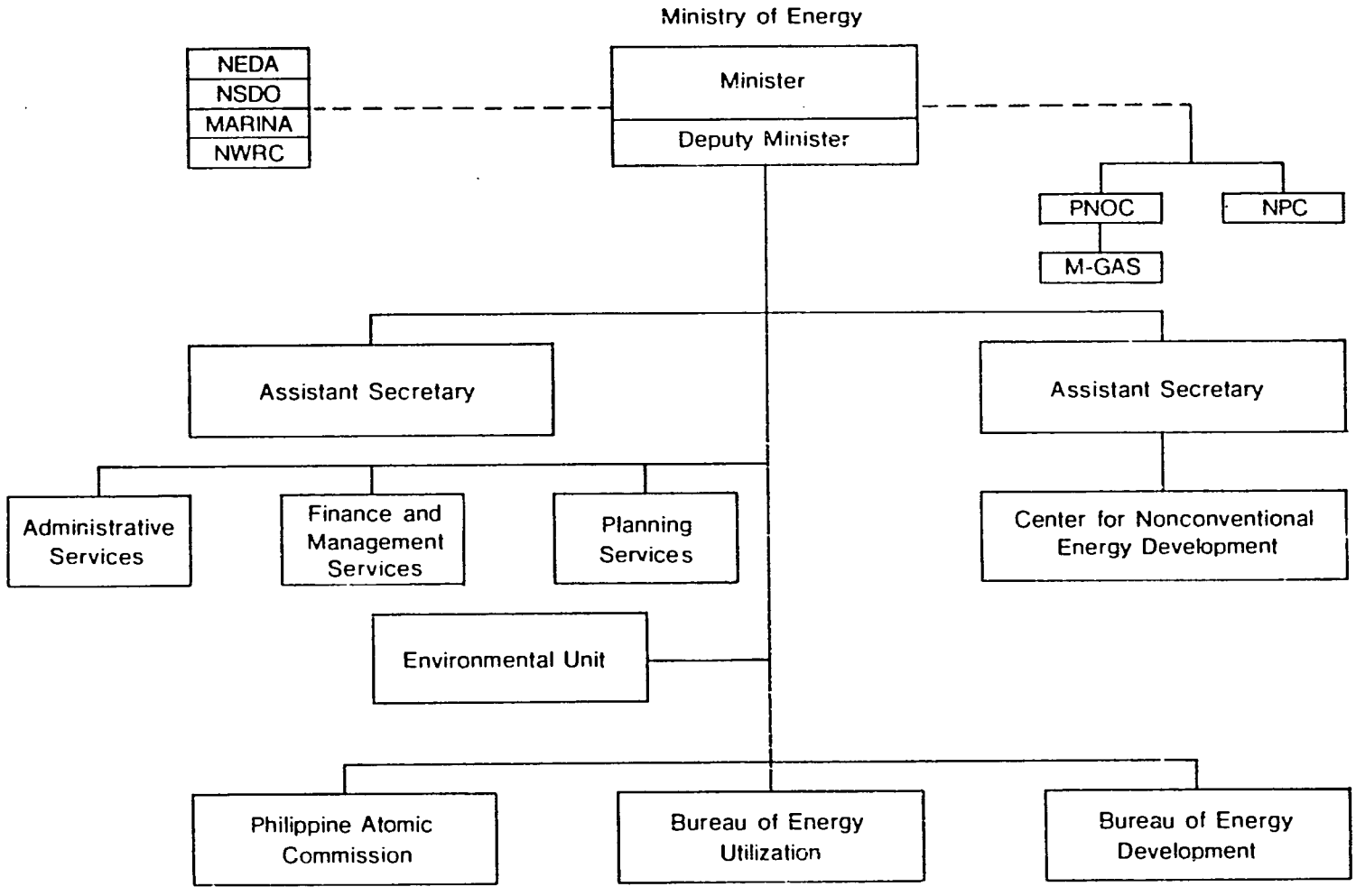


Fig. 1.2 Philippines Ministry of Energy, May 1980.

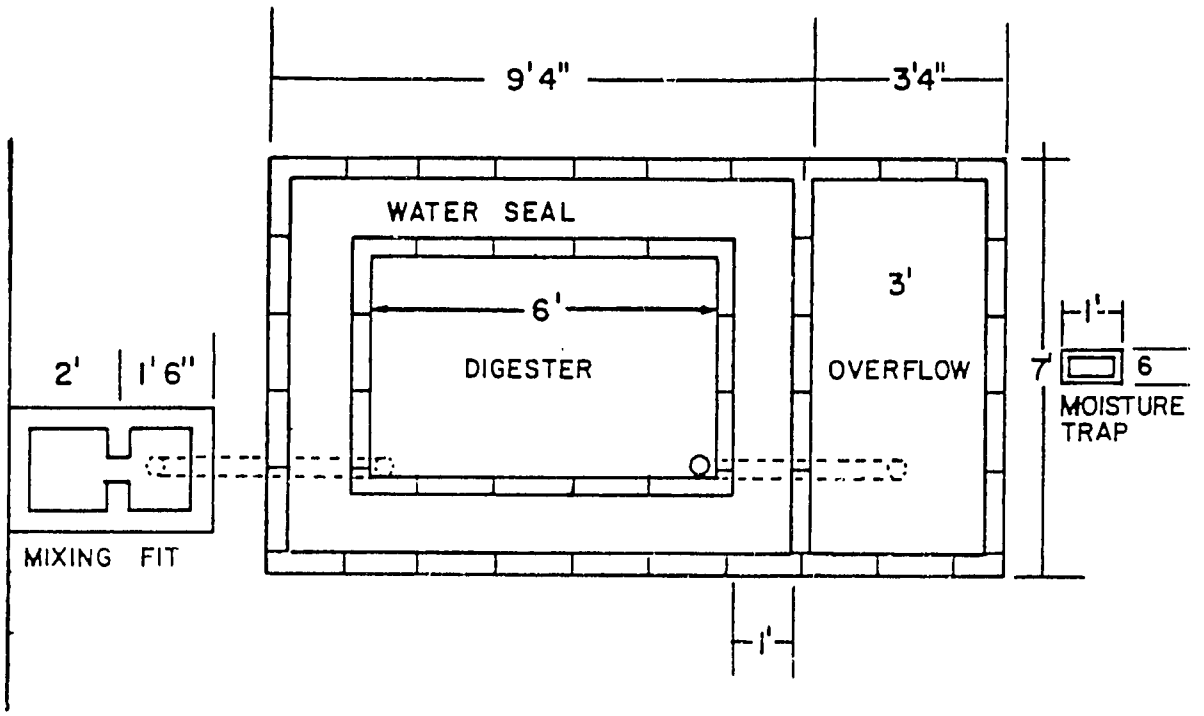
the last quarter of 1977; thus, it was only in early 1978 that most of the initial projects of the program, numbering around twenty-five, began to be implemented. Some of these projects involved biogas production and utilization.

Technical Aspects of Biogas Development

Even though the term biogas appears to be relatively recent in origin, methods for its production have been known decades before the onset of the oil crisis. Biogas is a fuel generated from the anaerobic or oxygen-free decomposition of certain organic raw materials such as animal manure. The combustible component of biogas is really methane, which comprises 55 to 65 percent of the gas mixture. Carbon dioxide, at 34 to 45 percent, is also a major component. The rest are small amounts of nitrogen, hydrogen, and hydrogen sulfide. Biogas burns with a blue flame and has a heating value ranging from about 4450 to 6230 kcal per m^3 when its methane content ranges from 60 to 70 percent.

In general, a biogas plant has three main parts: (1) a digester, where the fermentation of the methane-producing materials takes place; (2) a gasholder, where the biogas is stored until it is used; and (3) auxiliary systems, such as stirrers, pipings, and safety devices. Figure 1.3 shows a typical engineering drawing of a biogas plant. In the digester, various types of anaerobic bacteria first break down the raw material substrate into soluble compounds, then convert these to organic acids and finally to methane and carbon dioxide. Ordinary "mesophilic" bacteria works best in the range of 30° to $40^{\circ}C$. Gas production is significantly reduced at low temperatures.

Biogas plants may be broadly classified into two types: batch systems and continuous systems. In the batch system, the digester is charged completely and then discharged at the end of the "retention period" for each cycle. In the continuous system, the digester is charged daily--or at shorter intervals--with small amounts of raw materials. The newly charged materials automatically expel an equal quantity of effluent. The size of the digester depends upon gas



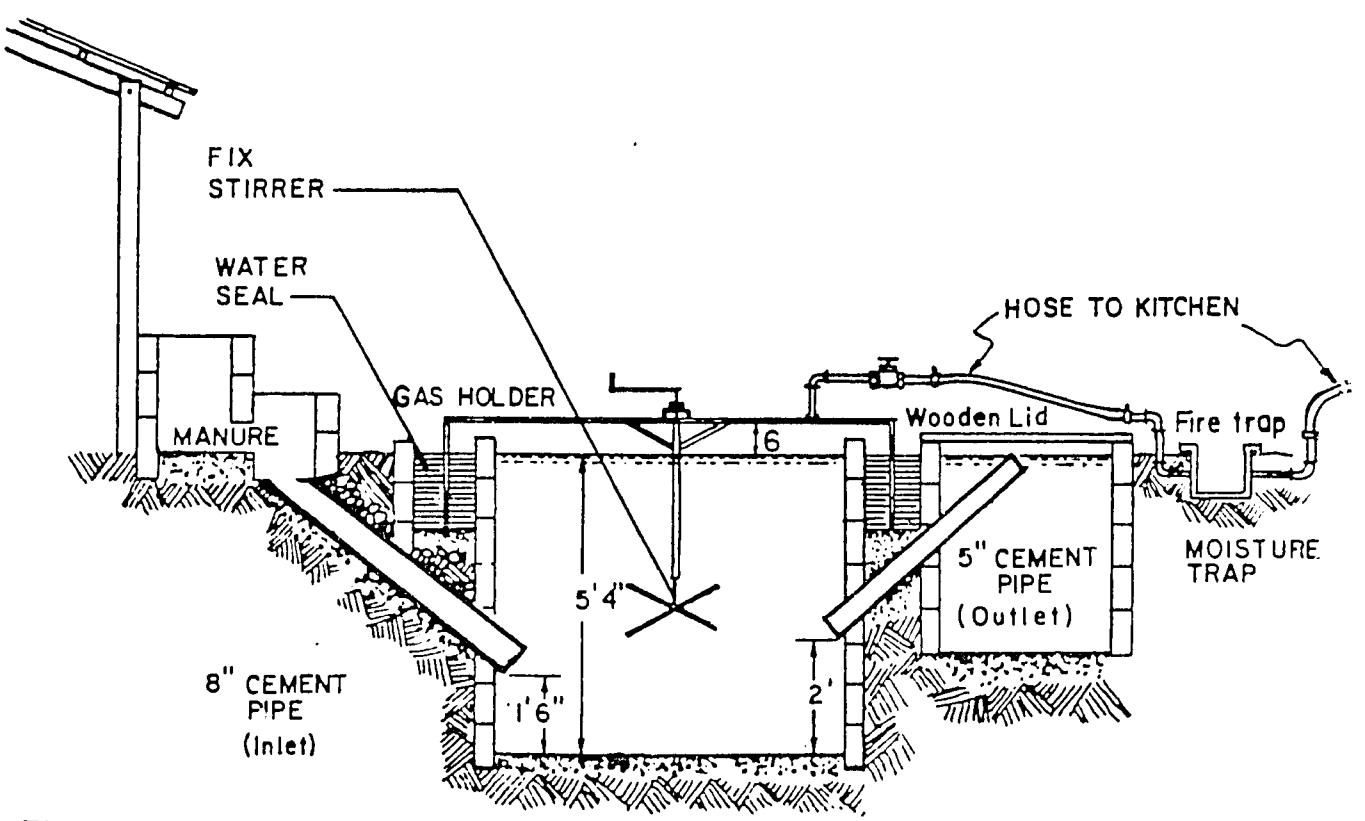


Fig. 1.3. Typical single-unit methane digester.

production desired, type of raw materials to be fed to the digester, and retention time. In designing a plant, literature values reported by other workers in roughly similar conditions are often used as a basis for calculations.

Biogas is primarily used for cooking. It has also been used in internal combustion engines, fully or partly, to run water pumps and electricity generators. It has been utilized for lighting lamp mantles and as fuel for absorption-type refigerators. In addition to generating fuel, a biogas operation yields sludge, which is an excellent soil conditioner. The sludge is also used at times as a feed supplement for animals, thus achieving complete recycling.

Information available to NCRD in 1976 indicated that a large number of biogas plants, mainly for household use, had been operating in India, Taiwan, Korea, and the People's Republic of China for some years already. For the most part, the reports extolled the virtues of biogas production as a technology of special relevance to developing countries.

PHASE 1: PLANNING, APPRAISAL, AND DESIGN

Biogas development was identified by NCRD as a priority area for several reasons: (1) the technology was relatively simple and the required hardware was all locally available; (2) there was already a certain degree of public awareness about biogas; and (3) resource data indicated that considerable amounts of animal manure were being generated yearly in nearly all regions of the country. Statistics kept by the Bureau of Animal Industry showed that some 13 metric tons of animal wastes were produced annually as of 1975. Converted entirely to biogas, the total potential would be equivalent to 3 million barrels of oil (MMBOE).

Actually, other "noncon" areas had also been identified as targets for immediate development. These were direct solar energy applications, wind energy conversion, and conversion of biomass to fuels. Biogas production was classified under the biomass category, which includes renewable resources such as agriculture and forestry wastes and energy crops and trees. Agro-forestry wastes alone had a total of 60 MMBOE in 1975, and the whole biomass category was calculated to have a total theoretical potential of over 100 MMBOE annually.

An important influence in the biogas development plans of the country was the existence of Felix Maramba's large biogas works at his Maya Farms in the Antipolo Hills of Rizal Province, Philippines. The story of Maramba's biogas project is a case study in itself and has been so treated elsewhere.[2] Its success is to a large extent attributable to the unique character of Maramba himself. President of Liberty Flour Mills, Maramba was 76 when he started building his first unit in 1973 at Maya Farms, an integrated livestock farm, meat processing, and canning operation. His principal motivation appeared to be pollution control, with energy recovery only a secondary operation. Today Maya Farms produces 50,000 ft^3 of biogas each day, providing some 50 percent

of its internal fuel requirements. In addition, a large quantity of sludge is produced daily and used as biofertilizer and animal feed supplement. The farm, which has some 10,000 pigs, has no problems at all with the pollution control authorities. The Maya Farms case provides a contrasting backdrop for the other smaller biogas projects treated in this chapter.

Although biogas clearly had great relevance to large-scale business establishments, it did not preclude applicability in household and similar small-scale situations. Information about biogas programs in other countries, notably India, indicated that the major thrust was toward the propagation of domestic-sized units that would generate enough fuel for the cooking needs of individual families. An important consideration was the fact that in developing countries, over 50 percent of the energy demand of rural households is for cooking and a large fraction of this end use is provided by fuelwood. The threat of rapidly dwindling forest reserves and the concomitant effects of soil erosion, flooding, and other effects are thought to be alleviated by widespread introduction of a substitute fuel such as biogas.

In the Philippines, a number of household biogas units had been built, either privately or with assistance from the National Science Development Board (NSDB) which, before the creation of the EDB, was in charge of research and development in science and technology, including the field of energy. Documentation of these existing systems was lacking, but it was generally believed that the units were all functioning as intended.

It was apparent that the intended program for development would have to include surveying and documenting systems already in existence and building more units of various scales and modes of utilization in order to gather more techno-economic data. There was also a need to establish working linkages among various government and private agencies, who seemed to be operating

independently of one another's programs.

Among the government agencies, NSDB and the Bureau of Animal Industry (BAI) were clearly the primary agencies that NCRD would have to work with. In the private sector, of course, the involvement of Maramba and his Maya Farms staff would be an important requirement. With the assistance of these three parties, it was felt that suitable biogas projects could be effectively solicited or developed and pushed to early implementation.

Because NCRD had only a handful of staff members in 1977, external assistance was necessary. Some staff had previous research experience in solar energy or biogas as assistants in university projects. Most, however, had no previous exposure to noncon energy projects. For this reason, the author kept alive the ad hoc committee for solar energy which he had chaired during the 1976 "Survival" conference. The five members of this committee came from government, academic, and private sectors. The author looked to this group for advice from time to time and tapped the members as resource persons in the evaluation of project proposals.

Foreign expertise was also drawn on. Regular communications were maintained by the author with Dr. R. L. Datta, an Indian expert on solar energy, who was a principal guest at the "Survival" conference. Dr. Datta, now president of the International Solar Energy Society, had significant inputs in the initial year of the program, especially in determining priorities for direct solar energy applications projects. And finally, for the biogas subsector of the program, Felix Maramba agreed to be principal consultant to EDB at "₱1 a year."

Project proposals received by NCRD were processed in accordance with a standard procedure (see Figure 1.4). In most cases, however, the proposals did not emanate unilaterally from their proponents. They were actively solicited collected, pre-discussed, and structured by the NCRD staff itself.[3]

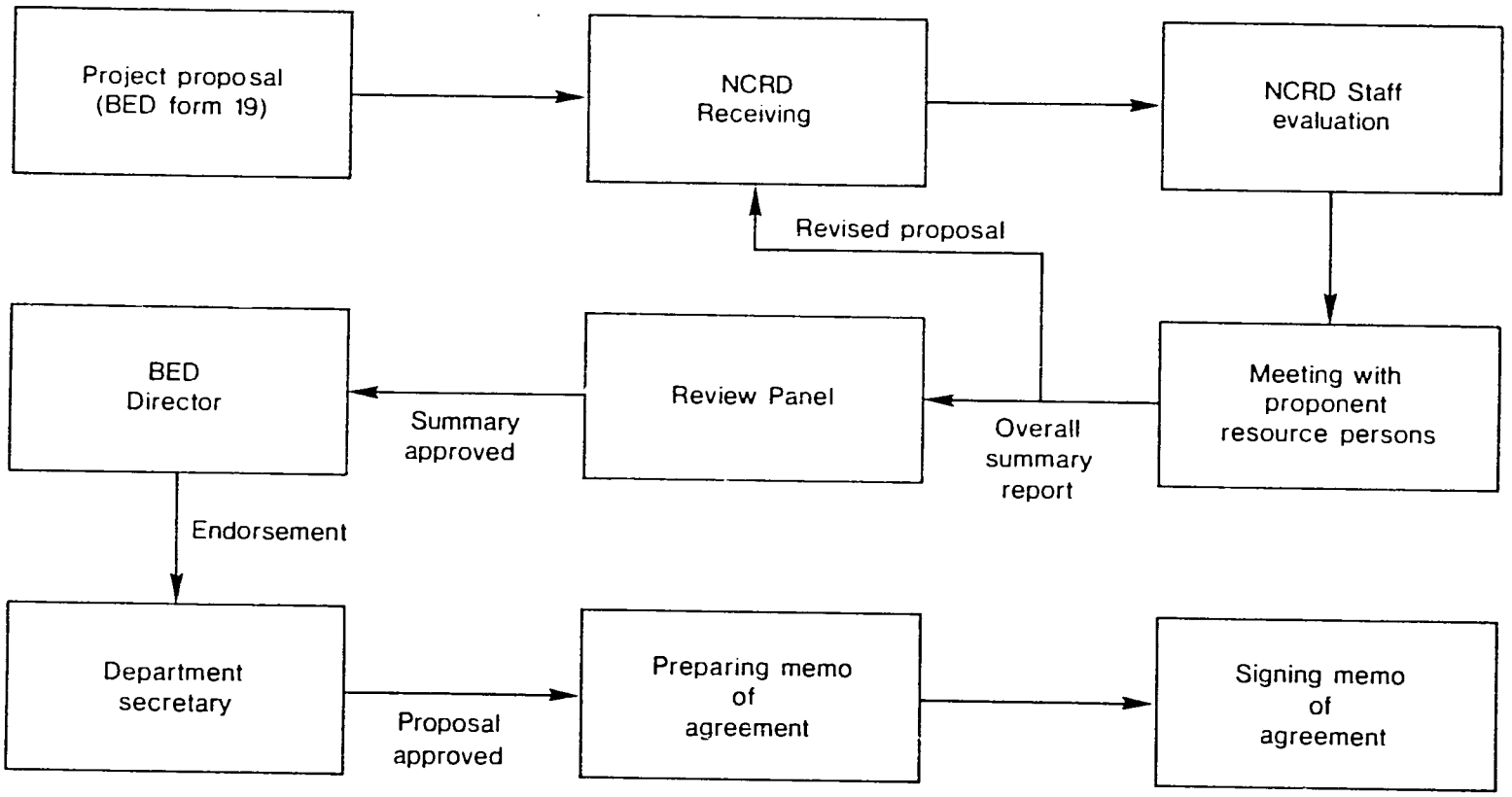


Fig. 1.4. NCRD procedure for processing a project proposal.

PHASE 2: SELECTION, APPROVAL, AND ACTIVATION

Regional Biogas

In early November 1976, during a meeting called by EDB and attended by Felix Maramba, Dr. Salvador Escudero III, director of the Bureau of Animal Industry Jose Leviste, EDB executive director, and the author, the first biogas project under the EDB program was planned.

The plan was to construct demonstration biogas units, one in each of the country's twelve regions, in three months' time. The units were to be built on the BAI regional stock farms, not only to ensure adequate supply of the manure feedstock but also to ensure that the units would be properly and continuously maintained.

This meeting was in fact the offshoot of another meeting held several days earlier in the same room and attended personally by President Marcos. Chairman Velasco briefed the President on EDB's current activities, which were then mainly on oil exploration. He mentioned, however, the inclusion of noncon development in the overall programs and then asked the author and Maramba to speak briefly on the subject. The President's attention focused on biogas and he directed Velasco to establish more biogas plants so that "at least one is in every region in the next six months and one in each province within one year, until every town and every barangay has one."

It was thus agreed during the subsequent meeting that BAI would provide the manpower and demonstration sites; Maya Farms would train the selected BAI technicians on how to construct, operate, and maintain the biogas units; and EDB would provide the funding and the necessary coordination. NCRD had no funds as yet, except for the salaries and operating expenses of its few personnel. Velasco assured the author that he would advance the financial requirement from PNOC coffers so that the project could proceed immediately.

Metro Biogas

During the meeting with President Marcos, the question of biogas from urban wastes--garbage and sewage--was also brought up. The technical people in the group appeared to be less conversant with this topic than they did with biogas from animal wastes. The President verbally directed that feasibility studies also be made of this possibility, noting that the technology was already being applied in some Western countries.

On November 12, 1976, just a few days after the meeting, a brief handwritten note from the President was received by both Velasco and Secretary Alfredo Juinio of the Department of Public Works, Transportation and Communications (DPWTC). The note read: "I hereby direct that the biogas experimental project should include one big model for the city of Manila garbage. Prepare the plans and the funding required for submission to me soonest."

Upon receipt of a xeroxed copy of the note, Director Leviste directed the author to convene a meeting of all parties concerned, including resource persons. Called to the meeting were representatives of the Planning and Project Development Office of the DPWTC, the Refuse and Environmental Sanitation Center (RESC), the NSDB, and Maya Farms Corporation. NSDB was represented by Dr. Venancio Reyes* and Maya Farms by Felix Maramba.

It became evident in the meeting held November 16, 1979, that there was a noticeable lack of local experience and expertise on biogas generation from municipal wastes. The RESC representatives revealed that talks were currently going on between the city authorities and several foreign firms on the possible establishment of a modern waste disposal and processing system for the greater Manila area. It was not known, however, whether there was a biogas component

*Fictitious name. The names of all project implementors have been changed to protect their privacy.

in the proposed system. Dr. Venancio Reyes said that if interest was specifically focused on the biogas aspect, a pilot plant must be started to generate the necessary feasibility data for larger plants. Maramba suggested that NSDB, through Dr. Reyes, handle the technical aspects of this project. Dr. Reyes indicated his willingness to be tapped for this effort, but asked EDB formally to request his participation from the NSDB Chairman. Accordingly, a letter was sent to Chairman Magno the following day.

BATEK Biogas

After PD 1068 was signed on January 12, 1977, the decree was circulated and given publicity. In accordance with its provision, EDB invited all those who were engaged in or planning to engage in nonconventional energy projects for research, development, or utilization to register such projects with the EDB for accreditation. Accredited projects would receive priority for financial and technical assistance, as available.

The Philippine Women's University (PWU) was one of the institutions which responded to this call. Dr. Igmedio Mateo,* head of the Department of Food Science and Technology of PWU, wrote a letter to Velasco in April 1977, seeking to register as a participant in the noncon program PWU's Barangay Teknolohiya (BATEK) Center, located at Dasmariñas, Cavite. BATEK was described as a "project concerning village-level processing of low-cost, nutritious food supplements for the First Lady's nutrition program..."; the Center was described as practicing "waste recycling and the use of alternative sources of energy."

In May 1977, two NCRD engineers, Ramon Benet and Noilan Abesamis, visited the BATEK Center and reported that the following nonconventional energy devices

*Fictitious name.

were currently in use: a windmill for pumping water to a piggery, two tent-type solar dryers for drying fruits and vegetables, and a small biogas digester. Biogas was being used for stoves and ovens when available. Effluent from the digester was pumped to a chlorella pond located at the top of the pigpen. A fish pond was also being fed with effluent, but this had to be carried manually.

The engineers observed that the windmill was crudely made. Its diameter was too small for the power it was supposed to generate and the tower was too short, so that the windmill was not entirely clear of the tall fruit trees which abound on the site. As a result, the windmill was pumping out very little water.

The solar dryers were simple structures draped with polyethene sheets. They were an improvement over direct sun drying, but better design could further increase their efficiency.

The biogas digester was a long distance from the pigpens, so that the hog manure had to be manually transported. The object apparently was to locate the digester close to the point of use. The engineers felt that a better way would be to locate the digester close to the pigpens, even if this meant piping the gas some 150 meters.

It was also observed that hot water was used in substantial quantities at the Center for cleaning, blanching, and other tasks. Because the temperature required was well below boiling in most cases, it was thought that a solar water heater could very well meet this requirement.

The author briefed Director Leviste on the engineers' report and suggested that the BATEK Center would be an ideal situation to demonstrate the viability of various noncon devices. He further recommended that a group called Project Sta. Barbara (PSB) be tapped to provide the technical expertise needed for the BATEK project. This recommendation was made for two reasons: (1) PSB facilities were also located in Cavite in a town not far from Dasmarinas; (2) the

author had been associated with PSB for almost four years as a full-time consultant for chemical engineering and solar energy projects and had maintained a close personal link with its head, Colonel Armando Proceso,* and other personnel. PSB's technical staff came from both civilian and military agencies. Located in a naval base, PSB conducted projects for both military and civilian purposes.

Later, a second visit was arranged in which Colonel Proceso and the author were able to meet with Dr. Mateo. Mateo stressed the fact that although BATEK itself was a private facility, it was performing functions highly supportive of the First Lady's social welfare activities and thus deserved government assistance.

Colonel Proceso brought along some of his technical staff so that a preliminary assessment of what needed to be done could be made. This was necessary for estimating the financial requirements of the project. It was agreed that the windmill would be changed, with a new one to be procured from a local fabricator. Larger solar dryers with provisions for air convection were to be built at the PSB facilities. For the design, the author provided PSB a copy of a compilation of solar dryer designs in various countries, as prepared by the Brace Research Institute of Canada. A new biogas digester would be built <u>near</u> the pigpens.

PSB worked on the designs and costings for several weeks, with assistance from the NCRD staff. On July 27, 1977, the proposal was finalized and formally submitted to EDB, where it was processed quickly and Velasco's approval was obtained. The approval grant was for ₱84,600.

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*Fictitious name.

Despite this approval, the project could not be started, since NCRD was still waiting for its funds to be released by the Budget Commission. The Presidential Decree signed January 12, 1977 provided ₱10 million to EDB's noncon program to be appropriated "out of any available funds in the National Treasury." As mentioned earlier, the actual release of this money to EDB was made only in the last quarter of 1977. Thus, it was only in December 1977 that a memorandum of agreement on the BATEK project was executed between EDB (which had become the BED as of October 1977) and PSB.

NIST Biogas

In mid-1977, a project was submitted to EDB which aimed to study the use of biomass materials such as leaves, rice straws, and so on as feedstock for biogas digesters. The proponent was Julio Bacungan,* a microbiologist at the National Institute of Science and Technology (NIST), an agency of the NSDB. Bacungan had been principally involved in NSDB's past efforts in biogas and had also represented the country at several conferences hosted by the UN and other agencies on this subject.

NCRD's overall appraisal of the proposal was positive. But looking over the list of biogas projects already approved, it was felt that a software analysis of biogas systems was needed. Bacungan's background indicated that he would be a suitable person to do such a study. Consequently, the author met with Bacungan and persuaded him to restructure his project proposal so that its main objective would be to analyze the economics and energetics of biogas systems operating in the Philippines. This was done and the revised proposal was then processed until a memorandum of agreement was signed between BED and NIST in December 1977. The MOA stipulated that the project objectives

*Fictitious name.

were to examine existing types of biogas systems and evaluate their net-energy and cost-benefit characteristics in relation to waste input, gas production capacity, nature of use, and other factors. It would aim to compare, from a policy standpoint, the social and economic benefits of establishing a large number of small biogas units against a small number of large-scale installations. The grant awarded to the project of one-year duration was ₱81,700.

PHASE 3: OPERATION, CONTROL, AND HANDOVER

Regional Biogas

For the regional biogas project, Maramba's staff designed a six-day training course on biogas technology to be held at Maya Farms in Antipolo. Lectures were to be held daily for four hours. Practicum sessions, in which the trainees would have on-the-job exposure to the Farms' biogas operations, were to be carried out also for four hours daily. Except for a representative of NIST and another from the Pollution Control Commission, all the lecturers came from Maramba's group of biogas specialists. The lectures themselves covered the spectrum from theory to socioeconomic aspects, but more hours were devoted to actual design work. The first training class began on November 11, 1977 with Chairman Velasco himself present to do the opening honors. There were twenty trainees.

Before the opening, Escudero was asked to select the most appropriate BAI personnel to attend the training classes. He chose the top people in the regional offices, most of whom were veterinarians; BAI had no engineers on its staff. Escudero explained, however, that some BAI veterinarians had built and operated small biogas plants in the past and he felt that those with no experience could cope similarly with the task. BAI brought the trainees to Manila at its expense, and EDB shouldered the training costs: lunches, handouts, honoraria for lecturers, and daily transportation from Manila to Antipolo, amounting to some ₱10,000 per class.

A basic design for a biogas unit emerged from the training course: a rectangular-shaped, one-chamber digester with double walls on the upper part to hold the gasholder tank in the water seal (see Figure 1.4). The trainees did not like the less expensive single-wall type where the gas holder floats directly on the sludge. The digester was to be roughly 4 ft by 4 ft by 6 ft

deep, but it was decided that the exact dimensions could be finalized later, depending on specific conditions in each regional site such as terrain, number of pigs, available materials, and so on. EDB had informally assured Escudero that it would support ₱10,000 of the cost of each unit, or a total of ₱120,000. Any excess expenditures would be borne by BAI. This cost ceiling, then, was the primary limiting factor on the size of the demonstration biogas units.

After the first class, two more training classes were held. The graduates of the first class, however, which was composed mainly of regional directors, had the responsibility of finalizing the design and cost estimate for each regional unit once they got back to their stations and to transmit this information quickly to the BAI Head Office. The final designs were examined by a combined panel of EDB, BAI, and Maya Farms personnel to ensure that they met basic technical requirements as well as cost constraints.

A simple letter of agreement dated December 9, 1976 was signed by the deputy director for EDB, W. R. de la Paz, and Escudero formally committing a ₱120,000 grant to the project. The agreement stipulated that BAI would cause twelve biogas plants to be operational within three months from receipt of the fund, to construct the units in accordance with the submitted designs and cost limitations, and to submit progress reports as EDB required.

Actual construction of the twelve units commenced shortly thereafter, interrupted only by the long Christmas holidays. BAI sent brief monthly reports to EDB on the progress of the work; it was not possible, however, for NCRD to make a physical inspection of the various sites. Most of the units were reported completed and operational by early March 1978, well within the three-month target.

Metro Biogas

Venancio Reyes sent a formal proposal to EDB on December 1, 1976 outlining a program for urban biogas consisting of a one-month technical feasibility study phase followed by construction of a pilot plant for a period of three months.

The third phase would be one year of pilot plant operation and economic feasibility study. In his proposal, Reyes stressed that the most difficult problem in anaerobic digestion of garbage was "variability of quality and composition of refuse material which affects microbiological reactions responsible for the success of the fermentation process," hence the necessity of the pilot plant approach. The proposal did not give an estimate of the size of the pilot plant envisioned nor its approximate cost. These were to be determined after the technical feasibility phase. Reyes did ask for an immediate financial allowance to cover his travelling expenses, per diem for assistants, consultants' fees, and representation expenses. EDB Director Leviste did not look at the proposal favorably. He instructed the author to seek more expert advice from other sources and to hold Reyes' proposal in abeyance.

Meanwhile, unknown to EDB, MWSS had responded to the situation by drafting a Presidential Letter of Instruction (LOI) which would put all efforts in biogas development, urban or rural, under an ad hoc body chaired by the MWSS general manager. The move was apparently a reaction to a memo by Juinio dated November 17, 1976, addressed to the director of BPW, the administrator of NHA, and the general manager of MWSS. The memo referred to the President's handwritten note.

Proposed as members in the LOI were the deputy director general for Programs and Projects of the National Economic and Development Authority (NEDA), the chairman of NSDB, the administrator of the National Housing Authority (NHA), the director of the Bureau of Public Works, and the assistant secretary of DPWTC. Although the preamble of the LOI cited as rationale the government's efforts to harness alternative energy sources, EDB was not included in the draft's proposed ad hoc body.

LOI 487 was signed by the President on December 14, 1976 but he inserted, in his own handwriting with authenticating initials, the line "Representative of the Energy Development Board" in the list of members of the appointed body.

With the Christmas holidays, no action was made on the LOI until January 13, 1978 when MWSS called a meeting of all agencies named in the LOI. Leviste and the author attended the meeting, where Leviste formally expressed his view that the envisioned functions of the MWSS-led body might run into conflict with the jurisdiction of the EDB, which covered the exploration of all non-oil-based alternative energy resources. He cited as examples projects that were currently implemented jointly by the EDB and BAI on the generation of biogas from animal manure.

After some discussion, an agreement was reached whereby the Metro Biogas Committee would confine itself to biogas extraction from sewage and urban wastes in the Metro Manila area and other urban areas wherever feasible. Thus, the meeting marked EDB's formal turnover of the area of biogas from urban wastes to the Metro Biogas Committee.

BATEK Biogas

Upon approval of the BATEK biogas project, Colonel Proceso appointed Lt. Rey Alonzo* and Lina Suero*, both PSB chemical engineers, to work on the biogas portion of the activity. Dr. Mateo, on the other hand, designated Adel Forma*, a BATEK engineer, to assist the PSB team. The biogas system was expected to be completed in six months' time.

The system was sized by assuming full hog occupancy of the existing pigpen; the estimated daily gas production was some 400 ft^3. Instead of building one big digester with gasholder, it was decided to build four units with interconnected gasholders. PSB wanted to test commercially available concrete culverts for the

*Fictitious name.

digester structure. It was also thought that building four smaller digesters would reduce cleaning and start-up time and permit operation even if one or two of the digesters were down.

The system was completed in April 1978 but, except for start-up tests, could not be operated because of lack of pigs and hence lack of manure. BATEK was experiencing budgetary problems and could not as yet buy the necessary pigs. Twelve pigs were finally bought in August 1978, not enough to provide the design waste input but sufficient to sustain operation of at least one digester unit. A lecture-seminar on how to operate and maintain the system was held by PSB at the site on August 30, 1978. The seminar was attended by PWU nutrition instructors and students who were doing work at BATEK. After the seminar, the system was formally turned over to BATEK and the direct care of engineer Forma and utilityman M. de la Cruz*, who by that time were already knowledgeable in biogas operations having worked closely with PSB engineers since the beginning of the project.

The biogas produced was used for cooking stoves and ovens in the food processing section, displacing some 30 percent of the normal LPG requirements of the Center. Auxiliary installations were also completed. The pigpen as designed had a shallow pond on the flat concrete roof intended for growing chlorella, at the same time providing cool accommodation for the pigs. The windmill erected by the project was used partly to pump water to this pond. Chlorella was actually produced but was never used as a feed supplement. Reyes explained that they feared the algae was badly contaminated with pesticides regularly sprayed on the mango trees around the pigpen.

NIST Biogas

It was only in March 1978, when the first disbursement of funds could be made, that the NIST biogas project was actually started. The delay was caused by

*Fictitious name.

difficulties encountered in meeting requirements for bonding the project's disbursement officer. Bacungan nevertheless reported towards the end of March that the design of the biogas system that would be built under the project had been completed, including the auxiliary oxidation and chlorella ponds. NCRD engineers who visited the project site in late April 1978 found evidence of construction work just being started. A report submitted in June 1978 by Bacungan confirmed the slow pace of the project activities but attributed this to certain administrative difficulties. For one, the project co-investigator, E. Arce*, could not get cash advances from NIST out of the remitted project funds; requisition of materials had to go through the normal, time-consuming channels. Bacungan also complained about his inability to hire research assistants, as the NIST auditor required such contractual help to obtain approval of the Civil Service Commission, another time-consuming process. He explored the possibility of EDB's hiring these contractual assistants instead and detailing them to his project. This alternative approach was in fact carried out later.

On June 19, 1978 the author wrote Bacungan reminding him of the primary objectives of the projects, which were to examine existing types of biogas systems and evaluate net-energy and cost-benefit characteristics in relation to waste input, system scale, and other factors. This communication was prompted by the observation that Bacungan's reports dwelt only on the biogas system that he was building at Bicutan. The letter stressed EDB's view that the hardware experiment being conducted was only of secondary value.

Responding partially to this reminder, Bacungan started developing a biogas plant survey questionnaire which contained detailed queries on digester type and design, feedstock, gas utilization data, usage of effluent and sludge, and costs. The four-page questionnaire focused on relevant data, but it was not the type that could be answered effortlessly by the average technician or homeowner.

*Fictitious name.

Not surprisingly, out of the 100 questionnaires sent nationwide to known biogas operators, only two responded.

Thus it was decided to conduct actual interviews. Due to cost constraints, however, only selected provinces in the Luzon and Visayan areas were visited. A total of 33 biogas installations of various sizes were surveyed by the end of November 1978. Meanwhile, Bacungan's assistants continued with their experimental work at Bicutan, finally completing the digesters and aquaculture ponds and reporting data gathered on production rates. For reasons not made clear, none of the reported runs used nonmanure materials.

A request for project extension to March 1979 was made to enable survey data to be processed as well as to complete data-gathering work on the Bicutan biogas system. This was granted by EDB primarily because the project start date was really March 1978 and not January.

In his final report, Bacungan summarized the findings of the survey, which covered biogas systems of digester size ranging from about 100 to 4000 ft^3. Except for some units which partially used chicken droppings or rabbit manure, all the units used hog manure. Investments on the units ranged from ₱1,300 to ₱80,000. Gas production, whenever available, was used for cooking in all the units, with one or two also using the gas for running absorption-type refrigerators. Few of the surveyed systems utilized the sludge or effluent for fertilizer or aquaculture.

A disturbing result was the finding that 19 out of 30 surveyed units, or 64 percent, were not functioning at the time of survey, some having been inoperational for as long as a year. The reasons were varied: clogging of inlet ports, leakage, and faulty digester design. A common nontechnical reason was "no more pigs"--therefore no more manure supply.

PHASE 4: EVALUATION AND REFINEMENT

Regional Biogas

The standard memo of agreement normally executed by EDB with project implementors contains a provision requiring quarterly reports on the technical and financial status of the project. These reports were to be the basis for subsequent fund releases to the project, which are normally made quarterly. The BAI project was a special case, with a coverage of only three months, and thus a simple letter-agreement was deemed sufficient. The Metro biogas project, of course, did not reach the MOA stage.

Theoretically, every quarterly report was supposed to be routinely verified by actual site inspection by NCRD representatives. This verification, however, was virtually impossible to accomplish during the first year of the noncon program, owing to the lack of personnel. Site inspections were made for all of the projects but not on a regular basis.

In the case of the BAI project, the inspection stage posed an especially difficult problem because of the highly dispersed locations of the installations. Even if enough NCRD personnel could be sent out to the twelve regions, the cost of sending them would have been prohibitive. It was therefore decided to tap for this purpose Petrophil engineers stationed in bulk plants (depots) all over the country. Petrophil Corporation is the marketing arm of the Philippine National Oil Company headed by EDB Chairman Velasco; thus, it was not difficult for the inspection arrangement to be pushed through. Jess Lopez*, PNOC operations manager, was asked to coordinate the inspection activity.

The author gave the Petrophil engineers a crash course on biogas systems

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*Fictitious name.

and the project background. This was done in early March 1977 during a regular meeting of the Petrophil regional personnel. The engineers were each given a copy of the basic biogas design agreed upon with BAI. Actual inspections were made by the engineers upon their return to their stations. By late March, written reports began to arrive at the Manila Petrophil office by Jess Lopez. He transmitted to Leviste the compiled reports from the twelve regions in early April 1977. The reports, which included photographs, gave details on dimensions, materials, and overall set-up of the projects.

The reports revealed that some of the plants were made smaller than the basic design and thus could not have cost ₱10,000 each. Other deviations were noted. The plant in Cagayan de Oro City, for example, did not follow the original plan in which manure flows by gravity to the digester. The transfer was being made manually, a practice which struck the Petrophil inspector, O. S. Remulla*, as "tedious and messy." Noting that some of the gas collectors were not painted inside and outside, the inspectors predicted quick corrosion of these tanks. All the plants, when inspected, were generating biogas, but whether or not the amount being generated was in accordance with the design estimates could not be determined.

The author transmitted a copy of the compiled reports to BAI Director Escudero and requested a full financial statement of project expenditures. It was also requested that the observations and suggestions of the Petrophil engineers be noted and followed by the regional operators. Escudero complied with these requests, explaining in his response that although some of the units did not spend ₱10,000 each, other larger ones spent more. He requested that BAI

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*Fictitious name.

be allowed to use any unspent funds out of the ₱120,000 EDB grant towards the construction of more biogas digesters on other sites.

Later in 1979, a post-evaluation survey on the condition of the original plants was made by NCRD. This time, the assistance of NSDB regional officers and ENERCON directors were employed.[4] The results indicated that although most of the plants were still in operation, many had technical problems such as leakage and insufficient gas generation. The plant in Zamboanga City had been idle "for the past two years." The plant in Camalig, Albay, on the other hand, had an oversupply of gas which was just being allowed to leak into the atmosphere.

The problems could be traced mainly to poor maintenance. Personnel turnover brought in new untrained technicians and helpers. There appeared to be little effort exerted by the regional directors to train the new people and even to monitor the biogas operation. An aggravating circumstance was the retirement on August 1978 of Dr. Juan Calura*, who had been designated by Escudero at the beginning of the project as coordinator for BAI. Before his retirement, he had required a periodic reporting scheme from the regional directors. This practice was not continued by Calura's successor.

Metro Biogas

The Metro biogas project, as stated earlier, never became EDB's responsibility. Since the agreement with MWSS reached in January 1977, NCRD limited its attention in the biogas area only to systems using nonurban wastes. From a policy standpoint, this appeared to be an appropriate move considering that EDB's primary objective was energy generation and not waste disposal.

Later analysis and consultation with experts confirmed the feeling that methane generation from municipal wastes could be viewed only as a very minor

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*Fictitious name.

component of the main job, which was proper waste disposal. As one expert put it, "obtaining gas from sewage sludge at any cost is rather like buying a nice pair of shoes because you fancied the shoelaces."[5] The same expert also pointed out that (urban) sludge produced in African and Asian countries generated very much less gas than in Western countries because of the low protein content of the diet of the people in the former countries. The amount of useful gas that could be obtained in terminal digesters would also be much less than in tropical countries because the high ambient temperature would already cause methane generation in the sewerage networks and consequent loss of much of the gas to the atmosphere.

This effect was in fact experienced by MWSS in two pilot installations completed in 1977. One was in a newly completed residential village in Bicutan, Taguig on the outskirts of Manila, where a septic tank-biogas generator system capable of handling 150,000 gallons per day of sewage effluent from the village was installed. The other was at Philam Homes in Quezon City, which processed 230,000 gallons of sewage per day. A check made with MWSS engineers only recently revealed that little useful gas was actually collected in both installations and that further experiments were discontinued.

BATEK Biogas

The BATEK project was considered completed in early 1977, in accordance with the provisions of the memo of agreement. Since the project resulted in the installation not only of a biogas generation and utilization system but also a windmill, solar water heater, and solar dryer, the Center became a popular stopover for visitors wanting to see alternative energy devices (see Figure 1.5). NCRD analysis indicated that the devices did not really displace a significant amount of conventional fuel for the Center; they were too few and of insufficient size. The project, however, had a high demonstration

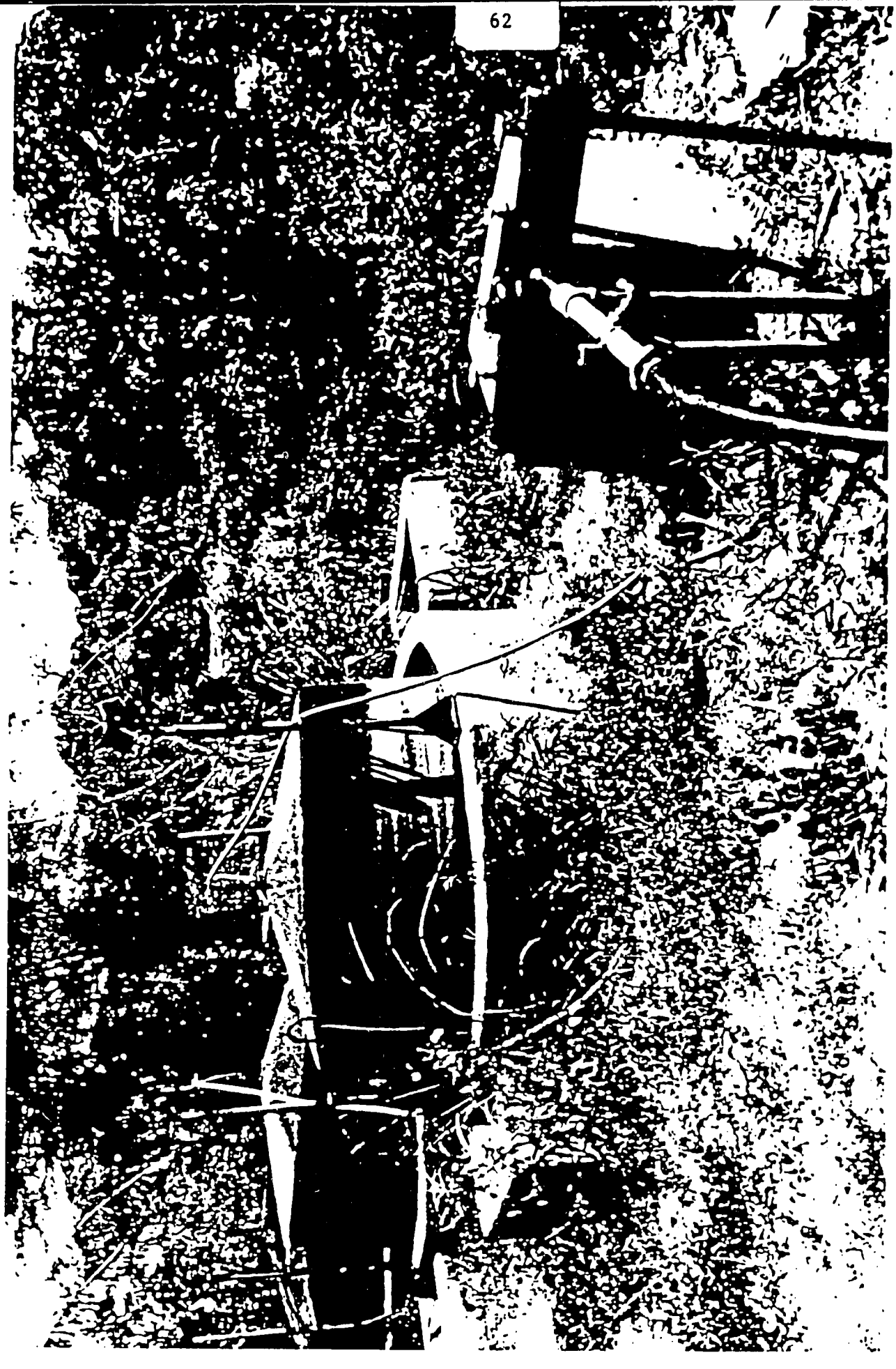

Fig. 1.5. Biogas "cluster" constructed for BATEK project.

value. The solar dryer designed for the project--a mobile multiray type using inexpensive material--became more popular than the other devices and was replicated by many external users. The biogas system, operated intermittently, was later shut down for a long period when the pigs were sold and purchase of replacements delayed. In 1979, model residential cottages were built in the BATEK compound and the biogas lines were transferred from the food processing center to the cottages so that the gas could be used for cooking. An NCRD engineer sent recently to check the installation reported that the biogas unit was shut down for repair of the gasholder and for cleaning of the digester. There appeared to be sufficient motivation, however, to undertake the repair and put the unit back in operation as early as possible; the BATEK facilities were constantly used by students and the Center always had many visitors.

NIST Biogas

In contrast, the NIST project failed to achieve most of its intended objectives. Only the survey component, in the author's opinion, was a truly useful result. The biogas system (digester, algae pond, fish pond) did not incorporate the use of nonmanure feedstock as originally proposed. Hog manure, perhaps because of its more familiar nature, was used as substrate. Instead of examining the economics and energetics of existing types of biogas systems, the economic assessment was made only on the system actually built. No net energy analysis was made.

This result was surprising in view of Bacungan's good reputation in the field. It can only be surmised that not much time was actually devoted by the principal investigator to the project, perhaps because of demands of his main job and perhaps due to a number of trips abroad that Bacungan made in the course of the project.

Refinement of Policy and Planning

Some lessons have emerged from the results of the projects described. One is that, despite the "simple" nature of biogas systems, they require trained attention. Even in the BAI and BATEK installations, both of which benefited from full-time caretakers, technical problems caused many plant shutdowns. It is not surprising, then, that the number of discontinued operations of household units has been shown to be high. The ordinary homeowner has neither the background nor the patience to troubleshoot a unit that ceases to function because of, say, an unseen leakage which causes air to enter the digester and kill the methane-forming bacteria. In such an event, observations show that the homeowner simply reverts to the use of conventional cooking fuel, such as firewood or kerosene, if such an alternative is available.

Perhaps aggressive extension work can alleviate this problem. The fact remains, however, that the household biogas unit built to provide only cooking gas is in most cases not a viable proposition. First, the investment cost of a unit is too high for the average rural family to afford. Furthermore, if only hog manure is used, a family needs four to six pigs to produce an adequate gas supply. The number of rural families in the Philippines that can afford to have this many pigs is small.

If the sludge or effluent could be used to fertilize a family vegetable garden, the benefits of the biogas system greatly increase. Studies recently made by Maramba have shown excellent economics for the case of a 1.2 - 2 ha farm which practices integrated piggery-agriculture-fish pond operation centered on a medium-sized biogas system.[6]

Thus, there seems to be no doubt that the best way to maximize the benefits from a given quantity of animal manure is through large biogas

installations. In a livestock farm, for example, with 1000 heads or more of cattle or swine, one or more technicians trained in biogas operation could easily be supported. The presence of such personnel would certainly minimize discontinuity of operations because of simple technical problems. And a large farm run as a business would see to it as a matter of course that maximum use is made of all by-products such as sludge.

These policy considerations have guided BED in its later activities in the field of biogas. In 1979, a series of seminars was held to interest and educate livestock farm owners and managers in biogas technology. Several coordination meetings were held with officials of the National Pollution Control Commission. These meetings resulted in the NPCC's paying special attention to livestock farms that do not yet practice pollution abatement measures. It also reorganized NPCC's official stance to include biogas operation as an acceptable means of pollution control on such farms. At the time of writing, the first of a series of seminars directed at financing institutions for biogas operations was being conducted jointly by BED and BAI.

On the administrative side, the cases show little control was exercised by EDB in the course of the initial projects. This was, again, due to lack of personnel within NCRD, a situation that persisted up to the end of 1979. NCRD's expansion into a separate unit, a process now underway, will greatly increase its number of personnel and thus enhance its monitoring capability for externally executed projects.

The nature of institutional ties appears to have a strong effect on the outcome of development projects. The regional biogas case illustrates, among other things, how the proper institutional relationships could accelerate project execution and assure its success. In contrast, the absence of such linkages, as in the Metro biogas case, was shown to create the petty jealousies

and organizational chaos that doom an interdisciplinary activity even before it starts.

In particular, the personal relationships that exist among institution heads have considerable influence over the effective execution of interdisciplinary projects. Even if official demarcation lines are blurred, mission-oriented leaders with a give-and-take philosophy can guide projects to their intended ends.

Biogas is a good example of a development area where significant overlapping of functions of government agencies can occur. The energy agency is clearly interested in the product gas itself, the agricultural agency in the fertilizer by-products, and the environmental agency in the ecological aspects of the technology. Finally, a human settlements agency charged with the totality of a community's basic needs would appear to have jurisdiction over all facets of biogas technology. Because of the conflicts of interest that can occur, there is a very real need to delineate the precise roles of such agencies in the pursuit of development projects. This need is made even more acute by the circumstance that many projects in a developing country are born out of political considerations. In such cases normal execution channels are often not followed and consequently the ideal project management cycle becomes difficult to apply.

NOTES

1. Sectoral Reports of the Energy Committee, "Energy for Development," presented at the International Conference on The Survival of Humankind: The Philippine Experiment, Metro Manila, Philippines, September 6-10, 1976.

2. K. Smith, "Biogas Powered Piggery in the Philippines," Soft Energy Notes 1:45 (1978):45-46.

3. The specific projects described in this chapter comprise the first activities on biogas undertaken by EDB in the initial years of its non-con program. They are not to be taken as the only activities on biogas being conducted in the country at that time.

4. ENERCON is the acronym for the Energy Conservation Movement, a loose organization of private entities and individuals. Activities are funded mainly by the PNOC.

5. Communication dated December 3, 1976 from B.E. Hackley to I. Dimant, both of Simon-Hartley Limited of England. The company specializes in industrial and municipal waste treatment.

6. F.D. Maramba, "The Economics of Biogas Works," paper presented at the PDCP Dialogue on Non-Oil Energy Sources, Metro Manila, April 17, 1980.

   The focus on 1.2 - 2 hectare farms springs from the desire to help many Luzon farmers who were given landholdings of this size by the Land Reform Act.

ACRONYM KEY

BAI	Bureau of Animal Industry
BATEK	Barangay Teknolohiya
BED	Bureau of Energy Development (old)
BPW	Bureau of Public Works
CNED	Center for Nonconventional Energy Development
DPWTC	Department of Public Works, Transportation, and Communication
EDB	Energy Development Board
LOI	Letter of Instruction (Presidential
MWSS	Manila Waterworks and Sewerage System
NCRD	Nonconventional Resources Division (old)
NEDA	National Economic and Development Center
NHA	National Housing Authority
NIST	National Institute of Science and Technology
NSDB	National Science Development Board
PNOC	Philippine National Oil Company
PSB	Project Sta. Barbara
PWU	Philippine Women's University
RESC	Refuse and Environmental Sanitation Center

CASE 2

INTEGRATED BIOGAS DEVELOPMENT: FIJI

George Chan

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PROJECT BACKGROUND

A quick analysis of all attempts at rural development in the Pacific Islands, and indeed in the whole tropical world, will reveal that three essential elements are necessary for its success: fuel, feed, and fertilizer. Other important factors must also be considered, but these can be acquired more easily through training and technology.

If fuel, feed, and fertilizer are not available locally, they must be purchased. Using foreign aid money to meet these needs has been the time-honored custom of both outside advisors and local leaders in developing Pacific Island rural economic programs. Even while local leaders and farmers may want to become self-reliant by increasing production and processing their crops to replace many imported foods and goods, they have found it difficult to make the transition from the traditional pattern of export and import with more developed countries.

It is not surprising, therefore, that a striking feature of the rural areas of the South Pacific has been their lack of physical, social, and economic development as compared with the relatively high level of sophistication in the urban sector. This circumstance, which has led to the worst case of rural exodus in the world, has long been recognized. When the South Pacific Commission was created in 1947, many resolutions were passed to improve the health, social welfare, and economic development of village populations in the South Pacific (see Appendix I).

This neglect of the rural sector is clearly linked to the emphasis previous administrators of these islands have placed on exploitation of natural resources for export as cash crops, rather than on development of the local population. The gap between the small elite which benefits from this system and the majority of local populations in the Pacific continues to widen. Towns are expanding along Western lines, but time stands still in the villages. Those who do migrate to towns end up in slums where they find a more miserable and stressful life than that of the village. High food costs, low wages, unemployment, and allied problems dim hopes for improvement, and the situation is exacerbated if the transplanted villagers develop a taste for new and expensive items such as processed foods, alcohol, and cigarettes.

Back in the villages, island people still lack decent housing, a safe water supply, sanitary waste disposal, disease vector control, basic medical care, a balanced diet, appropriate education and training, cultural and recreational facilities, sources of energy, cottage and small industries, and opportunities for development and progress within their own culture.

PHASE 1: PLANNING, APPRAISAL, AND DESIGN

Identification

As public health engineer for the South Pacific Commision and other organizations in the region for seventeen years, the author had firsthand experience of village problems while providing technical assistance in small-scale self-help projects throughout the Pacific Islands. Villagers are anxious for water supply projects because they want to have water on tap near their houses. Disposal of excreta and garbage, however, is a different matter. Kitchen wastes and refuse are dumped on the ground, with dogs and pigs salvaging the edible part and leaving the rest for

flies and other vermin to breed in. Cans and bottles are also dumped indiscriminately to become breeding places for disease-carrying mosquitoes. Few toilets are found in villages and in most cases are not used properly or are only used by outside visitors. Beach, creek, bush, and plantation are used as toilets, with pigs doing the scavenging. The pigs go back to the villages and leave their excreta, attracting more disease-bearing flies. Consequently, many diseases are propagated among the people; most suffer from worms as well. Investment in toilets, however, is considered a waste of time and money, since people cannot see the tangible benefits of sanitary waste disposal.

Local diets in the Pacific also show protein and fat deficiencies. After breast feeding, children are raised on starchy foods due to ignorance of nutritional requirements and lack of milk, eggs, or meat in the diet, despite an abundance of goats, cows, chickens, and pigs roaming freely in the villages.

The practice of shifting agriculture primarily to grow root crops because of lack of fertilizer and absence of irrigation leads to wasteful destruction of land and forest. This in turn reduces the areas available for hunting and increases erosion of valuable topsoil and siltation of fish-producing streams. There is further a strong trend toward replacing local diets with imported rice, flour, canned mackerel, and corned beef, all imported at high cost. Most of the cash income is thus spent on food which could be produced locally, given so much available land and water and the best conditions for photosynthesis. In villages throughout the Pacific Islands, animal husbandry is almost nonexistent; little cereal and legume planting is done; there is no fish farming or plankton culture in ponds; and hardly any crops are processed.

The greatest waste, however, is of manpower, the most precious resource in the islands. People who leave school have nothing to do in their villages because their education is not relevant to rural problems. They move to towns

in search of a better life but end up facing numerous urban problems instead.

After five years of unsuccessful attempts to deal with sanitation problems in the South Pacific, the author concluded that villagers would not be motivated by the germ theory of disease cited by health educators as the main reason to safely dispose of excreta. Instead, excreta disposal should be an economic proposition, producing fuel, feed, and fertilizer for farmers to increase productivity and provide new amenities for their homes.

Impact of the Oil Crisis

The 1973 energy crisis focused attention on the sad state of small farmers and villagers in the South Pacific and led to new policies calling for island governments to develop action programs directed at the energy needs of these people. These programs included emphasis on fuel production for domestic, agricultural, and industrial purposes. They aimed to provide stockfeed, fertilizer, and raw materials for small industry, while encouraging control of environmental pollution and conservation of resources.

Thousands of small-scale and subsistence farms in the South Pacific are inefficient because of the shortage of protein feed and fertilizer that restricts yields from both land and water. In addition, there is waste because of shifting cultivation or overgrazing which causes soil erosion and siltation of water courses, with subsequent reduction in plant and aquatic life. In most cases, farmers who barely keep enough to feed their own families are forced to sell their produce as cheap crops or raw materials to buy imported processed foods or other consumer goods at relatively high prices.

Leaders of the South Pacific countries share a desire to improve the quality of life in rural sectors by raising productivity through better technology, but without relying too heavily on outside input. Long before the oil crisis broke, they could see the great potential for biogas as a cheap and convenient source

of fuel to replace costly energy imports, as well as to process raw materials exported at the lowest prices. They could see that biogas and its fertilizer by-product could be the key to developing village economies and a means of disposing of wastes in a sanitary manner, thereby preventing the pollution and health hazards created by these wastes. Although the oil crisis increased the urgency of dealing with this problem, however, leadership was still not ready to take the final step.

While leaders in the South Pacific hesitated, Asian countries tackled the problem aggressively. Digester construction programs in these countries are impressive: China has over 5,000,000 digesters, India has built over 100,000 since the oil crisis, and even a cold country like the Republic of Korea has over 60,000 digesters. Other countries such as the Philippines, Thailand, Pakistan, and Nepal are implementing sizeable digester programs in their rural areas.

The Taiwanese Experience

In 1969, the author made his first visit to Taiwan and learned about their rural reconstruction movement, which began, with considerable infusions of U.S. aid, in the 1950s. Instead of the industrialization plan originally submitted by the U.S. government, the Taiwanese adopted a rural reconstruction project.

For fifteen years, the rural sector was reorganized to improve the lot of the farming community. All farmers were helped in buying their farms. Farmers' associations were established to deal with the provision of supplies and equipment, marketing and processing, banking services, and other administrative and technical problems, allowing farmers to concentrate on improving productivity. Methods of composting farm and domestic wastes were improved through the introduction of the waste digester. This last innovation, in the author's opinion, was the most important factor in Taiwan's successful campaign to involve farmers in the rapid

economic development of the island over three decades.

As one farmer in Linkuo explained, the digester improved his farm operations in a variety of ways. First, his composting operation was both more efficient and more sanitary, since the process provided a continuous source of fertilizer and eliminated handling of the excreta. Second, the digester provided the farmer's domestic fuel needs, thereby relieving his children of the need to collect firewood and allowing them to concentrate on their schoolwork. The farmer was able to keep his land and was not forced to work in a factory.

Therefore, even though industrialization did not come to Taiwan until fifteen years after the rural reconstruction movement started, today both farms and factories are in full production and the traditional Chinese family structure remains intact. Although rural electrification is now common in Taiwan and the modest digester has become a showpiece, during the first years of this miraculous development it played an important role, providing fuel and fertilizer to the farmer.

The author observed two other developments in Taiwan which were to influence his work in the South Pacific: the production of algae in shallow basins using septic tank effluent, and the fertilization of fish ponds with human or animal excreta. From these ideas gained from the example of Taiwan came the conception of the Integrated Biogas System (livestock-aquaculture-agriculture) for use in the Pacific Islands.

Design

The digester consists of a digestion chamber and a settling chamber (see Figure 2.1). The digestion chamber is double-walled, with the wastes entering the

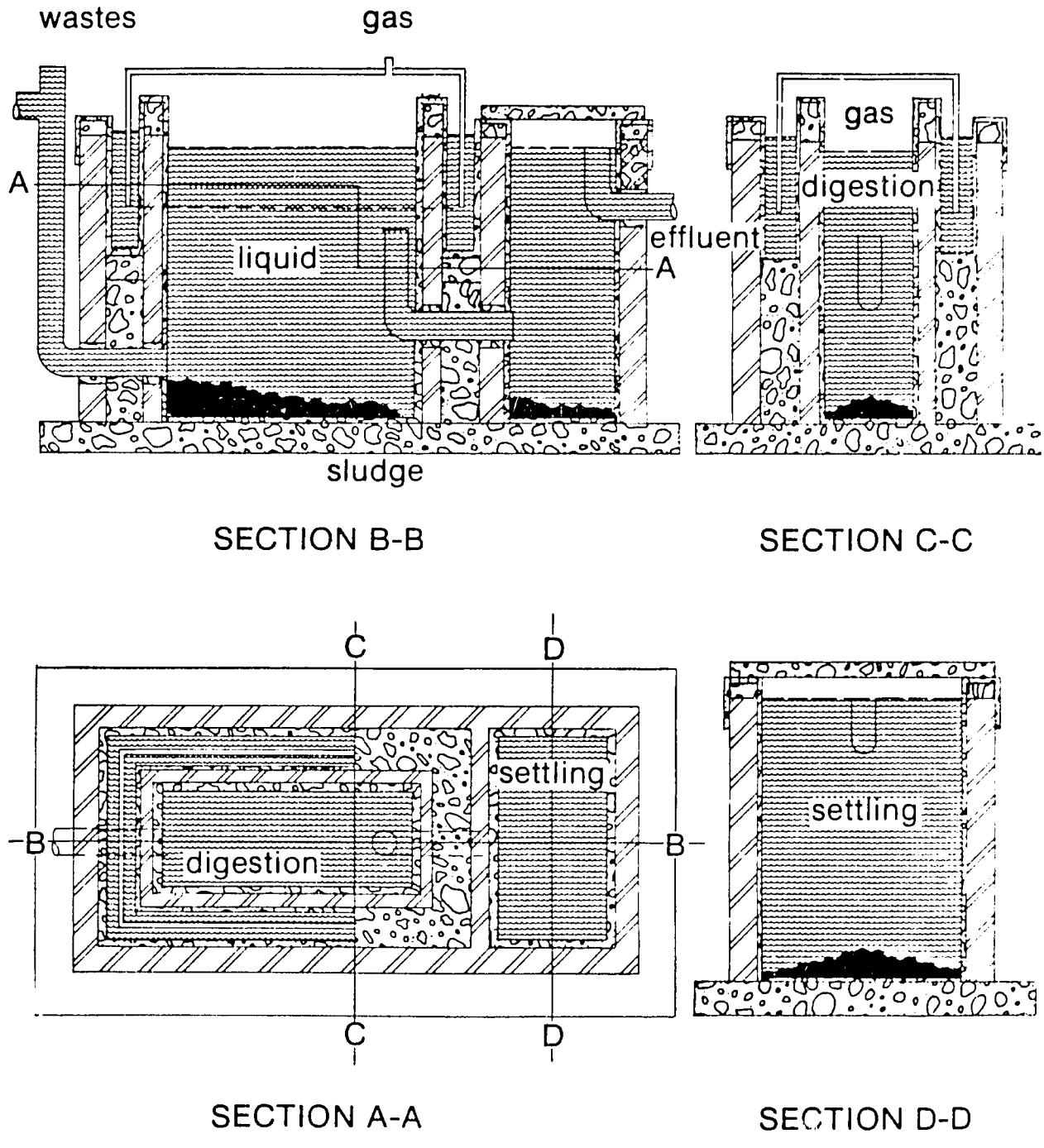

Fig. 2.1. Three hundred gallon concrete and steel digester.

Source: George Chan, South Pacific Commission, 1969.
Courtesy: University Press of Hawaii

inner chamber, and a steel gasholder floating between the two walls that contain water topped with oil to prevent evaporation. This water seal prevents the gas from escaping until the gasholder rises high enough to break the water seal. The gasholder then drops down again until equilibrium is reestablished. As more gas is formed but not being used, the same thing happens again. This process works like a safety valve, allowing the extra gas to escape.

The digester is the heart of the integrated biogas system because it treats the wastes sufficiently to allow the effluent to serve a useful purpose in the basins and then in the ponds before it is absorbed in the soil by plants. Without this digestion and liquefaction process inside the digester, the wastes would pollute both the water in the soil and the basins or ponds. The methane gas replaces other useless gases that would have been produced if air had been allowed inside the digester. This is the only difference between the digester and an ordinary septic tank: The digestion process involves the methanogenic bacteria under anaerobic conditions to produce methane (CH_4) instead of ammonia (NH_3), sulphides such as H_2S, and a disproportionate amount of carbon dioxide (CO_2).

The rate of methane production depends upon many factors such as temperature (no problem in tropical islands), pH (can be controlled if the digester is not overloaded), dilution (too much water will flush the digester instead of retaining the organic matter for digestion), and proper maintenance to prevent obstruction at the inlet.

No special skills are required to build or maintain a digester. It must not leak, of course, and must not be loaded much above the capacity for which it is designed, as this can increase the acidity of the mixture and stop the growth of the methane bacteria. Sometimes lime is added to reduce the acidity, but it is still better not to overload the digester. A common problem is the obstruction of the inlet by floating wastes or fibers from grass and leaves the animals have eaten. There should be a screen at the inlet to prevent grass and leaves from

entering the digester, and every day a plunger should be used to clear the inlet and push the wastes inside the digester. If this is not done, floating wastes will accumulate at the inlet and prevent the wastes from entering the digestion chamber, causing gas production to suffer.

This digester design, which was universally used five years ago, has one problem, namely, the high cost of the steel gasholder, which represents two thirds of the total cost of the digester. Many attempts have been made to find a substitute for steel, the price of which multiplied four to five times after the oil crisis. Among the materials tried were fiberglass and plastic. The fiberglass gasholder was still expensive and had to be made thin in order to cut cost, but it developed many pinholes that made it useless for storing gas. Plastic gasholders were cheaper but required expensive molds that could justify their costs only if made in very large numbers, and no one wanted to pay for the high initial costs. Thinner steel sheet was also tried, but it corroded very quickly.

Not only does the digester isolate farm and human wastes to solve a public health problem (as an ordinary septic tank would do), it also produces biogas containing two thirds methane. The methane can be used as a fuel, and the digestion partly mineralizes the organic matter for use as fertilizer. The effluent from the digester is subsequently oxidized in shallow basins while producing algae, and in deeper ponds while producing fish and other aquatic life--all as high protein feed for livestock--for complete mineralization. This final effluent is used for irrigation and fertilization of crops.

The cost of the digester was relatively high if measured by the amount of gas produced from the treatment of a given quantity of waste. Furthermore, it was not possible to put a monetary value to the public health benefits or environmental protection from pollution the digester provided. Because critics of this concept refused to acknowledge the intangible benefits, it was necessary

to integrate the digester with aquaculture in relatively cheap ponds and include fertilized and irrigated agriculture to increase tangible benefits.

PHASE 2: SELECTION, APPROVAL, AND ACTIVATION

Some critics still argued that the Integrated Biogas System was "too much work" for Pacific Islanders. These islanders, however, invest much effort in cultivating starchy vegetables or producing copra to buy imported foods and goods. They carry water from polluted wells, nurse sick children because of unsanitary village conditions, and are willing to work eight hours to earn one or two dollars to pay school fees or buy a can of corned beef. What often appear to be the castoff foods of developed countries are prime staples in the islands: beef brisket and lamb flap, for example, or corned beef and canned sausages. The integrated biogas program, on the other hand, encourages the production of fresh pork and chicken or duck, fresh vegetables, and a larger variety of cereals and legumes. Included in the scheme is the possibility of processing local crops to produce oil, vinegar, sauce, soap, and other items using simple equipment operated by the biogas.

Many local leaders could see the benefits that village people would derive from integrated biogas development, but they still found the financial investment prohibitive for their kind of economy. Advocates of the digester felt that foreign aid money should be used for this purpose to give more people the necessary means to produce goods and food with locally provided fuel, feed, and fertilizer. Island leaders concurred in this feeling, but the aid donors themselves and their technicians did not.

When government support was not forthcoming at this time, the South Pacific Commission could not cosponsor the Integrated Biogas System because SPC funds were supposed to go to government-approved projects. The author therefore decided to fund the project himself after a Fijian farmer put his land at the

author's disposal in 1969. The farm, owned by Ratu Langivala, was located at Sawani, a rural area 10 miles out of Suva, the capitol of Fiji. The first digester in Fiji was built on Saturdays by the author, the Fijian farmer, and his son for a total cost of $300.

When completed, the digester had a capacity of 300 gallons for digestion and 300 gallons for settling (Figure 2.1). The gasholder, which also had a capacity of 300 gallons, was made of steel plates. The digester was designed for a three-sow unit, or about 30 pigs of various sizes, but the new pigpen, with a concrete floor for easy flushing of wastes, was built for half this number because of a shortage of funds.

At this point the author realized that the cost of the digester would be prohibitive for the average small farmer in the South Pacific, but he was then unable to find any better materials than concrete for the digester tank or steel plate for the gasholder (both expensive materials that were not much used on farms). Because it was important to get maximum returns on the financial investment, the author integrated the digester with aquaculture and agriculture, using livestock wastes as raw material.

The overall plan of the integrated project thus included algae basins, fish ponds, and gardens. These were built in 1972 when the Fiji Ministry of Agriculture provided additional funding. Three plastic-lined basins were built to receive the effluent from the digester for growing algae as animal feed. The effluent from the algae basin was discharged into a deep pond for fish and duck farming, and the final effluent was used to irrigate and fertilize food crops.

PHASE 3: OPERATION, CONTROL, AND HANDOVER

The digester, still in operation during a visit by the author in 1978, is now operated on a full-time basis by the farmer's son, who also plants other food crops on the farm. He has completed the pigpen and buys four or five weaners every month, feeding them for four months before selling them. This means that

at any given time he has 16 to 20 pigs on his farm. The biogas produced supplies the six family members with fuel for cooking three meals a day plus 3 to 4 hours of lighting at night. They are the only farm family in the area that does not have to eat dinner in the dark or burn expensive kerosene for an inefficient lamp, and the children can do their homework at night. The lamp they use was specially designed in India to use biogas and has a small clay venturi to increase the velocity of the gas and air mixture before it is burned to produce a bright light.

During the first year of operation, while the author was still stationed in Fiji, the number of pigs did not exceed one dozen, yet the digester produced enough gas on a sunny day to cook three meals for a family of eight. Subsequently, a closed farming system was instituted--and it worked.

A problem in operations that did arise, however, concerned the use of algae as feedstock. The farmer, reluctant to feed his pigs with the algae, had been advised by a university lecturer that the algae was poisonous. When the author returned to Fiji four years later, he showed the farmer how his pigs loved the algae mixed with the usual feed of wheat pollard and cassava and thrived on it. When the author showed the lecturer statistics on Taiwan's export of algae at $15 per kilogram to Japan and West Germany as protein feed concentrate (45 to 50 percent protein) and that 1 percent of the algae added to chicken feed resulted in 10 percent more growth or more eggs laid, he retracted his advice, but the farmer was still hesitant to use the algae.

PHASE 4: EVALUATION AND REFINEMENT

It has not been possible to assess the maximum output in aquaculture due to lack of local expertise in algae and fish culture. Similarly, agricultural output is not easily assessed because of the lack of space for growing crops using the final effluent for irrigation and fertilization. There is evidence, however, that the algae, fish, ducks, and crops grow well. There should be

no doubts concerning the economic benefits obtained from digestion of animal wastes and utilization of the effluent in a closed farming system. Asia has demonstrated this concept to the world for many decades, and due to the oil crisis the industrialized countries are now conducting research and development studies in these fields.

The most important feature of the integrated biogas development is its viability for small and large farms. All the by-products can be utilized immediately and also provide the farmer with the three elements (fuel, feed, and fertilizer) essential to an integrated livestock-aquaculture-agriculture-industry system of closed-cycle development. Figure 2.2 shows a schematic of this Integrated Farming System with proper water, land, and resources management (see also Appendix II).

The Sawani project aroused much interest among the Fijian and Indian farmers and prompted the government to subsidize the construction of other digesters in Fiji. This decision was made in December 1971, after the author had transferred to Papua New Guinea for three years. With government support. funds could then be released by the South Pacific Commission for a similar project at an agricultural school.

The Fijian government subsequently financed three digesters for Indian farmers--two of 1,000 gallons each in Tailevu and one of 4,000 gallons at Vuda Point, halfway between Nadi airport and Lautoka. Of the two 1,000-gallon digesters, one was abandoned by the farmer after he had some problems with blockages in the pipe connecting the piggery to the digester, which was located about 100 feet down a very steep slope. In this case, the digester site was poorly chosen; a digester should always be installed next to the piggery for easy cleaning and prevention of blockages. The other 1,000-gallon digester, the most successful of the big digesters built in Fiji, has been in operation without interruption since 1974, supplying gas to a family of sixteen for all their cooking needs. The digester has never been cleaned because the owner

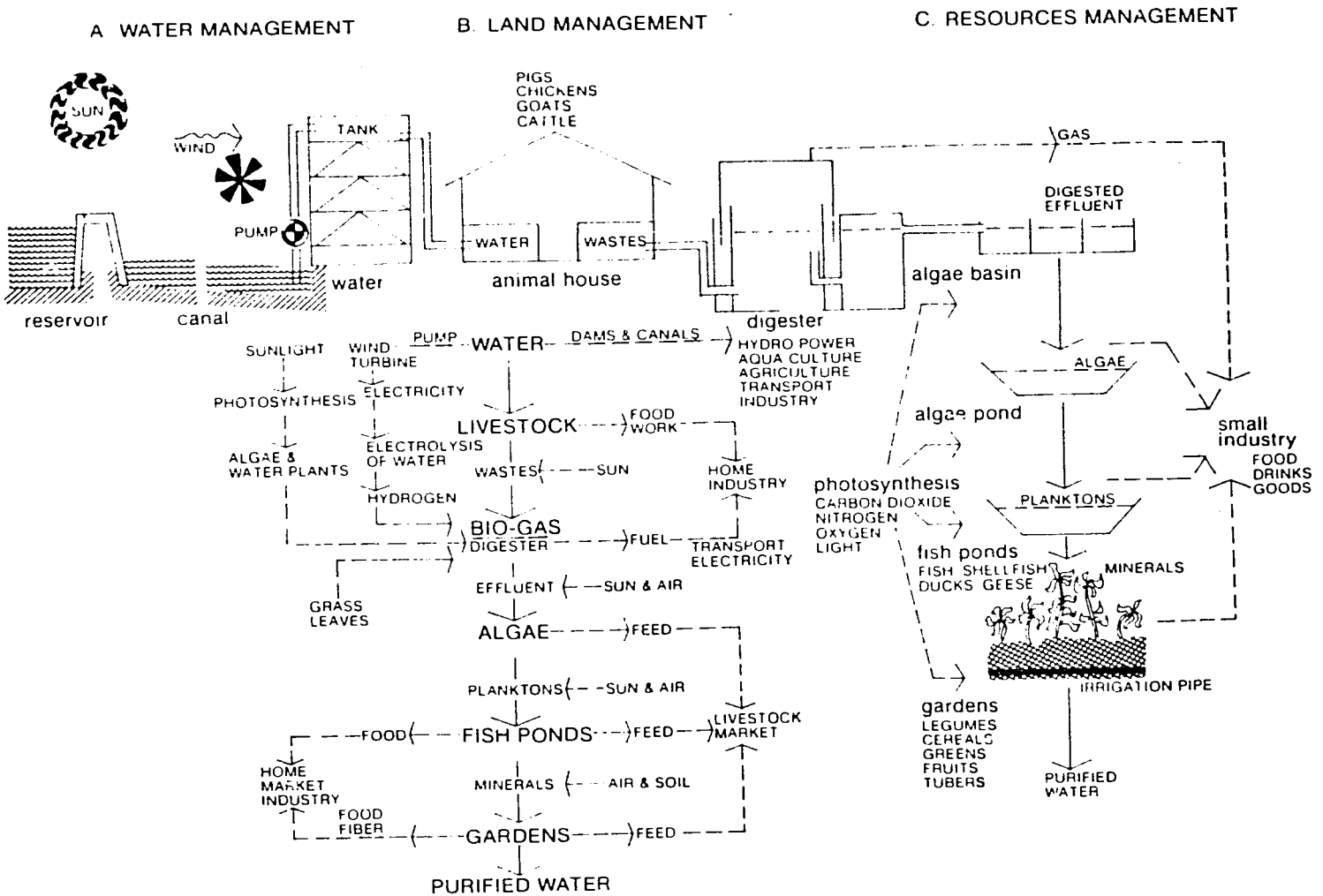

Fig. 2.2. The Integrated Farming System.

Source: George Chan and Balwant Saini, in Gwen Bell, ed., *Strategies for Human Settlements: Habitat and Environment* (Honolulu: University Press of Hawaii, 1976).

never had more than 100 pigs in the pen, the number for which the digester was designed. This digester has been filmed by the United Nations and was presented at the Habitat '76 Conference in Vancouver, Canada.

On the other hand, a similar digester built in 1975 for a Fijian high school had to be cleaned four times in a single year because 200 to 300 pigs were being used for a digester designed to accommodate 100. Other digester projects experienced similar problems when design specifications were not followed to the letter. The 4,000-gallon digester, designed for 400 pigs, had been overloaded with 1,000 pigs. In another project, the digester would not operate after it was built with a thicker steel plate on the gasholder than that originally specified.

Other problems encountered with various digester projects throughout the country often involved faulty implementation of a design and lack of experience in identifying and correcting simple functional problems as they arose. Algae harvesting was hampered in its development because of a reluctance on the part of some high-level government and university staff to accept an "Asian" development.

The high cost of the digester, a problem in Fiji, was also a problem in many other countries. The first breakthrough in this area came from Taiwan, where experimenters did away with the expensive steel gasholder and substituted a bag digester made of Neoprene rubber to store the gas above the digestion liquid. This inexpensive method combined the digestion chamber, settling tank, and gasholder into one unit (see Figure 2.3). The idea of using a rubber or plastic sheet as a gasholder had been tried before, but anchoring the sheet and making it leakproof was very difficult. This problem was solved by having a continuous sausage-like bag with the liquid at the bottom and the gas at the top. The bag digester worked very well, but it was difficult to repair any leak and was necessary to put rubber bands or a compressor over the bag to pressurize

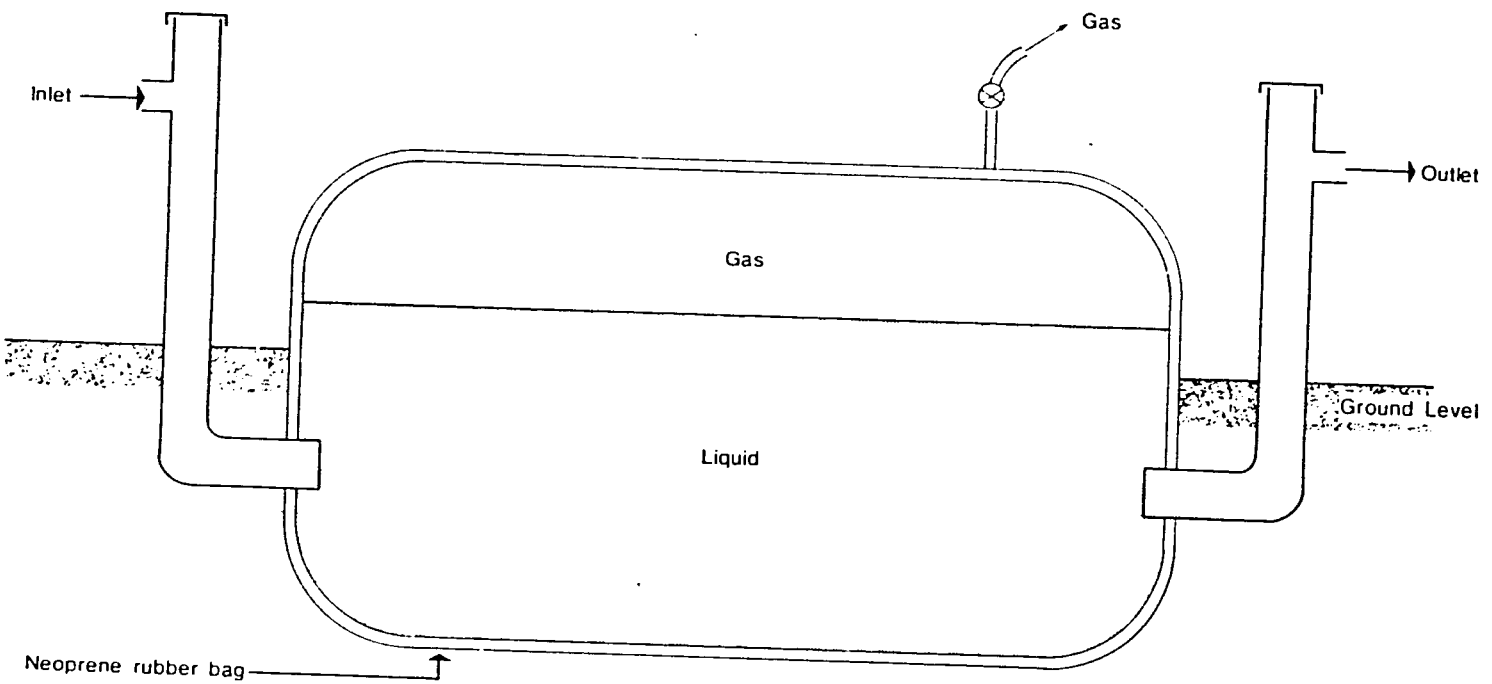

Figure 2.3. The 1,000-gallon bag digester.

Source: Dr. Chung Po, Joint Commission for Rural Reconstruction (JCRR), Taipei, Taiwan.

the gas. This problem was solved by a mainland Chinese innovation: The digester was lowered beneath the inlet and outlet so that the column of water in these two pipes was at a higher level than the liquid inside the digester and could therefore compress the gas inside the bag. This technique was subsequently adopted when the bag digester was replaced by an all-concrete one.

The author installed a Neoprene bag digester at a Fijian farm near Nasinu to test this water displacement method. He buried the bag digester enough to set the inlet and outlet at a slightly higher level than the bag, and made sure that the outlet was always filled with water to maintain pressure inside the bag.

The bag digester was later redesigned as a final product using reinforced concrete and is now called the all-concrete digester (see Figure 2.4). With no steel gasholder, it uses the water displacement method to pressurize the gas. Instead of the outlet shown in the drawing, a water basin is now built on top of the digester to make use of the concrete slab and to maintain the water level in the settling chamber, in order to keep the pressure fairly constant. Algae is also grown in this basin. One such digester was built by students at the Fiji College of Agriculture, but it was not completed by the time the author left.

Table 2.1 shows the comparative costs of different digester designs in Fiji.

Table 2.1

COMPARATIVE PRICES OF DIGESTER DESIGNS IN FIJI

Design and Capacity	Number of Pigs	Gas Production	Price
300 gallon capacity digester in concrete and steel	30	300 ft^3	$600 (1969)
1,000 gallon capacity digester in concrete and steel	100	1,000 ft^3	$2,000 (1971)
1,000 gallon capacity digester in Neoprene rubber	100	1,000 ft^3	$500 (1975)
1,000 gallon capacity digester all in concrete	100	1,000 ft^3	$1,500 (1978)

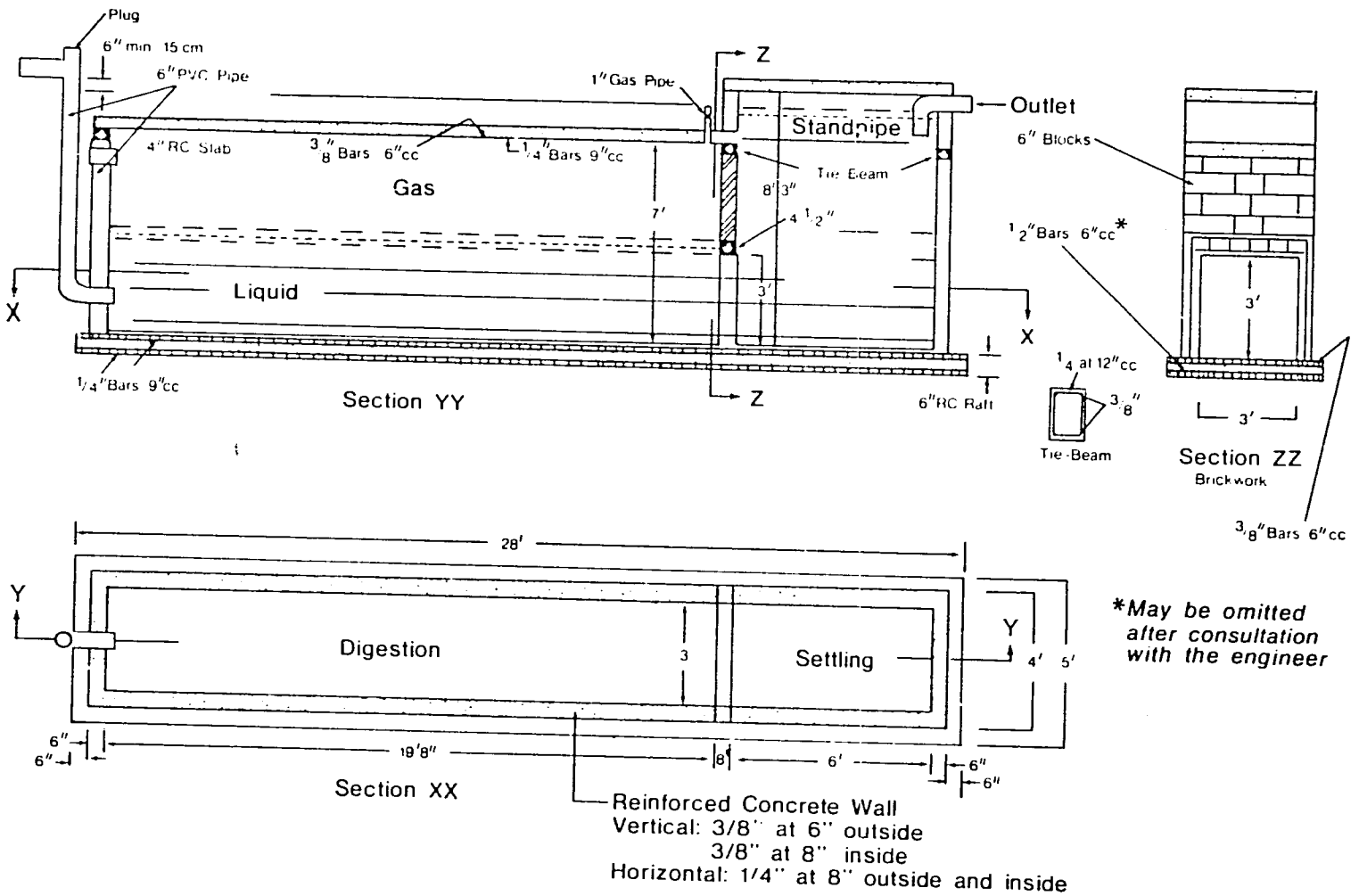

Figure 2.4. The 200 f^3 all-concrete digester.

Source: George Chan, South Pacific Commission, 1975.

It can be said that the integrated biogas system works when it has full backing from all parties involved--local farmers, agricultural officials, and government. The outlay involved in starting the digester projects was small and, unlike the norm for these situations, did not leave behind costly abandoned buildings and equipment. Equally important, digester projects can be revived with little extra investment.

CONCLUSIONS

Integrated Biogas Development in Other Pacific Islands

Work on the digester project did not proceed as smoothly in other Pacific Island settings as it did in Fiji. Many valuable lessons can be learned from the successes and failures of these projects.

When the Sawani digester became operational, the South Pacific Commission sent a circular to all countries and territories in the region describing the digester and its integration with aquaculture and agriculture, under the joint name of the Integrated Farming System or IFS (see Appendix II). Requests for technical assistance to build this system came from three islands.

On one island, a 300-gallon digester was built in two weeks at an agricultural station. The request had been tendered by the island's Financial Secretary, who saw the benefits this system offered for the economy of an isolated island. The project, however, met strong opposition from the Chief Agricultural Officer, who was certain that the digester would not work. Because of this internal resistance, the completed digester was subsequently abandoned.

On the second island, work on a 3[illegible]lon digester was started at an agricultural college while the author was [illegible]t. Because of a shortage of on-site materials--a common problem in these projects--it was not completed during the author's stay. The digester was finished by a worker who abandoned the original plan on the advice of others for a different inlet design. This new design was

made by an advisor inexperienced with digesters and placed the inlet lower than the outlet, resulting in constant inlet overflow and build-up of solids in the digestion chamber. As a result, the digester never became operational. Repairs and adjustments were not adequately made and subsequently, the principal of the college, despite the evidence of the Sawani project and the many functional digesters he had seen in India during his visit in 1975, did not want to invest further effort in the digester.

The third request for technical assistance came from Papua New Guinea. At this project, where the author spent three years, the digester was built at a public health demonstration center and had a capacity of 50 gallons. In this project the author had the full cooperation of the expatriate officer in charge of the center. With his help in overcoming bureaucratic resistance, the project was highly successful and gained a good deal of publicity.

Throughout the course of these projects, much resistance was offered about the capability of peasants to run aquaculture projects. Many Western advisors doubted the merit of what they considered Asian farming techniques, despite the evidence of success from countries such as China and India. The history of each digester project reveals the large role played by bureaucratic approval and the necessity to educate government officials and advisors as well as villagers themselves in the technology of the Integrated Farming System.

New Policy Issues

The thrust of the digester project in the 1970s was directed at improving sanitary conditions and public health. The benefits of proper waste disposal, though considered superfluous by most rural populations in the South Pacific, were a key to control of disease, with energy by-products as additional benefits.

In the 1980s, however, the digester has emerged as an energy priority which offers one of the few means of survival for most villages. As land becomes scarce and populations increase, it is no longer possible to continue slash and

burn methods of subsistence farming. It would be equally foolish to adopt open farming methods when the cost of fuel, feed, and fertilizer has become prohibitive. A viable alternative to these two methods is the Integrated Farming System (see Appendix II), in which all materials are recycled in a closed system to recover all resources. Pacific Island nations would be wise to direct their planning strategies toward greater utilization of wastes in rural areas as raw materials for the production of fuel, feed, and fertilizer in integrated farms.

APPENDIX I

JUSTIFICATION FOR INTEGRATED RURAL DEVELOPMENT IN THE PACIFIC ISLANDS

The Pacific Islanders have lived in organized village communities for centuries, with their traditional systems taking care of all their basic needs while they lived in harmony with nature. The impact of outside cultures has had many deleterious effects on these balanced societies and created social, environmental, and even economic problems that were recognized by the metropolitan countries administering the whole Pacific Island Region.

Among other resolutions, the South Seas Conference that created the South Pacific Commission in 1947 approved the following:

11. The Conference urges that the problem of health be regarded as having economic, cultural, and educational aspects, and that all these aspects be taken into consideration in any program for the improvement of health in the village.
12. The Conference emphasizes the importance of greater attention to preventive public health measures in villages rather than merely curative measures.
13. The Conference stresses the importance of education and propaganda for public health... The Conference recommends that films suitable for public health education be made available for distribution to the territories.
14. The Conference recognizes the important part played by women in the health of the village and the value of women's committees as a means of promoting knowledge on and practice of hygine.
15. The Conference asks the Commission to invite the Research Council to advise the Territorial Administrations on modern techniques for

the conversion of house and village refuse into compost for the enrichment of the soil.

16. The Conference brings to the notice of the Commission that in the low coral islands, further advice is needed in regard to protection of wells against pollution and the best types of latrines.

17. The Conference invites the Commission to arrange for an expert to study in the different territories the conditions that make our villages unhealthy and to demonstrate the means of making them healthy.

More than 30 years later, despite many rural projects that are mostly inappropriate even if they are aimed at improving the quality of life in villages and isolated islands, the same resolutions are still applicable. Many conditions are even worse because of increasing migration from rural to urban areas, deterioration of traditional values, the energy crisis, and disproportionate dependence on outside aid. In fact, most islands subsist on external charity when they possess abundant natural resources such as sun, sea, wind, wave, soil, coral, flora, and fauna. They also have the best conditions for photosynthesis and bacterial action, but very little has been done to improve productivity in livestock, aquaculture, agriculture, and agroindustry.

APPENDIX II

THE INTEGRATED FARMING SYSTEM (IFS)

The IFS is a concept which holds promise for the people of the South Pacific and those parts of the tropical world where there is plenty of water and solar energy--the nonpolluting sources of power for this technologically simple system. It is designed as an alternative to the highly technical systems which brought economic development to the industrialized countries.

The IFS approach is based on effective management of water and food systems and involves a complete recycling program. Using the sun as the only external energy source, the production of food, animal feed, and fertilizer is accomplished with minimal cost and without significant pollution.

Water Resources

A sound water management design is necessary to maximize the use of presently wasted water resources. Storage is vital for irrigation purposes and can be easily integrated with other beneficial uses, including aquaculture, recreation, transport, and hydroelectric power production.

A safe and adequate water supply to a village can be an economic proposition if it is kept simple and small, with water used not only for domestic purposes but also for farming, agriculture, and industry. Small stone and earth dams at suitable spots in creeks, even only 1 m high, can store enough water and give sufficient head to operate one or more hydraulic rams to pump water with water 24 hours a day without any fuel cost.

Local energy requirements can be met by using wooden water turbines to produce hydroelectric power from various dam overflows. Small windmills made of bamboo, wood, and some metal pieces can make use of free wind power to pump water from wells, to generate electricity, and to operate small machines.

At the regional or even the national level, streams and rivers can be connected by channels and artificial lakes to store and distribute water throughout the country for development purposes and, in some cases, transport as well.

Vast areas of land in the South Pacific are nonarable, either because the soil has been depleted of its fertility through monoculture and exclusive use of chemical fertilizer or because it is not properly irrigated, fertilized, and managed. Land management is most important; there should be terracing of sloping land to halt erosion, using draft animals and simple implements, proper drainage, and local materials such as stone and bamboo. Organic fertilizer, planting and rotation of crops, and biological control should be used as much as possible. Swamps should be deepened in areas and used as fish ponds instead of being filled or drained. The excavated earth can then be used to fill the remaining area for agriculture, farming, and small industries.

Farm Wastes

Anaerobic digestion of human, animal, and agricultural wastes can be used to produce methane gas for cooking, lighting, refrigeration, and other domestic and industrial purposes.

The animals should be housed in a building constructed of local materials except for the floor, which should be of concrete or fired brick to facilitate the washing of wastes from pigs, chickens, goats, or cattle into the digester. On the average, the wastes from a single pig produce 10 ft^3 of gas per day, but this can be increased with the addition of dried leaves or grass to boost the carbon/nitrogen ratio from 20-25 to 1 in the animal waste to the optimum ratio of about 35 to 1 for gas digestion.

Aquaculture

Algae, fish, and shellfish can be produced in swamps and ponds, as well as in a variety of makeshift containers--such as basins, old tires, and bamboo halves.

In addition to human consumption, the protein-rich products from aquaculture can be used as animal food, thereby increasing the production of eggs, milk, and meat. The partially treated effluent from the digester is oxidized in algae ponds or other shallow containers to complete the treatment. Through photosynthesis, free solar energy and carbon dioxide in the air are used to produce oxygen and stimulate the growth of natural algae for use as a high-protein feed for animals. The rate of growth is about 1 ounce (dry weight) per ft^2 (equivalent to over 400 tons per acre per year), with a protein content of 35 to 40 percent.

The Blue Revolution which is taking place in Asia, America, and Europe may be the answer to the ever-increasing demand for protein in human and animal diets. Shellfish such as prawns cultured in controlled ponds or oysters, clams, and mussels grown on rafts floating in ponds are marketable much earlier than those bred in the natural state, and they also produce incredible yields. For example, long-legged Malaysian prawns cultured in Hawaii yield biannual harvests of over 40,000 per acre, weighing over 2,000 lbs. This species is popular and widely distributed. Mussels cultured in Spain yield 700,000 lbs per acre annually, which is equivalent to 80,000 lbs of pure protein powder. By comparison, the best cattle in the South Pacific can only yield about 150 lbs of beef per acre per year.

Agriculture

Production of natural fertilizer through reclamation of minerals from the stabilized wastes can improve soil fertility and increase crop yields. Stabilized water from fish ponds overflows into gardens through subsoil bamboo or thin plastic pipes to convey both water and nutrients to the roots where they are needed.

The subsoil is fertilized every time the animal pens are washed--two or three times a day--with nutrients that are readily available to the plants because

of the complete oxidation of the organic matter in the waste into nitrate, sulphate, phosphate, and so on.

In this system, little spacing is required between plants which are fed regular "meals" daily. Rapid healthy growth ensues from seeds that are sown directly on the land without any transplanting or thinning of the seedlings.

There is no interference with the soil organisms that aerate or condition the soil for good agriculture, as no harmful chemical fertilizer is added to the soil. In addition, except for the top layer, there is no need to disturb the soil for a long period after the subsoil pipes have been laid. Thus, it is possible to plant continuously, intercropping between the plants as harvesting proceeds.

Rotation of crops is essential in this system so as not to deplete the soil of certain types of plant food. Making use of plant foods at different levels in the soil is also important, as well as allowing sufficient time for each level to recover.

Draft animals and small farming machines are used to increase production. One water buffalo and a man can plough and harrow 1 acre of land in less than a day; or a man and his hand-operated farm equipment can both level a paddy field and transplant rice seedlings over one acre in one day. Apart from intensifying existing local crops, the emphasis should be on growing vegetables to replace food imports such as rice, flour, sugar, and condiments; animal feed such as corn, sorghum, soybeans, and other legumes; and others such as potatoes, tomatoes, cabbage, carrots, celery, cucumber, and peas--many of which can also be processed to produce a whole range of consumer goods.

Nutrition

The scientific combination of cereals, legumes, and other dried or fresh vegetables with meat, poultry, or fish can produce balanced diets that are healthy

and economical. Proper cooking methods to preserve the nutritional value of foods and make them acceptable to the local people should be used. Perhaps the most important factor in the production of new foods, especially vegetables, is the method of cooking to make them tasty and attractive.

All the essential requirements of a balanced diet (protein, fats, carbohydrates, minerals, and vitamins) can be obtained from a combination of vegetables in their natural or sun-dried state that are properly cooked to preserve flavor and nutritional value. Some vegetables--bean sprouts, for example--contain all the nutritional essentials.

South Pacific villagers have not yet been taught how to preserve their own food without the potentially dangerous chemicals used in imported foods. Training is needed in the use of sun, salt, oil, spices, and wood smoke to preserve food and thus prevent waste--as well as reduce expensive processed food imports.

NOTES

For further reading on biogas digesters in Fiji and the Pacific, see:

George Chan and Balwant Singh Saini, "Integrated Farming System and Settlement Plan for Nissan Island, Papua New Guinea," in Gwen Bell, ed., Strategies for Human Settlements: Habitat and Environment (Honolulu: University Press of Hawaii, 1976).

George Chan, "Integrated Farming Project," proposal to the South Pacific Commission, 1976.

Suliana Siwatibau, A Survey of Domestic Rural Energy Use and Potential in Fiji (Suva, Fiji: University of the South Pacific, 1978).

United Nations Economic and Social Commission for Asia and the Pacific, "Workshop on Bio-Gas Technology and Utilization," October 13-18, 1975, Manila, Philippines.

United Nations Economic and Social Commission for Asia and the Pacific, "Workshop on Biogas and Other Rural Energy Resources," June 20-July 8, 1977, Suva, Fiji.

CASE 3

WOOD-TO-ETHANOL PILOT PLANT: NEW ZEALAND

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NOTE: This case is presently being reviewed by the New Zealand Forest Service for approval for publication purposes, and can only be used for internal purposes by RSI and AID/Washington at this time.

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APPROVAL OF THE CASE WITH SOME MODIFICATION IS EXPECTED BY EARLY NOVEMBER 1980

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PROJECT BACKGROUND

The land area of New Zealand is 27 million hectares divided almost equally between two islands, the North Island and the South Island (Figure 3.1). It lies between latitudes 34°S and 47°S and is approximately 2,000 km west of its nearest neighbor, Australia. New Zealand is isolated from the main shipping services, and vital raw materials, including oil, must travel thousands of kilometers to reach this South Pacific island nation. Strongly influenced by the ocean climate, the country is warm in the northern areas with more temperate conditions in the south. Rainfall varies over the country but falls most of the year, with dry spells usually occurring between January and March. The climate supports a major agricultural industry primarily based on pastoral farming, principally raising sheep for meat and wool, and cattle for the production of both dairy products and beef. Arable farming is undertaken to meet domestic grain demands, and orchards and horticulture produce a variety of products for both the domestic and export markets.

The population of New Zealand is just over 3 million, 70 percent of which live in the North Island. Outside the four main urban centers the population is distributed over smaller cities, towns, and communities close to the centers of agricultural and forest activities in the North and South Islands.

Although the country is in the process of industrialization, most industrial goods, either finished or for assembly, are still imported. Agricultural exports, meat, wool, and dairy products form the bulk of export revenue to finance imports. Industries have been established for further processing such basic commodities as wool for carpets, and wood chips and electricity for pulp and paper.

New Zealand is a relatively affluent nation, but its per capita income dropped from fourth place on a world scale in the early 1950s to about twenty-fifth by the late 1970s. Many reasons have been proposed to account for this

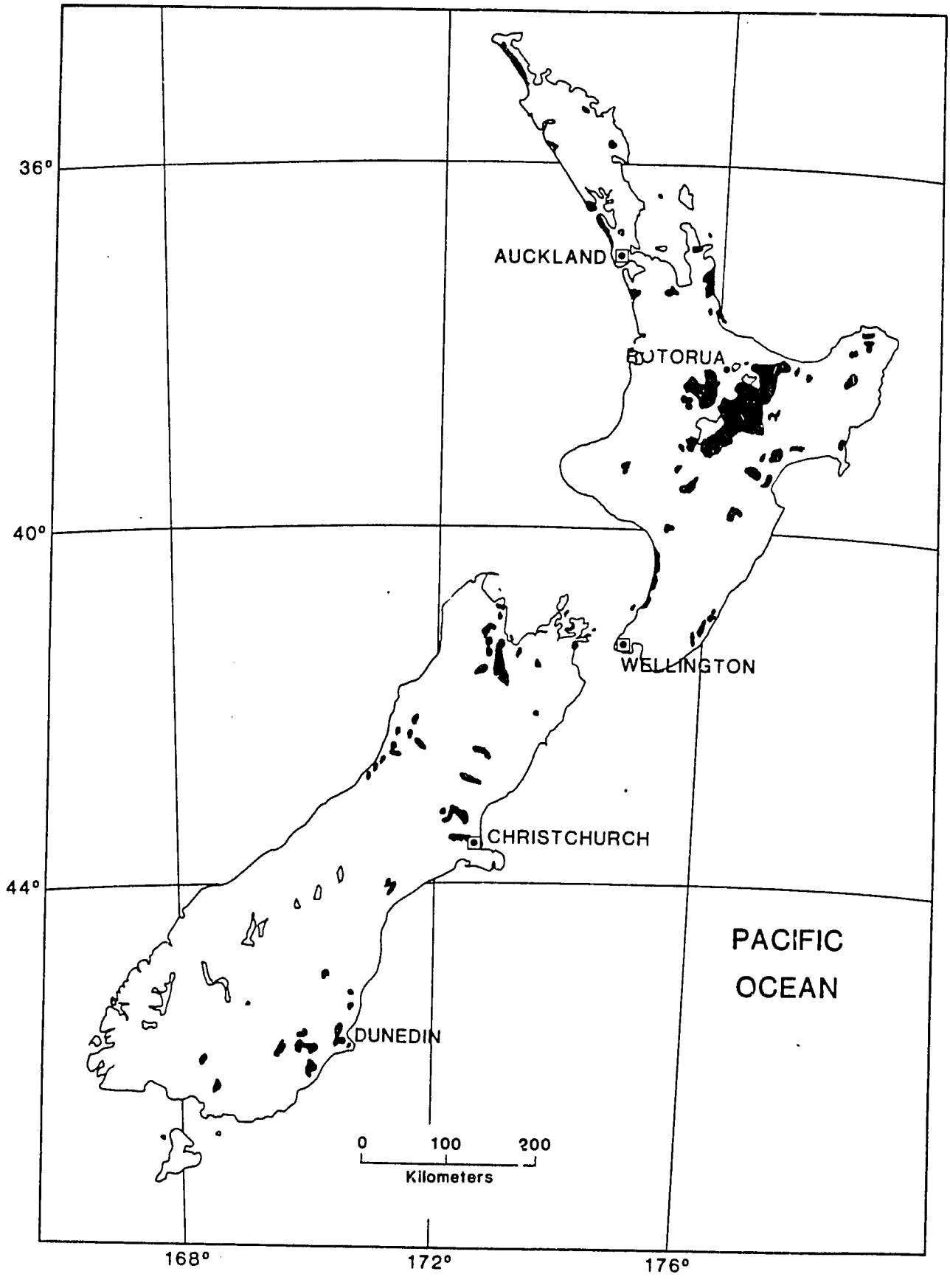


Figure 3.1. Map of New Zealand showing the main cities, Rotorua, and areas of exotic plantation forests.

reduction in relative affluence, including the restriction of mass production benefits by low population, distance from markets, the United Kingdom's entry into the European Economic Community with a consequent restriction of meat and dairy sales, and inefficient utilization of capital plant. Since 1973, increases in oil prices have been a major contributor to the country's economic problems, with an increasingly higher proportion of total exports going toward meeting the ever-rising costs of imported oil (see Table 3.1).

The Energy Scene

The real significance of the project to be described in this chapter--a wood-to-ethanol pilot plant--can only be appreciated if the energy scene within New Zealand is fully understood. The fact that an old technology was resurrected, improved, and thoroughly tested after it had been abandoned in the Western world thirty years earlier may seem a puzzle in itself. When the economic and strategic problems relating to the supply of transport fuel are studied, however, the reasons for wanting to develop an indigenous system for producing an oil substitute become apparent.

In the early days of New Zealand development, the principal energy source was wood from native forests. As the forests were cleared and steam-powered transport and industry were introduced, coal became the dominant fuel. By 1910, coal was the most important source of energy, and the next twenty years marked the era of "King Coal."

Signs of the future, however, were already evident by 1924, the earliest year for which comprehensive energy consumption data are available. Oil and hydroelectricity were contributing a small but rapidly growing proportion of the total energy supply. Table 3.1 summarizes subsequent developments, the most notable features being the stagnation of coal and the tremendous growth in oil, both of which had to be imported. The increase in electrical power from hydro and geothermal resources is also significant.

Table 3.1

PRIMARY ENERGY CONSUMPTION
in petajoules (PJ)

Calendar Year	Coal	Oil		Natural Gas	Hydro and Geothermal Electricity	Total[a]	Imported Oil
		Imported	Indigenous				
1924	75	10	-	-	0.5	86	11
1934	56	19	-	-	3	78	24
1944	72	30	-	-	7	109	28
1954	66	59	-	-	14	139	42
1964	66	103	-	-	34	203	51
1973	60	201	7	13	55	335	60
1974	62	193	8	14	55	332	58.1
1975	56	187	8	15	64	331	56.6
1976	59	184	22	40	60	365	50.5
1977 (Prov.)	52	168	31	64	57	372	45.2

[a] Totals may differ from the sum of individual figures because of rounding and stock changes.

Source: Ministry of Energy Resources, 1978.

Production from an onshore gas/condensate field at Kapuni altered the balance of fuel use in New Zealand during the last few years. This single energy source provided 25.5 percent of the country's total primary energy in 1977; Kapuni condensate also provided 15.5 percent of the country's oil requirements. Much of Kapuni's gas output now substitutes for imported oil, either directly or indirectly, by reducing the need for electricity and manufactured gas which might otherwise have been produced from oil. Kapuni condensate is characterized by a high wax content; consequently, its fuel oil is highly viscous and suitable mainly for power stations. With the declining use of heavy oil for electricity generation, however, not all of this is needed in New Zealand and the surplus is exported. Because the Kapuni field is a relatively small one, production will decline in the next few years.

In the 1960s, however, a large natural gas field--Maui--was discovered off the west coast of the North Island. This discovery has become the means by which New Zealand can face the energy future with some confidence. By 1979, a production platform and pipeline delivery to land were completed. The government of New Zealand has dominant influence over the use and future development of this gas field, and decisions will be made in accordance with overall government policies and priorities.

The intention in the early days of development had been to use the gas for electricity generation. In the late 1970s, however, after the realization that the new situation for the Middle East crude oil cost/supply was permanent, the government reconsidered the energy situation and established a Ministry of Energy to coordinate all energy departments, including the activities of the electricity, coal, and gas departments, and the supply and availability of oil products. Coordinated studies supported by this department clearly showed that high rainfall and mountainous topography meant hydroelectricity could provide the bulk of the country's electricity needs. Abundant natural gas and coal resources in

the North Island would also be used to supply power to industries. Exploration for coal in the South Island had revealed resources of lignite capable of sustaining the country for thousands of years. What had not been found in significant yields anywhere was oil.

With a small population extended across the country and an agricultural system relying on transport for raw materials and products, New Zealand has a very high per capita demand for transport fuel, exceeded only by the United States, Canada, and Australia (see Table 3.2). It was soon appreciated that the country's only energy problem was a supply, at reasonable cost, of liquid fuels for commercial and private vehicles. Eventually, this fact was generally recognized by members of government, industry, and the population at large.

Table 3.2

NEW ZEALAND ENERGY DATA

1978 Energy Consumption by Sector (PJ)[a]

	Solid	Oil	Gas	Electricity	Total
Industry	23.86	35.97	7.80	25.58	93.21
Transport	-	104.49	-	0.12	104.61
Domestic	5.84	1.98	2.43	29.93	40.18
Commercial	6.30	9.79	1.38	12.44	29.91
	36.00	152.23	11.61	68.07	267.91

Oil contributed 56.8% of total energy supply.

Transport consumed 39.0% of total energy demand and 68.6% of total oil consumption.

1978 Total Energy Resources and Production

	Proven (measured)	Probable (indicated)	Total (inferred)	Total	Annual Production
Fossil					
Coal	5,000	47,000	14,000	66,700	49.5
Oil	150	1,195	-	1,345	25.6
Gas	980	4,960	-	5,940	59.5
	6,270	52,360	14,000	73,290	134.7
Renewable					
Hydro	86	123	-	209	55.8
Geothermal	12	13	15	40	4.3
	98	136	15	249	60.1

[a] 1 PJ (Petajoule) = 10^{15} joules, 1,055 joules = 1 Btu

Forestry in New Zealand

The New Zealand Forest Service (NZFS) is a government department responsible for maintaining and supervising native forests and for establishing and maintaining exotic forests, now the main source of timber in New Zealand. It also supports the Forest Research Institute (FRI) to maintain and improve forestry resources, as well as to improve and develop methods for wood utilization.

The Forest Research Institute's main center is in Rotorua, a small city of around 50,000 people which is located toward the northern end of the central North Island. The city is a tourist center noted for geothermal activity and scenic lakes with trout fishing. It is also situated at the northern side of the Kaingaroa Forest a manmade forest stocked primarily with radiata pine, a tree originally from California (Monterey pine). With several sawmills in the city, it is also located between two major pulp and paper mill towns, Tokoroa and Kawerau. The nearest university is at Hamilton, approximately 100 km to the northwest, where agricultural research centers are also located. As the Hamilton (Waikato) University is small and new, there is in fact little interaction. Thus, although the Rotorua FRI was close to forest-growing and forest utilization centers, it was not influenced by neighboring academic or research establishments.

The Rotorua FRI is administered under three divisions--Production Forestry, Forest Sciences, and Forest Products. Each division has a director and approximately forty scientists. Around 400 persons are employed at the Rotorua FRI--scientists, technicians, and administrative and service staff.

The orientation of research work at the FRI is concerned with the cultivation of forests, the information being directly employed by the Forest Service but also available to other forestry managers. Research of the Forest Products

Division is mainly for the general benefit of the wood utilization and processing industries. Apart from two sawmills (one located in Rotorua near the FRI), the Forest Service is not directly involved in wood processing. The two sawmills, originally established to demonstrate the utilization of the exotic softwoods, are now run as conventional commercial operations.

Finance for the FRI could be considered to be partly covered by revenue gained by the Forest Service through sales of stumpage (standing trees) and export sales of logs and domestic sawn timber. There is, however, no direct correlation between the activity of the forest and wood-processing industries and the level of financial input to the FRI.

Scientific Research in New Zealand

Government departments are the most important centers of research activity in New Zealand.Largest is the Department of Scientific and Industrial Research (DSIR), with various divisions throughout the country covering basic to applied research activities. In conjunction with industry finance, it also supports industry-related centers, e.g., a Dairy Research Institute and a Meat Research Institute.

The Department of Agriculture and Fisheries supports research in a manner analogous to the Department of Forestry except that, in keeping with the greater national significance of agriculture, it is on a much larger scale. The major center for agricultural research is located at Hamilton, 100 km northwest of Rotorua. Research centers, however, are autonomous. With forestry, for example, ongoing research programs are monitored by advisory panels, with members drawn from major industrial companies and other government research centers.

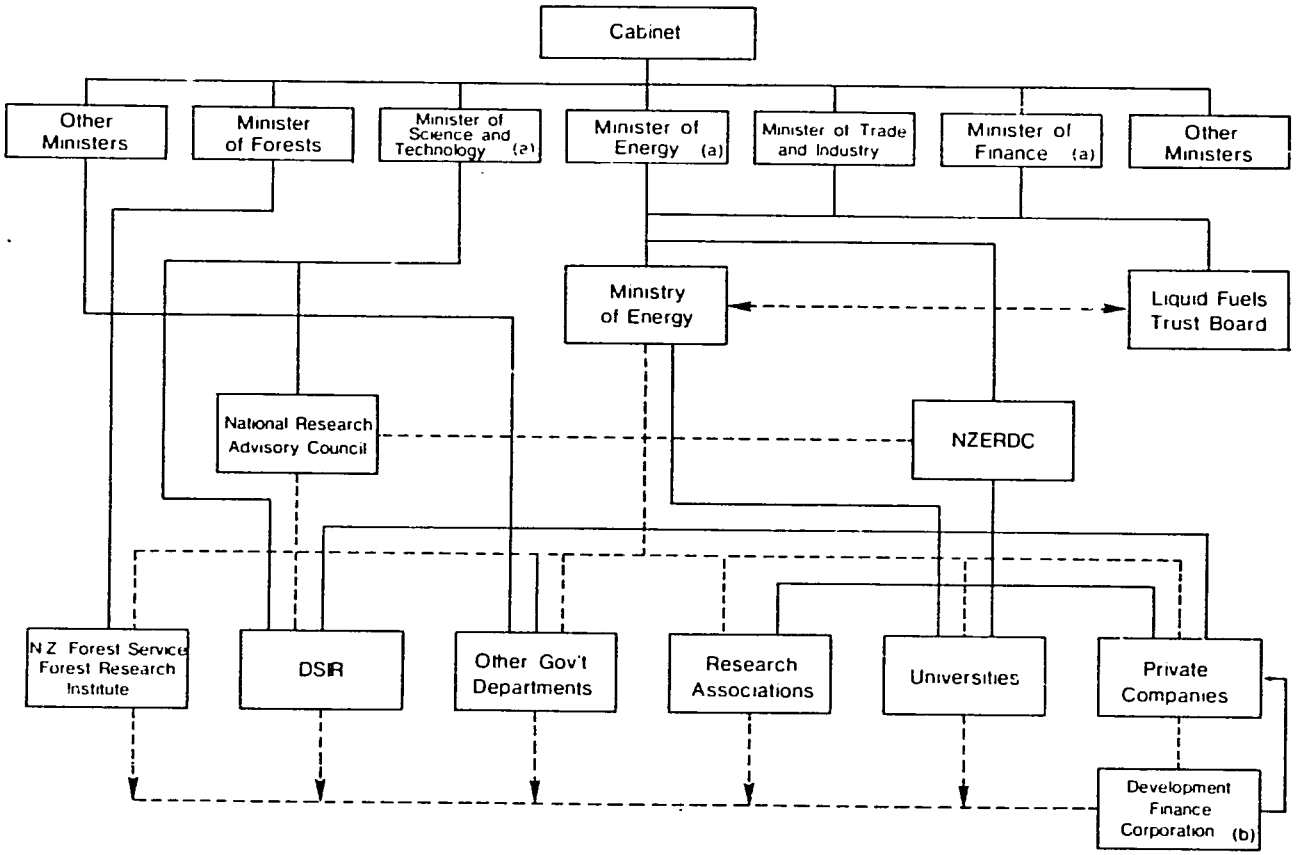
All research is overseen by the National Research Advisory Council (NRAC), which directs resources over the longer term to whatever objectives are considered desirable. Members of this council are drawn from university or retired

government and industrial scientists. New funding for staffing and capital equipment is tightly controlled: high-level approval is required for purchase of any major pieces of equpiment. Figure 3.2 summarizes the structure of New Zealand's research work in energy.

The universities, with high teaching loads for staff members and little emphasis on research, do not command the resources to engage in large-scale projects. Typically, research projects involve a university teacher and a student researcher; team efforts are the exception.

Thus, the work of the government research departments is generally closely related to the country's economic activity. Until 1973, energy research was concerned with the massive hydroelectric developments. The new Maui gas field was also originally destined for electricity generation. Coal, too, was a neglected area of research; most coal output was used for a thermal power station and the balance for industrial and domestic heating. Oil was the preferred heating fuel because of its convenient liquid form. Government and industry spending on research was, in fact, extremely low compared to that of many other countries.

There was thus effectively no research activity in the development of alternative liquid fuels. The New Zealand Energy Research and Development Committee (NZERDC) was established in 1973 under the chairmanship of Dr. Colin Maiden, Vice Chancellor of Auckland University. One of its objectives was the support of research and development of liquid fuels. NZERDC was created at the request of the Prime Minister from a joint venture in energy research between the United States and New Zealand, with New Zealand providing specialist knowledge in geothermal utilization. Its budget, however, was not large ($0.5 million per annum), nor was it able to direct funds to government laboratories which are, as indicated earlier, the country's major research centers. Funds were allocated for organizational maintenance, to sponsor university research and obtain



(a) The Minister of Energy and the Minister of Science and Technology are the same person. The Prime Minister is also the Minister of Finance.

(b) The Development Finance Corporation is a government-owned bank established to provide finance for projects of national benefit

Fig. 3.2. Government funded energy research and development in New Zealand.

consultants' reports, to perhaps provide a catalyst for energy research, and to bring out all interested persons and options. It did not engender any new technology or productive capacity for desired energy products.

The Liquid Fuels Trust Board, established in 1978 under the chairmanship of Dr. Colin Maiden, was provided with revenues of 0.1 cents/liter of fuel sold (i.e., around $3 million per annum). This body was charged with preparing recommendations for the future supply of liquid fuels. By 1979, it had submitted recommendations on the conversion of available natural gas to a liquid fuel, namely, a process route to methanol and thence conversion to gasoline via a process developed by the Mobil Oil Company. The method relied totally on overseas technology, the Mobil process being still unproven commercially. Although a blend of up to 15 percent methanol with gasoline appeared acceptable and government fleet testing with methanol blends was underway, there was no policy on the future use of alcohol fuels. There was, however, a government-stated commitment to be 50 percent self-sufficient in liquid fuels by 1987. Natural gas was expected to provide the basis of liquid fuel supply through the 1990s, with biomass and/or coal developing onwards.

Compressed natural gas (CNG) and liquified petroleum gas (LPG) were also encouraged as immediate substitutes for gasoline. Tax incentives were provided to companies converting vehicles to these fuels. Extensive conversion was, however, constrained by the high costs, limited supplies of LPG, and lack of sufficient refueling stations for CNG.

Apart from the CNG and LPG programs and studies and policy recommendations, there was still nothing in the way of financial commitments to the indigenous development of new liquid fuel resources from biomass or fossil fuels. Thus, by the end of the 1970s--six years after the initial realization of an energy problem--there was no national coordinated body actively developing new resources

such as biomass liquid fuels. Any work underway was the result of individual initiative within different research establishments, with--if additional funding were required--approval and support from the NRAC. There was no noticeable increase in staff or expenditure anywhere in tangible energy research (other than perhaps government policy or study groups).

PHASE 1: PLANNING, APPRAISAL, AND DESIGN

Identification and Formulation

The research program of the FRI Forest Products Division was reviewed every three years by the divisional director and the senior project leaders, at which time research topics were established, expanded, or discarded. The Forest Products Division was organized into sectors administered by senior project leaders (see Figure 3.3). These sections included wood chemistry, pulp and paper, wood preservation, wood quality, timber drying, adhesives and composite products, and timber engineering. The concept of employing a biochemist in the Wood Chemistry section was recognized in 1968, and a laboratory was in fact included in new buildings under construction at that time. But there was to be a delay of several years--until the 1974-1976 program--before the position could be defined.

For the 1974-1976 period, a project on the biochemical utilization of wood was established under Wood Chemistry, whose objective was to determine procedures for the production of useful chemicals from wood or its products through biological or biochemical methods. The project proposal implied, though it did not explicitly state, that the feedstock for such processing could be wood and forestry residues regarded as waste.

The project's work plan was to:

1. Assess and compare the yields of sugar obtainable by chemical and biochemical procedures.

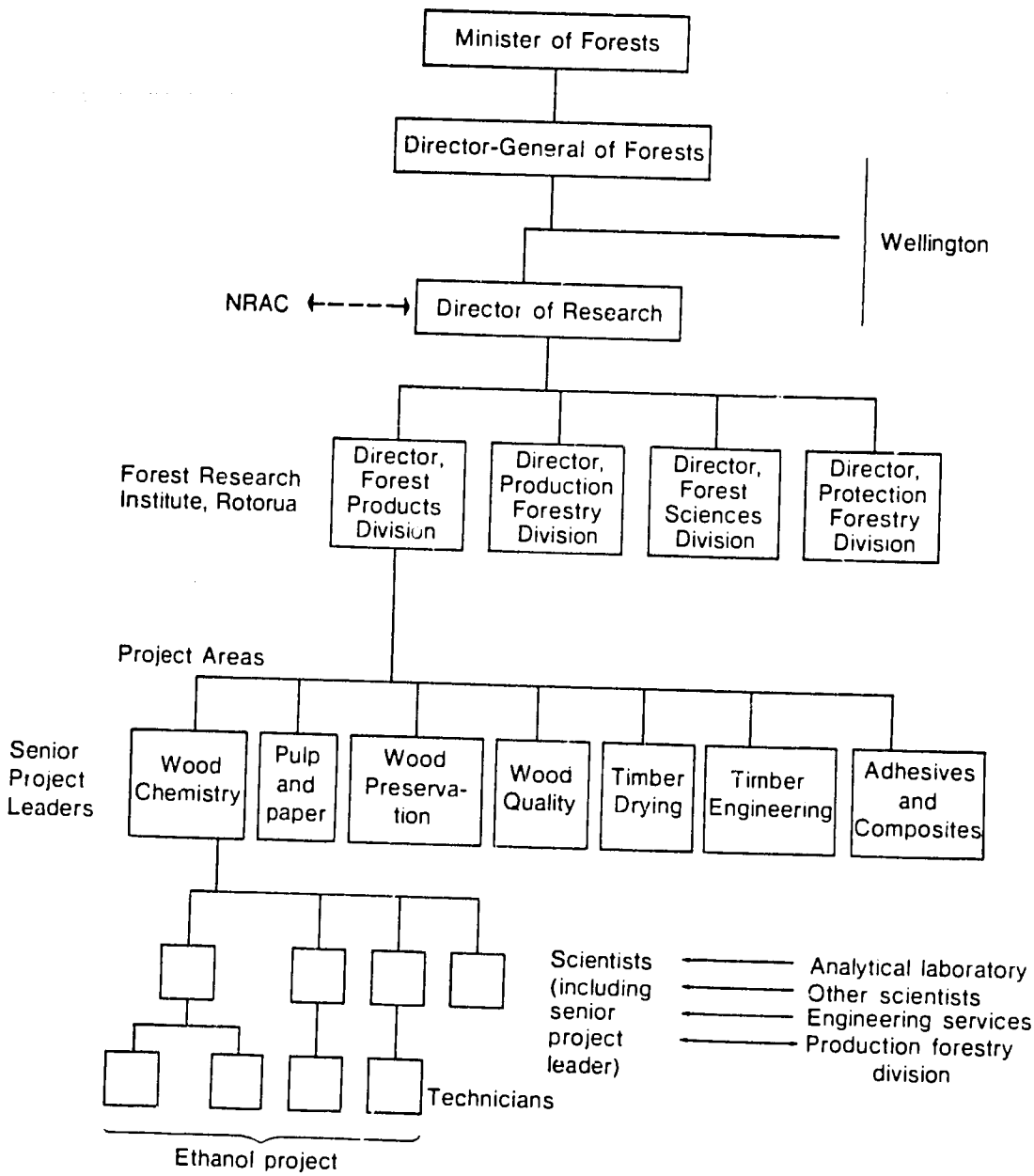


Fig. 3.3. The Forest Research Institute of the New Zealand Forest Service.

2. Determine biomass production using suitable micro-organisms on the substrates. wood sugars, or low molecular weight and water-soluble polysaccharides. Microbial pulping was to be a further area of inquiry.

A "Biochemist" position was established to activate this project topic, and the vacancy was advertised internationally. Related projects run by wood chemistry staff members were also underway in the meantime, including work on establishing industrial procedures for wood hydrolysis and assessing yields of hydrocarbons, or alcohols, obtainable from wood carbohydrates.

The successful applicant for the position took up the post in August 1975. He had degrees in biochemistry, biotechnology, and chemical engineering from universities in England and Canada. Subsequent work in a large Danish brewery further developed his experience in yeast and alcohol fermentations. Clearly, this background would influence his approach to the planned work program.

Forest Research Institute administrative organization. The formal organization structure shown in Figure 3.3 now demands our attention. Although the senior project leaders and divisional director were responsible for establishing project areas, the specific identification of projects (called "subprojects" and "work plans") was at the project leader or scientist level. Scientists were under the authority, or control, of a senior project leader according to research area. Although projects frequently involved more than one scientist of different seniority, the project leader was held to be responsible for overall progress.

The long-term nature of forestry work also tended to influence the establishment of any specific research activity, since extended time horizons had to be recognized. Topics were identified in work plan proposals. Subject to approval by the director, a formal work plan would be drawn up to describe in

some detail the proposed execution of the project. Completed work plans were reported in either laboratory or divisional reports, the latter available throughout the Forest Service and to outside organizations, the former on a more restricted basis. Work was also reported in outside publications, either in semitechnical or scientific journals. Reports of this nature went through an internal refereeing and editorial process.

Acquisition of new equipment and supplies for any project in the FRI was a long process. All items requested by project leaders had to be approved by senior project leaders and the divisional director, with low thresholds before requiring approval from the Director of Research and then the Director General of Forestry. Large equipment items, such as equipment grants greater than $100,000, required approval by other government departments. Acquisition of data-processing equipment was subject to approval by a separate government department. Most equipment for research was ultimately supplied from Europe or the United States. The FRI had its own purchasing office where small items could be purchased directly. Items of a significant sum were purchased through the NZFS Head Office Purchasing Section in Wellington, which also purchased items from overseas through embassies and high commissions. Except for replacement or extending items, a system of competitive tendering was routinely followed. New Zealand suppliers and agents had import licenses to cover some equipment, which could then be purchased directly.

With local equipment, ex-stock, a delivery time of not less than two to four weeks could be expected; for overseas equipment with a one- to three-month ordering time, a three- to six-month fabrication period, and a shipping time of three to four months, a total delivery time of eight to twelve months was normal.

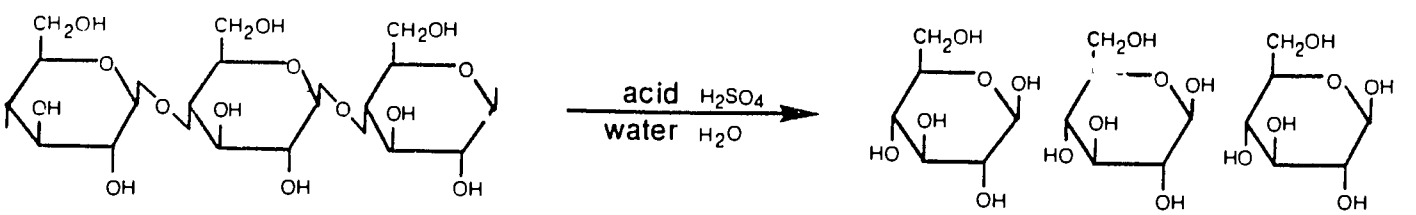
Budgets had to be drawn up approximately three months in advance for a fiscal year April to March, although approvals to order were frequently not received until August. Unless budgets were drawn up over several years, maintaining a definite expenditure in a fiscal period was not possible. In addition, there were intervals of months between items being received and coming to charge against a budget. Flexibility in budgetary control, however, ensured that projects were not held up for minor items; "horsetrading" was often practiced among research groups according to their needs. Project leaders, although advised of the budget allocation, were not kept informed of the subsequent cost of equipment or the expenditure time frame. With a clear definition of the program and budget requirements, however, the system was slow but did work. Problems were only experienced when a new project required funds in excess of the norm or when a new project had not appeared on the program.

The FRI also had a servicing branch essentially for maintenance of plant, buildings, and equipment. This branch was also responsible for construction of specialist equipment at a charge for materials only to the project. With constraints on government expenditure and growth, restrictions on service staff number limited their involvement in research projects. Outside engineering consultants and contractors were being used more frequently, with consequent charge for time and labor to any project.

Establishment of a laboratory and preliminary investigations. The project area was under the Wood Chemistry section, which was closely associated with the Pulp and Paper section by virtue of a common senior project leader. The interactive nature of these two topics meant that there was only a fine line of distinction between them, particularly in areas such as chemical pulping. Over the years, extensive studies on the carbohydrates of radiata pine and

various native hardwoods had been performed. For pulping purposes, radiata pine cellulose had also been extensively examined. Laboratory facilities were established and a competent and experienced staff resource built up. This infrastructure of laboratories and staff with knowledge of and the ability to analyze wood carbohydrates was to prove an essential ingredient to the development of the project. Thus, although the work program remained flexible, the underlying theme in the Wood Chemistry section was the preparation of chemicals from wood. One other project area under consideration was the production of charcoal and methanol through pyrolysis.

An experienced carbohydrate chemist in the Wood Chemistry section developed a simple procedure for hydrolyzing wood to sugars based on a technique used for wood analysis.



cellulose

sugars (glucose)

This procedure was adopted as a standard method for producing wood sugars suitable for fermentation. In the first few weeks, there was no firm commitment to any fermentation process. In the previous year, the newly formed NZERDC had sponsored universities and a research establishment to examine methods for producing ethanol from both wood and agricultural crops. It was felt, therefore, that fermentation products other than ethanol, such as higher-value organic acids, should be investigated.

During this time, however, a one-day conference was organized to review the prospects of energy farming for the production of useful fuels. The presentations included participants in the university projects which covered ethanol

production. The FRI Wood Chemistry senior project leader, an early proponent of the use of wood as a chemical and fuel resource, gave a presentation. This meeting was also attended by the scientist who had recently been appointed to lead the FRI's wood sugar fermentation program.

From this meeting it was realized that little was being done in a practical sense to investigate the production of ethanol from wood or even agricultural crops. Discussions between the senior project leader and the scientist, who had, in any case, a strong background in yeast and ethanol fermentations, determined that the production of ethanol from wood should be a topic for investigation at the FRI.

Although the scientist was experienced in yeast fermentation technology, he had had no previous exposure to the various aspects of wood relevant to its utilization as a source of fermentation sugar. He thus undertook an extensive examination of the available literature, which revealed a most interesting history described in detail by Egan Glesinger in 1949 and reviewed here.[1]

A history of wood sugar and its fermentation. The relationship between wood and sugar was discovered as far back as 1820. Sugar is a molecule of carbon units and six water units. Cellulose, the major component of wood, is composed of chains of sugar molecules each devoid of a water molecule. Adding a water molecule to each six-carbon unit in the cellulose--a process known as hydrolysis--converts it to sugar.

Although the generation of sugars as a by-product of the sulphite pulping process has been well known for many years (in Scandinavia, particularly, it is an important source for producing yeast and ethanol by fermentation), the specific hydrolysis of wood for sugar production has had its own history. The first wood sugar factory was built in Georgetown, South Carolina in 1910. Yields were low--only 80 liters per tonne of wood--and the factory was closed

and dismantled by 1918 when the log supply diminished. This operation, however, attracted interest in wartime Germany and Austria; in 1917, there were unsuccessful attempts to convert sawdust to alcohol.

Interest in the idea was maintained, however, particularly by military strategists. In 1926, Dr. Heinrich Scholler in Tornesch succeeded in extracting significantly higher yields of sugar from wood using hot dilute sulphuric acid. By 1928, the process was at the pilot plant stage, ready for commercial development. German strategists estimated 30 million m^3 of wood to be available annually for such a process. Scholler, reportedly an enthusiastic Nazi supporter, had to create interest in his process in competition with another Nazi, Professor Friedrich Bergius, noted for his work in coal hydrogeneration. He exploited an idea developed by a Swedish pulp chemist, Erik Haegglund, who had improved ethanol yields by up to four times the amount realized in the original Georgetown plant. Bergius established a company, encouraged the idea to become known as the Bergius Process, and attracted British and Dutch capital for experiments, pilot plants, and promotion expenses. The first full-size factory was built at Rheinau near Heidelburg. When in 1936 the foreign capitalists proved reluctant to reinvest further, the whole enterprise was taken over without compensation by the Nazi government.

The process promised high yields of pure sugars (60 percent of the wood), with a residual lignin suitable for further chemical processing. To achieve this, concentrated hydrochloric acid had to be used, with severe corrosion problems. Components had to be made of quartz and platinum, which dramatically raised costs. By 1939, technical problems still remained and the cost and yield figures were questionable.

Meanwhile, Heinrich Scholler had developed his process using a 1 percent sulphuric acid which could be tolerated by various materials. Yields as high

as 270 liters of ethanol per tonne of dry wood were reported--less than the 330 liters reported by Bergius but a remarkable advance over the Georgetown plant.

Prior to 1926, the hydrolysis processes were batch operations, and the conditions which promoted hydrolysis also caused the sugars formed to be destroyed. Scholler developed the process in such a way that by percolating the hydrolysis acid once through the wood, sugars were removed when formed. Once his preliminary experiments were completed, he contacted Richard Schaefer and his son Erwin, who were operating a fermentation plant at Tornesch near Hamburg. When further experiments, supported by Schaefer, were successful, an approach was made to the head of the German government alcohol monopoly. Impressed by his results, this government department gave its support to Scholler, and within two years a Scholler wood sugar factory went on stream in Tornesch. Yields surpassed expectations, with a minimum of 210 liters per tonne of dry wood. After allowances for costs and profits, the plant supplied the German government with ethanol at 7 cents per liter, compared to 15 cents--which was more than it was paying for alcohol from grain, sugar, and potatoes. Wood sugar thus became the cheapest source of ethanol. The Tornesch plant was small, with an annual output of 1.3 million liters, but it soon became well known. Two more plants were quickly established, each with a 4 million-liter capacity.

At this time, however, Bergius was presenting his proposals promising higher yields at lower costs. While the Scholler process was better established, Bergius had better connections, including a personage named Von Monroy who had been entrusted by Goering to blueprint a huge industrial wood program. To play safe, both processes were backed by a four-year plan which proposed ten Scholler and ten Bergius plants with a total capacity of 200 million liters

annually. The Japanese were also aware of the developing technology, but trusted the Scholler process and commissioned him to build their first factories.

Thus, wood hydrolysis for ethanol production was a well-established part of the Axis economies before the beginning of World War II. (It is intriguing to note that in the later war years, ethanol was the fuel used in Germany's V-2 rockets.) Wood sugar had become a political project. Scholler pointed out to the authorities the absence of Aryan blood in Erwin Schaefer's grandparents. On the night of November 10, 1938, after receiving an advance royalty of $200,000 from the Japanese government, Erwin Schaefer was picked up by the Gestapo and sent to a concentration camp. He was released only after donating everything he owned to the Nazi party and the government. In 1939, he arrived, destitute, in the United States.

Some years previously, Schaefer had had contact with the Dow Chemical Corporation of Midland, Michigan, which had built a pilot plant based on the Tornesch process at Marquette, Michigan. This plant, though highly successful, was abandoned because the process was not compatible with the company's planning.

After the United States entered World War II, Schaefer again promoted his concepts. Established interests were against it, however, and it was only through the efforts of O.J. Borkin of the Antitrust Division and J.A. Hall, principal biochemist of the U.S. Forest Service, that by 1943, the Office of Production Research and Development instructed the U.S. Forest Service to reexamine the Marquette plant. Investigations demonstrated ethanol yields of 270 liters per tonne of wood in reaction times of 5 hours, compared to 15 hours for the original Scholler process.

Late in 1943, a group of sawmills in Eugene, Oregon applied for funds and permission to construct an ethanol-from-wood plant. This permission was given, but a succession of problems traced back to established oil and alcohol interests

delayed construction. Senator Harry Truman was enlisted to overcome these problems, and construction eventually commenced in mid-1944. But by mid-1945 the war was over and government support for the Eugene plant was cancelled before proper operation could begin. With a capacity of 15 million liters annually, it was the world's largest and most efficient ethanol-from-wood plant.

While the Eugene plant and commercial production of ethanol from wood was thwarted in the United States, scientists at the U.S. Forest Products Laboratory and the Tennessee Valley Authority performed detailed laboratory and pilot scale investigations through to the early 1950s. This information, published and readily available, had been unequaled for its excellence and comprehensiveness. It provided the basis for the New Zealand Forest Service investigations, which could not have been conceived without this knowledge.

While the progress in Western countries is well documented, published information from the U.S.S.R. indicates that in 1936 the first wood sugar plant was commissioned in Leningrad. Although information is fragmented, over the years at least forty plants have become operational, consuming on an annual basis over 7 million m^3 of wood. Ethanol and yeast are but two of the products of this wood chemical industry. The process used was that first developed at Marquette and investigated by the U.S. Forest Service and then reevaluated by the New Zealand Forest Service.

Formulation of plans. Extensive review of the published information on the process clearly indicated that producing ethanol from wood did not pose any major technical problems, provided the proven route of hydrolyzing wood with hot dilute sulphuric acid was followed. In New Zealand, a well-established phosphate fertilizer industry existed for the rye grass and clover pastoral farming regime. Sulphuric acid was manufactured extensively for the production of this fertilizer; the other ingredients for the process--lime and water-- were

also readily available. There was also a major source of wood in the Kaingaroa Forest, located over a geothermal field with a several thousand megawatt potential. This field could provide abundant hot water for hydrolysis and steam for ethanol distillation.

With the raw materials for production confirmed, the question of a market for the product--ethanol--was raised. The New Zealand population was small. It was, however, very dependent on motor transport and imported oil for fuel, with a gasoline market in excess of 2,000 million liters annually. Ten percent of this market could be substituted by converting most of the existing forest and sawmill residues to ethanol and blending this product with gasoline. Twenty-five to 50 percent of this market could be met by projected future supplies of forestry residues. Literature studies had shown it was not the technology that had delayed or inhibited the establishment of ethanol-from-wood industries, but implementation with existing economic and political environments. It was thus realized early on that although the process was well documented and proven, practical handling and operating data could not be gained from the literature, and extensive and expensive investigations would have to be made. The necessary financial and staff support for such studies could only be realized by presenting the values of the process in the most convincing form. In the mid-1970s, future secure supplies of motor fuel were of general major concern and the concept of producing this fuel from wasted forest resources was justifiably attractive.

The prospects for producing liquid fuels from wood were proposed in New Zealand Forest Service reports in 1975 and presented in a New Zealand Energy publication in 1976.[2]

Parallel Events 1974-1976

Events in the Middle East during October 1973 and the subsequent fourfold increase in crude oil prices and related energy costs affected New Zealand, with its dependence on imported transport fuels. In April 1974, as mentioned earlier,

the government of the day established the New Zealand Energy Research and Development Committee. The purpose of this body was to coordinate and encourage research and to provide government funding for nongovernment research.

In 1974, the first New Zealand Energy Conference[3] was held at the University of Auckland, followed by a second in 1975 in Christchurch. During the same year, students in an interdisciplinary systems engineering course at Stanford University, California, produced a report entitled "Beyond Petroleum, A cost benefit and implementation comparison of alternative non-petroleum energy chains."[4] A scientist from the DSIR who was on an extended visit at Stanford returned with this report, which showed a promising future for biomass-produced fuels. In response, a one-day conference on the potential for energy farming in New Zealand was held in November 1975 at the DSIR in Wellington.[5] It was well attended, with participation from the FRI senior project leader administering the Wood Chemistry section; the recently appointed scientist for the wood hydrolysis project also attended. Papers presented covered the production of ethanol from wood and the production of methanol from wood via a gasification process. The meeting ended in general enthusiasm for the clear potential for energy farming in New Zealand.

In other countries the concept of producing useful fuels from biomass was also being examined. In the United States, Raphael Katzen and Associates produced a report in 1975 under a U.S. Forest Service commission on the production of fuels and chemicals from wood.[6] In the same year, the Australian CSIRO produced a report, "The Production of Solar Energy from Australian Forests"[7]; the Pulp and Paper Research Institute of Montreal, Canada published a "Feasibility study of production of chemical feedstock from wood waste"[8]; and the Canadian Forestry Service brought out a report entitled "A look at the economic feasibility of converting wood into liquid fuel."[9]

While reports and studies were being published by various government agencies, the state of Nebraska in the United States was considering the introduction of gasohol (a 10 percent ethanol/90 percent gasoline blend), while Brazil was increasing its ongoing commitment to utilize more ethanol from sugarcane as a gasoline substitute.

In New Zealand, research grants were given to universities to investigate ethanol production from wood and agricultural crops. Regular meetings between interested parties, including the FRI, were organized by the NZERDC to review progress on the production of automotive biomass fuels. While biomass fuel options were attracting interest, the Maui natural gas field mentioned earlier was being opened up on the west coast of the North Island. Before 1973, it was intended to use the gas for power generation, but the revised energy pricing structure clearly indicated the benefit of alternative uses. In 1974, a group drawn from various government departments was commissioned to examine those options. In June 1976, a background report on petrochemical development in New Zealand was published. One of the options discussed was the production of methanol with a potential application for fuel use.

At every meeting, the FRI's work on wood hydrolysis, carbohydrate, and ethanol production at the small-scale level was discussed. The scientists concerned realized that the FRI work required expansion. The senior project leader therefore prepared a proposal for a wood hydrolysis pilot plant to be financed by the NZERDC. Plant specifications were determined from discussions with the scientist engaged in the project. The proposal did, however, include information on the existing laboratory and research infrastructure and expertise.

Due to administrative changes, the NZERDC, which had previously channelled funds to government establishments, was restricted to financing university and private organizations. The proposal, however, came to the attention of the

NRAC, in particular its Energy and Environmental Committee, which had some interchange with NZERDC committees. Eventually (within ten months), the proposal bore fruit.

Feasibility and Appraisal

Having identified the project and general problems, it was now necessary to determine whether the detailed investigation thought necessary was in fact possible.

The process involved five distinct stages: (1) hydrolysis to break down the polymeric carbohydrates in wood to soluble hexose and pentose sugars, together with neutralization and treatment to remove the acid and any other undesirable components from the resulting liquor; (2) fermenting the hexose sugars (in a softwood, about 85 percent of the total sugars produced; in a hardwood, about 70 percent of the total) to ethanol; (3) recovering and concentrating the ethanol by distillation; (4) processing the residual liquor from the still containing the pentose sugars, production of yeast being a potentially suitable process; and (5) effluent processing to render the liquor suitable for discharge or reuse.

The main differences in using wood as the feedstock, compared to an agricultural crop of sugar or starch, are the more complicated first-stage hydrolysis for sugar recovery, the more dilute nature of wood sugar liquors, and the presence of pentose sugars. Although these factors could be considered disadvantages if compared to an agricultural crop, wood is nonseasonal and can be stored for long periods without any losses in sugar content.

1. Hydrolysis. Hydrolysis is a process of introducing water to a molecule with the effect of breaking down the molecule into smaller components. Starch and cellulose are large molecules, comprising chains of distinct glucose sugar molecules. Hydrolysis breaks down the chain and releases separate glucose molecules.

Hydrolysis of starch can be achieved by the use of catalysts such as enzymes or dilute acids. Cellulose, however, is a more stable polymer and requires more rigorous hydrolysis conditions. Enzymes have not been demonstrated to be commercially successful. Acids can be used either cold and concentrated or dilute and hot. The basic problem with using hot dilute acids is that the conditions (termperature and acid concentration) which promote cellulose breakdown also promote degradation of the glucose formed. It was not until the development of a percolation reactor system by Scholler, in which hydrolyzing liquor is passed once through a stationary bed of cellulose material, that high levels of sugar recovery could be achieved--on the order of 70 to 75 percent of the total potential (the potential being about 75 percent of the wood input).

The hydrolysis process is further complicated by the fact that the carbohydrate in wood is not pure cellulose; it also contains hemicelluloses, polymers containing hexoses (glucose, galactose, and mannose), and pentoses (xylose and arabinose). While the cellulose can be hydrolyzed at a temperature of around 180°C (in the presence of 0.5 percent sulphuric acid), hemicelluloses are hydrolyzed at lower temperatures--140 to 150°C, and exposure of the free sugars other than glucose at temperatures around 180°C results in their rapid degradation. Hydrolysis processing thus has to be accomplished in two stages: the first at low temperature and the second at higher temperature, reaching 180 to 190°C. After cooling, however, the high-temperature liquors can be used for low-temperature hydrolysis.

After hydrolysis, the liquors are neutralized with lime to remove the sulphuric acid catalyst and some of the degradation products that are acidic and then cooled for fermentation. Flash cooling is employed to avoid the build-up of tars (resulting from the degradation products) on the heat exchange surfaces. The flash vapors contain most of the volatile decomposition products.

2. Ethanol Fermentation. The liquors from the hydrolysis process contain degradation products, a complex mixture from the carbohydrate and lignin components of the wood with the clear potential to inhibit yeast activity. Using high concentrations of yeast or pretreating the liquors with reducing agents, active fermenting yeasts can rapidly convert the hexose sugars to ethanol.

$$\underset{\text{hexose sugar}}{C_6H_{12}O_6} \longrightarrow \underset{\text{ethanol}}{2C_2H_5OH} + \underset{\text{carbon dioxide}}{2CO_2}$$

Side reactions also occur.

Fermentation of 1 kg of hexose sugar results in the release of 600 J of heat in the production of: 0.48 kg alcohol, 0.47 kg carbon dioxide, and 0.05 kg other products (glycerol, succinic acid, and cellulose). Effectively, a theoretical ethanol yield of 51 percent based on sugar fermented is possible, but production of by-products reduces this to around 95 percent of the theoretical maximum.

The concentration of hexose sugars in wood hydrolysate liquors is very low, around 4.5 percent; the release of heat--0.6 MJ/kg of sugar fermented--has minimum effect on the temperature of fermentation liquor, which should be maintained in a range of 30 to 35°C. Thus, simple tanks can be used for fermentation. As high yeast concentrations are preferred, both to minimize fermentation times and to overcome inhibiting effects of the fermentation liquor, yeast recovery via centrifuges is a necessary processing step. Although the inhibitory compounds in wood hydrolysates cause problems in ethanol fermentation, they do effectively inhibit fermentation by contaminating micro-organisms.

3. Distillation. Ethanol produced by fermentation has to be separated from the water. The established method of achieving this is to rely on the difference in volatility of ethanol and water. By application of heat (steam

at 120°C or above), successive vaporization and condensation of a dilute ethanol liquor can result in enrichment of the ethanol until it is about 95 percent (volume basis) concentration. Removal of the remaining water--dehydration--requires an additional processing step. This can be simple treatment with hydrophilic agents such as calcium oxide or distillation with a third component.

Distillation, like ethanol fermentation, is a well-established process technology; several potential suppliers can furnish equipment. Most of the market, however, is concerned with the distillation of liquor with a much higher ethanol concentration (6 to 12 percent v/v) than found in fermented wood sugar liquors (not more than 2.5 percent v/v). This difference in feedstock concentration was not believed to be a problem, as the early published reports had not made special note of it and detailed specifications of distillation conditions had in fact been reported.

4. Secondary Fermentation. The residual liquor from the distillation column contains the unfermented pentose sugars and soluble degradation products. With softwoods, the concentration of the pentose sugars, being 15 percent of the total sugars produced, is about 1 percent. With a hardwood feedstock, this is about 2 percent. With softwoods one can consider discarding the pentose sugars, but with hardwoods, this approach appears exceedingly wasteful. Soluble sugars in the effluent would contribute to a very high oxygen demand reading which could cause problems for direct discharge into a waterway. There was thus every reason to consider utilizing the pentose fraction.

One product that can be made from wood sugars (and is extensively produced in the U.S.S.R.) is yeast. It can be used as a food-grade product, commanding a high value, or as a desirable high-protein animal feed supplement. The technology for producing yeast is more complicated than ethanol fermentation, in

that air, organic nitrogen, phosphate, and various inorganic inputs are also required. The air supply is particularly important, dictating specially designed fermentors and a substantial electrical power input. Only certain species of yeasts can be produced on the pentose sugar mixture, and yeast color, taste, and the presence of wood decomposition products have to be taken into account.

5. Effluent Treatment. The degradation products from the hydrolysis process are mixtures of carbohydrate degradation products, furfural, levulinic and formic acid, and combination products from the lignin fraction called "humic" substances, about half of which are completely soluble, with the remainder forming tarlike materials removable by filtration or settling processes. From a given input of wood, about 50 percent is recovered as sugars, 30 percent remains solid, and 20 percent results as soluble and insoluble degradation products. Most of the insoluble degradation product fraction is separated at the neutralization stage when a chalk (calcium carbonate) or lime (calcium hydroxide) suspension is added and the resulting gypsum (calcium sulphate) is filtered off, leaving only the soluble degradation products.

For the percolation process to work, the volume of process water has to be several times that of the wood--approximately tenfold. Consequently, the concentration of sugars and thus ethanol is low, not more than 2.5 to 3 percent by volume. For every liter of ethanol there will be 40 liters of effluent. Although it is not toxic or dangerous, this effluent poses a volume-handling problem in itself.

Process summary. Information on the process was detailed; it had been operated extensively on a production scale in the past and was operational on a production scale in the U.S.S.R. There was no apparent complexity in the process that would cause difficulty with implementation and operation in New Zealand. Technical advances in computers and construction materials achieved over a thirty-year period and information on the U.S. processes offered potential improvements to the technology.

An adapted laboratory hydrolysis procedure using locally available woods had produced sugars which were routinely fermented. The step from laboratory processing to a production plant is considerable, however, and only rarely can it be achieved in a single stage.

Need for a pilot plant. Although the published literature clearly showed that the process worked, what was fundamentally important were the actual costs involved in producing ethanol from wood. The last plant constructed outside the U.S.S.R. was in Oregon in 1943-1944. Working drawings for the plant were not available, nor was anyone with firsthand operational experience to comment on the performance characteristics of such a plant. Cost information from published literature was taken and adjusted for inflation and scaling. This demonstrated that with known costs, the process was clearly potentially viable.

To translate a potentially viable process based on thirty- to forty-year old data to a factual base on which to invest millions of dollars for a production-scale facility requires the intermediate stage of a pilot plant, especially when the following conditions exist:

1. The main feedstock is wood, a solid with well-known handling problems.
2. Biological transformations that are difficult to predict accurately are being performed.
3. The production process cannot be simulated exactly in the laboratory.
4. No one with operational experience of the process is available.
5. No working drawings of the previously established processes are available.
6. New equipment and technology, particularly in cheaper corrosion resistant materials (e.g., fluoropolymers) are available.

An established and operational pilot plant would provide staff with the practical experience necessary to design a production-scale process and would thereby, for a start, allow accurate determination of costs. Costings would

be required for capital sums, together with anticipated depreciation and maintenance for the various items of process equipment. With additional inputs of variables--costs of wood and other raw materials and utilities, costs of labor and capital--the actual costs of producing ethanol could be accurately assessed. If these assessments proved to be attractive, a production-scale facility could be designed and built with the information and experience derived from the pilot plant.

Moreover, long-term research and development to explore changes in process variables is not possible in a plant with a production schedule to meet. In contrast, there is no loss of income if a pilot plant is nonoperational for an extended period. Thus, even if a production-scale plant were established shortly afterwards, a pilot plant would still be desirable for process development and modifications.

Last but not least, a pilot plant would provide tangible evidence of the process to senior decision makers.

Design

The November 1975 Energy Farming Symposium held by the DSIR, in which the concept of producing fuels from biomass was brought to life, was also attended by representatives from industry, including one of the two major forest processing industries--Tasman Pulp & Paper, located at Kawerau, a mill town 60 km east of Rotorua. In 1976, an expatriate New Zealand engineer returning from North America took up a managerial engineering post at Tasman. He quickly became concerned about the New Zealand situation and realized the potential role that forest biomass could play in producing useful fuels.

The DSIR was developing a project to gasify wood for production of methanol with the support of the scientist who had organized the Energy Farming Symposium, and soon made contact with Tasman Pulp & Paper. A continuing contact existed between the FRI and Tasman through pulp and paper research group activities.

Through 1976, the FRI scientist investigating the hydrolysis route to convert wood into a liquid fuel was reviewing the literature, performing laboratory experiments, and appraising the feasibility of the total process. In July of that year, he presented a paper on the process to a well-attended joint meeting of the New Zealand Institute of Chemistry and Australasian Pulp and Paper Institute in Auckland. The general impression generated by this meeting was that the FRI was promoting the hydrolysis of wood to ethanol and the DSIR was promoting gasification of wood to methanol.

At the instigation of the senior engineer from Tasman and the director of the Forest Product Division, a meeting was held in mid-1976 with representatives from Tasman, the methanol proponents from DSIR, and the ethanol people from FRI. It was believed that Tasman, a company with nine-figure assets, might become financially involved in a development project of either process, thus rapidly accelerating the laboratory studies then being pursued slowly on a minimal budget. A subsequent meeting was arranged to compare the two processes in more detail and possibly to assess prospects for support.

At the next meeting in November 1977, the FRI scientist prepared a detailed report with a process flow sheet, fundamental heat and mass balances, and budget estimates of all costs involved for establishing two sizes of a pilot plant for a wood-to-ethanol process. The small size was purely investigational, with a nominal output of 50 liters per day and a capital cost of about $100,000. The larger plant would have a useful ethanol output of around 5,000 liters per day and cost about $1 million.

The DSIR participants in the second meeting had not prepared any calculated assessment of a pilot plant to produce methanol from wood. There was no basis on which to compare the two processes, and thus the meeting achieved little. No subsequent interest in development work was demonstrated by Tasman, which at the time was undergoing problems in industrial relations, cash flow, and profitability.

A manager from Tasman responsible for wood procurement who attended the meeting did, however, produce cost figures for the collection and assembly of forest waste, the first research figures ever made available on this aspect.

In the following month, a former director general of the Forest Service and a member at that time of the Energy Group of the NRAC, visited the FRI for discussion on the potential of producing liquid fuels from forest biomass. He had already seen the proposal submitted by the senior project leader to the NZERDC. When the report on pilot plants for the hydrolysis process for ethanol production was presented, there was an impressive case for proceeding with a pilot plant. He was concerned that the potential role forestry could play in the production of liquid fuels be properly realized.

Although the report with the proposal for pilot plants was not claimed to be a convincing document, it was in fact the only detailed proposal for proceeding with an actual biomass energy plant which had been presented to any policy making, financing, or planning group in the country. The meeting with Tasman, although not a fruitful one, had in fact catalyzed the basic design of a pilot plant and caused the proposal to be completed in a report which could be circulated to interested parties.

PHASE 2: SELECTION, APPROVAL, AND ACTIVATION

Selection and Approval

With repeated laboratory experiments and scope for improvement exhausted and the literature examined and reviewed, there was little more that could usefully be done. It became clear that for the project to progress, pilot plant investigations would be necessary. But no clear basis existed for selecting any particular capacity or total capability for a pilot plant, investigational or small production. Limitations were, however, imposed by the organization. Large capital-intensive projects were not established practice; the basic research

activity was a single scientist-technician unit operating in a project area. There were also restrictions to staff expansion caused by government policies. A large pilot plant with production capacity would dominate the Forest Research Institute in terms of operational and capital budgeting and staff allocation. Moreover, it was by no means certain that the scientific and technical information generated from a production plant would be of significantly greater value than that of a smaller investigational plant.

It was generally felt that an application for a capital grant of $100,000 to build a small plant would receive more urgent consideration than a request for $1 million, a maintenance budget, and additional staff. The proposition was thus established at the beginning of 1977 that pilot plant development would require a capital budget of $100,000. This figure was in line with the estimate in the proposal prepared for the NZERDC the previous year.

While it was by no means certain that such a sum would in fact be granted, it was decided by the director of research and the senior project leader that the FRI would press ahead with a pilot plant "hydrolysis unit" during 1977-1978 in the absence of any extra funds for the wood-to-ethanol project. Fermentation investigations would have continued on a small scale. In mid-1977, however, the Forest Service, through negotiations by the director of research (who was located in Wellington) in conjunction with the NRAC, received approval for the $100,000 required--$60,000 in 1977 and $40,000 in 1978, and an additional staff member. Approval for the project thus came in two stages: procedure to a limited extent in January and February 1977, followed by approval for a complete pilot plant in mid-1977 and official authorization in August 1977. The NRAC had a major role in the approval process.

Activation

Following initial approval for limited involvement at the beginning of 1977, the project was underway. The staff consisted of the scientist (project leader)

and a technician. There was also continued involvement and support from the senior project leader of the Wood Chemistry section.

The initial work was to draw up plant specifications and gather information on potential equipment suppliers and the costs involved. Before any equipment had been ordered, notification of financial support for a complete pilot plant was received. This also included an additional permanent staff position to provide engineering input to the plant during the final assembly and operation stages.

The project's first tasks were to select equipment, gather information, and revise specifications. For many of the operations required, the project leader had no prior experience, nor recourse to anyone with firsthand experience locally. Travel budgets were severely restricted, limiting contact with other knowledge centers and potential suppliers, and encouraging decision making in isolation. There was thus heavy reliance on textbooks and manufacturers' information. It was realized at the time that these restrictions could cause problems, but it was hoped they would be minimal.

Equipment was selected and requisitioned for order. Because of the long chain between requisition and supplier, it was necessary to maintain an informal check to see that items were actually ordered and follow-ups made on delivery dates. The actual assembly of plant items was to be carried out by the engineering services staff. Initially, the plant was to be housed in an existing large laboratory allocated for pulp and paper research. Not until early 1978 was it realized that the plant's space requirements would exceed those allocated. A decision was made by the divisional director to convert a storage barn into a building suitable for the pilot plant.

After the necessary approvals for funds were acquired, conversion work began in mid-1978 and was quickly completed. By the end of 1978, effectively all the

major equipment items had been delivered and assembly was underway. The additional staff position had been filled in July by a recent chemical engineering graduate whose first tasks were to draw up final specifications for plant assembly and supervise the work, a job which quickly brought him into contact with service staff and familiarized him with the total process.

Delays in the delivery of critical items of instrumentation postponed start-up. It was not until March 1979 that equipment assembly was complete and the commissioning stage could commence.

In mid-1978, an additional $40,000 was sought for 1979 to cover extra instrumentation (including data-processing equipment) and unforeseen expenses. This funding was granted.

During the two-year period of pilot plant assembly, laboratory work on the process continued. This work included investigations on various operations anticipated in the pilot plant and a preliminary examination of the other established alternative route to ethanol--namely, hydrolysis of maize to starch followed by fermentation. It was felt that knowledge of one of the competing routes for ethanol production would be at least useful. Data were also published in a local journal. As it was ultimately intended to interface the pilot plant with a computer for on-line data processing and process control, a minicomputer was acquired at an early stage to permit development of operational experience during the waiting stage.

A carbohydrate chemist recently returned from completing a Ph.D. in Canada joined the Wood Chemistry Section in January 1978 under a general scientific staff vacancy. It was intended that ultimately he would work on the project when the pilot plant became operational.

Parallel Events

The approval stages and continued sustained support for the project were unavoidably dependent on events taking place in New Zealand and other countries

at this time. During 1977-1978, the price of OPEC oil had not risen dramatically, nor were there any supply problems. The urgency of the situation was thus diminished.

In May 1977, the Third New Zealand Energy Conference was held to cover the options available.[10] Later that year, A.P. Thomson of the NRAC gave an address at the 50th Jubilee meeting of the New Zealand Institute of Foresters, a meeting well attended by all persons directly involved in forest growing.[11] Thomson clearly described the role that forestry could play in the future supply of liquid fuels and proposed that the Forest Service should construct an ethanol production facility and have vehicles running on a 20-percent ethanol blend to promote the alternative fuel concept.

In May 1978, a biotechnology conference on biomass and energy held at Massey University noted the lack of tangible progress in the development of alternative fuels.[12] The same month, the Ministry of Energy published a report to map out the future energy supply.[13] In August of that year, an Alcohol Fuels Conference was held in Sydney.[14] The guest speaker, Professor Stumpf from Brazil, visited New Zealand en route to give talks on the Brazilian ethanol program. Subsequently, representatives of the NZERDC visited Brazil and reported on progress there. In October, the Minister of Energy sponsored a seminar on the Ministry's May report.[15] In the same year, the DSIR published a report on transport fuels for New Zealand,[16] and the Liquid Fuels Trust Board was also being set up.

Early in 1979, Auckland was the site of two conferences: the Australia-New Zealand Association of Science Conference, in which the energy topic was raised,[17] and the Fourth New Zealand Energy Conference.

Overseas, fuels from biomass were under development in the United States and the gasohol concept--10 percent ethanol:90 percent gasoline--became a reality.

PHASE 3: OPERATION, CONTROL, AND HANDOVER

Implementation

Construction and assembly of the plant were drawn out over a six-month period from September 1978 to March 1979. During this time, the building was converted for use and necessary services of water, steam, and power were supplied. The recently appointed engineer gradually took over some of the duties previously the responsibility of the project leader, particularly the day-to-day supervision of progress and the expedition of equipment deliveries. Toward the end of this period, as operational testing of the unit was performed, the group's chemist was brought in to assist with completion of the plant and familiarize him with the process.

Supervision and Control

The delivery of specially manufactured plant equipment from suppliers, usually in Auckland, 250 km to the northwest, was expedited by visits to the plants at regular intervals. With rare exceptions, delivery dates were later than specified; delivery of overseas items expected in three months took as long as twelve months. Given the long chain of intermediaries between supplier and project, there was little opportunity to control this time lag. In any event, a late-stage decision to convert a building required approval and pushed the project back at least three months, thus lessening the impact of other delays.

The FRI engineering services officer was actually in charge of the assembly. Because of the nature of the plant, steam and pressurized hot water were used and required special care. The project leader had no direct control over this stage, providing only the desired specifications for completion in the shortest time that could be arranged.

Completion and Handover

The plant was assembled according to original specifications. Every item was checked out for operation, and the task of the engineering services officer was considered complete.

The following six months constituted an extended commissioning period. The plant was in operation to the extent of hydrolyzing wood, fermenting the sugars, and concentrating ethanol by distillation. Publicity was released to newspapers, television, and radio about the completion of a pilot plant to produce fuel ethanol from wood. This news generated an initial surge of interest from forestry operators and assorted entrepreneurs.

Following initial operation, a series of modifications which stretched over six months had to be made on the hydrolysis unit. Problems were caused by the deposit of degradation tars in pipelines and the corrosion and blockage of valves. The tar problem was particularly difficult, as they formed on any cooling surface.

Another problem was that hydrolysis sugar yields, predicted to be 50 to 55 percent of the original wood input, were always lower, never exceeding 40 percent, although almost total hydrolysis of the wood had occurred. This circumstance caused considerable worry and doubt about the whole process, and attention was redirected to the theory of the percolation hydrolysis process.

As previously described, the German scientist Scholler's breakthrough was the realization that the conditions which cause hydrolysis also cause decomposition of the sugars once formed. By percolating the hydrolyzing liquid through the wood, the sugars could be isolated from the reaction zone and decomposition stopped by lowering the temperature. There is little evidence of a theoretical base for these observations; presumably, the Scholler process was based on empirical observation.

In the mid-1940s, an American scientist, J.F. Saeman, working at the U.S. Forest Products Laboratory in Madison, Wisconsin, performed a series of experi-

ments on the kinetics of wood hydrolysis in dilute sulphuric acid.[18] Most of the experiments were performed with Douglas fir, a softwood. This work has provided the theoretical base for all subsequent development of the process.

What Saeman derived were kinetic equations for the hydrolysis of wood and the decomposition of the sugars formed as a function of temperature, acid concentration, and time (Table 3.3). Increasing any of them increased the rates of hydrolysis and decomposition. What it did not define--and this information, although appreciated, is still undetermined--is precise information on the rate of diffusion of acid into the wood particle being hydrolyzed (but being rapid, not thought to be limiting), and highly important, the rate of diffusion of the sugar, once formed, out of the wood particle into the free-flowing surrounding liquid. This effect limited the maximum rate at which the reaction could proceed.

Because the whole concept of wood hydrolysis, outside of the U.S.S.R., was neglected through the 1950s, 1960s, and early 1970s, little theoretical advancement had been made. There were attempts to define the percolation hydrolysis process as a single equation using traditional reactor design techniques. One of these techniques--which was applied by at least two different investigators before computers became readily and generally available--was the use of an equation which assumed that both the wood and the liquid were flowing through the reactor.[19] Attempts to set up a computer simulation program to describe results under operating conditions using this technique together with Saeman's kinetic equations resulted in nonsense data. It was realized that a completely different approach would have to be taken to establish a meaningful simulation of the process.

Reviewing chemical process engineering texts, it became obvious that the hydrolysis percolation process was identical to leaching operations, which are common and well recognized, with the additional factor that the product (sugar) being leached was also subject to decomposition described by one of Saeman's kinetic equations.

Table 3.3 Hydrolysis Kinetic Data[a]

$$\text{cellulose} \xrightarrow{K_1} \text{glucose} \xrightarrow{K_2} \text{decomposition products}$$

for Douglas fir:

$$K_1 = 1.73 \times 10^{19}\ C^{1.34} . e^{-\frac{42900}{2.303\ RT}}$$

$$K_2 = 2.39 \times 10^{1.02}\ C^{1.02} . e^{-\frac{32870}{2.303\ RT}}$$

where C = sulphuric acid concentration, %
T = temperature, K
K_1 and K_2 = first-order reaction rate constants, min^{-1}
R = ideal gas law constant, 1.93 cal/g mole, K

Representative values for 0.4% acid:

Temperature, °C	Rate constant, min^{-1}	K_1 (%/min)	Rate constant, min^{-1}	%/min	K_1/K_2
170	0.00355	0.35	0.00534	0.53	0.66
180	0.01045	1.05	0.01219	1.22	0.86
190	0.02936	2.94	0.02685	2.69	1.09
200	0.07896	7.90	0.05722	5.72	1.38
210	0.20385	20.39	0.11816	11.82	1.73

[a]This table shows that with increasing temperature, the rate of cellulose breakdown increases at a faster rate than the rate of glucose decomposition. However, it also shows that at higher temperatures, the rate of glucose decomposition is really very fast.

In a reactor with, for example, 100 g of cellulose at 200°C, in 1 minute 7.9 g of glucose will be formed, of which 5.7% or 0.45 g will be decomposed; in the second minute, 5.7% of 7.9 - 0.45 at 7.45 g will decompose, i.e., 0.42 g, leaving 7 g of glucose, and so on. In 10 minutes, approximately half that glucose will have disappeared. This is the problem of increasing the rate of hydrolysis.

Source: Adapted from J. F. Saeman. "Kinetics of Wood Saccharification: Hydrolysis of Cellulose and Decomposition of Sugars in Dilute Acid at High Temperature, Industrial and Engineering Chemistry 37 (1945):43-52.

All that was necessary now was to set up a computer program to describe a leaching process with additional equations for product formation and decomposition. With the minicomputer on hand for the project (purchased for entirely different reasons) and the project team now familiar with programming this unit, the simulation model--one impossible to develop without a computer--was completed and operational within two months. Simulation data matched very closely the experimental results reported by the U.S. Forest Service.

With this additional confidence that results could be predictable under any given set of conditions, it was realized there must be a basic fault in the hydrolysis reactor. The possibility of the metal lining from the reactor vessel catalyzing sugar decomposition was considered, but after analysis, concentrations were found to be much lower than those known to be effective. Fortunately, the problem was solved by considering the flow dynamics of liquid in the reactor. The outlet was in the wrong place, stagnant zones existed, and the sugars were decomposing in the reactor instead of being removed. Relocating the outlet to a position which should have been obvious in the first place solved the problem immediately.

Many other minor faults also existed that should have been eliminated at the design stage as well as others which could only be corrected from operational experience. The limited experience in pilot plant work of the persons involved in the project also engendered unnecessary problems, primarily an attempt to introduce automatic measurement and control equipment at too early a stage. Ideal planning and organization were not possible, however, because of the long lead times in acquisition of all the equipment involved. An obstinate technical problem was proper temperature control of the water feeding the reactor. With the assistance of the senior project leader, a meeting was arranged with an engineer from New Zealand Forest Products Ltd. and a least-cost solution offered.

Equipment was borrowed from the FRI's Pulp and Paper section and the problem was solved. By September 1979, the commissioning period was judged complete.

As the commissioning period was completed and predictable operation of the plant became a reality, the need for additional staff became apparent. At that stage, four persons were involved--the project leader, technician, engineer, and carbohydrate chemist. Another technician joined the group for analytical work on the sugars, but it was clear that more technical staff were needed.

Each operation of the plant under a predetermined set of conditions was a lengthy exercise. A sample of wood had to be collected and dry weight determined. The wood was loaded into the reactor and the hydrolysis commenced--that is, steaming to bring the wood up to temperature, filling the reactor with hot water and acid in a fixed ratio, holding for a set period, and then starting a continuous flow or percolation of hot water and acid, collecting and sampling the outflowing liquor (hydrolysate). After percolating for a period determined by the concentration of sugar in the outflowing liquor, the residual solids were quenched with cold water and removed from the reactor.

The hydrolysate liquor was neutralized with lime and the resulting gypsum and condensed tars removed by filtration. The liquor was then mixed with yeast; after fermentation was complete, the fermentation broth was centrifuged to recover the yeast. Occassionally rather than routinely, the "beer" was distilled.

Each operation generated several samples for analysis: the concentration and composition of sugars in the percolate; carbohydrate in the residual solids, sugar, and ethanol during fermentation, with chemical methods for sugar and carbohydrate analysis being particularly time consuming. The experimental and analytical data had to be assembled and summarized in tabular and graphic form. With the exception of repair tasks, it was possible to operate the plant on a daily basis, thereby straining analytical staff resources. The entire process is summarized in Figure 3.4.

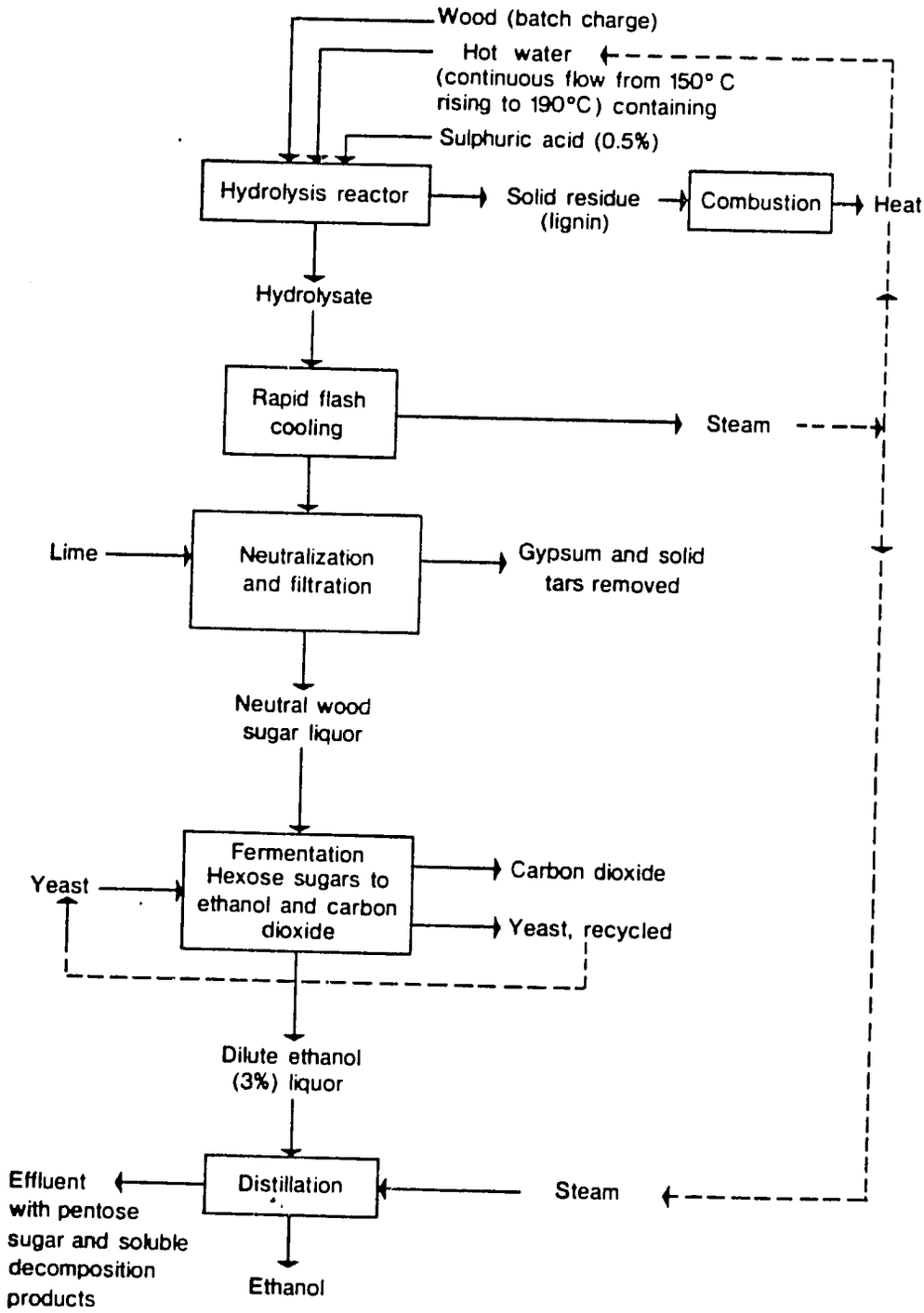


Fig. 3.4. The wood-to-ethanol process.

At the end of the commissioning period, September 1979, when routine operation was established, the need for a planned experimental program was foreseen. To justify the substantial investment in the project, with measurable capital outgoings of well over $150,000, it was imperative that progress reports be made available in a short time. At the request of the Ministry of Energy, a target date of mid-1980 was set for the completion of reports containing data adequate for commercial decisions on a production-scale plant. Ongoing summary reports would be completed for immediate availability if required.

There was some discussion on defining objectives--whether these should be clear and unequivocal but limited in scope, or more open ended and ambitious. As the purpose of the objectives was loosely defined, experimental analysis were ultimately flexible to match the progress of the project. A common purpose was set that by mid-1980, the whole process with radiata pine feedstock would be comprehensively examined.

With progress becoming a clear function of staff input and the demand for staff becoming obvious, another technician was transferred from the Pulp and Paper section and technicians from the analytical laboratory became involved on a full-time basis. At the end of 1979, a temporary technician was employed. The increased rate of experimentation clearly demonstrated the call for additional staffing. Subsequently, another technician was transferred from other duties to assist with the fermentation investigations.

In two years, the full-time staff allocation had grown from two to eight, with an additional two or three on a part-time basis. Although staff allocation had grown to a satisfactory level, the budget situation to cover extensions, modifications, and repairs was far from clear. At any given time, it was not clear how much had been dispensed on the project, and the actual expenditure

for a given year was not known until well after the end of the year. Financial aspects, however, did not develop as problems and work was not restricted.

By the beginning of 1980, major capital expenses were completed and the maintenance and repair bill was covered from normal research allowances. As parts of the plant hat not yet been utilized, there was no call for major extensions.

Technical data on the process, such as the various effects of operating conditions on yields of sugar and ethanol, were being generated. The results, such as yields of ethanol per tonne of wood, were meeting the predictions made at the initiation of the project, based on the earlier work of Scholler and the U.S. Forest Products Laboratory.

A major and unexpected delay in the completion of the plant's instrumentation was caused by the inadequate performance of the U.S. computer company. Initially, to cut the costs of buying a higher-priced modular system for interfacing, the company arranged to have this part manufactured locally. Local resources were, for various questionable reasons, strained to complete this work.

Much of the instrumentation was not critically necessary in the early stages of the project. Simple manual methods proved to be adequate within the total framework of conduct of the project. For example, experiments were only conducted during a normal working day with staff always in attendance, and output performance from the plant was not the limiting factor. Equipment was utilized on a progressive scale. Extensive use was made of the critical first hydrolysis stage, with lower utilization of subsequent fermentation and distillation units. However, useful laboratory experiments on fermentation were possible using wood sugars from the hydrolysis plant.

By the beginning of 1980, substantial data had been gathered on the effect of hydrolysis operating conditions on sugar yields from wood and thus ethanol yield. Experimental results clearly matched those predicted by the computer

program developed during the commissioning period. The need for an extensive experimental program to generate results became less important as the computer simulation was proving to be accurate, predicting yields within 5 percent of the actual results. More effort could thus be directed toward experimental problems.

Work not covered by this time was satisfactory routine operation of the distillation unit and secondary fermentation of the pentoses for yeast production. Both of these subprojects promised to be important challenges.

Parallel Events

The 1979 political upheaval in Iran had particular significance for New Zealand, as Iran supplied 50 percent of New Zealand's petroleum requirements. The reduction of output from Iran caused increasing pressure on prices, which again rose dramatically, and on supply. A system of carless days was introduced and gasoline sales on weekends were curtailed to curb demand. The situation thus reawakened interest in biomass fuels. The pilot plant was visited by the Minister of Energy, who was interested in finding out more information on the total potential of the process, including forest supply.

A Russian journal, effectively the home journal of the whole Soviet industry and packed with useful information, became available in translation.[20] Evidence was available that the whole technology was an active industry. Over 7 million m^3 of wood were hydrolyzed annually to produce a wide variety of products, including about 100 million liters of ethanol.

The government-appointed Liquid Fuels Trust Board presented its comments on the utilization of Maui gas, the pipeline having been completed earlier in the year with no commitments for its use. The recommendations were to construct three massive natural gas-to-methanol plants (2,000 tonne/day output), two thirds of the output feeding a so-called Mobil process which converted the methanol to gasoline, the remainder being used for export and as a direct blend of up to

15 percent with gasoline. By this approach, together with condensate from the gas fields, it was planned to have 50 percent self-sufficiency in transport fuels by the late 1980s. There was no mention of the expected costs of the product, but there were no promises of its being a cheap alternative. Also, New Zealand's only oil refinery (jointly owned by oil companies), after waiting seven years, was given a go-ahead to expand and install a cracker so that a wider range of crudes could be processed, thus reducing the need to import refined products.

No short-term future was seen for biomass transport fuels, although after its completion of the natural gas report, the LFTB was charged with examining coal and biomass for the long-term potential.

In August, the NZERDC published a comprehensive and valuable document covering nearly all aspects of energy farming.[21] The report's objectivity was distorted, however, by conclusions drawn from an inadequate data base. From cost information included, the report concluded that production of methanol from wood and production of ethanol from fodder beet were the preferred routes. The report recommended that production-scale plants for these processes be constructed. There was no information on where such plants should be located, who should provide the practical data, who should operate the plants, or who should provide finance. Analysis of the appendix in the report clearly indicated the limits of its accuracy, containing errors associated with the design and cost of the process plant option for producing ethanol from wood.

At seminars held later in the year, there was criticism of the beet-processing route and the raw material costs of the recommended beet route, an amount two and a half times that proposed as being realistic.[22] The fact was that little data were available on this crop, and achievable rather than actual production figures had been used. There was no query over wood cost data prepared by economists at the FRI. Based on this new cost data, both

ethanol and methanol from wood were the cheapest biomass routes. There was, however, no current research on wood to methanol, and no methanol via gasification of wood had been produced anywhere in the world on a commercial scale. A subsequent report by other workers on the methanol-from-wood process indicated much lower overall yields, thus implying that it was little different for the efficiency of energy conversion than the ethanol-from-wood process.[23] Also, with large methanol-from-natural gas plants being projected, there was no evidence of investment in methanol-from-wood research and development.

This energy farming report, while comprehensive, drew some incorrect summarizing conclusions which did little to assist the overall viability of biomass fuels. The report's excessive optimism in its summary and conclusions about undemonstrated technologies confused many who could not reasonably be expected to delve into the technical details. A third volume embodying criticism, comments, and new information, however, was to be prepared.

Early in 1979, the New Zealand Dairy Cooperative Ltd. decided to go ahead with plans to construct an ethanol-from-whey plant (2.5 million liters ethanol/year), using a process developed in Ireland, and sited adjacent to a dairy factory at Reporoa, less than 50 km south of Rotorua. This plant would be opened in late 1980. The product would be potable and high-quality industrial-grade ethanol to meet 50 percent of New Zealand's industrial alcohol needs. By the end of 1979, a second ethanol-from-whey plant (5 million liters ethanol/year) was already planned for a new dairy factory to be constructed at Tirau, 50 km northwest of Rotorua. This plant was to commence output in late 1981, with initial plans to use the product as a fuel blend.

In December 1979, the Ministry of Energy published a 96-page document on energy strategy as a follow-up to its report of 1978,[24] embodying the Ministry's thinking on the whole topic. The timing was considered to be a junction between a previous and present dependence on imported oil and a future determination to

develop indigenous resources. The report contained valuable data on current energy consumption and covered the whole range of energy use, of which oil was only a part. The strategic goals delineated were:

1. To reduce dependence on imported oil
2. To increase diversity in the energy supply system
3. To ensure efficient usage by avoiding waste and using appropriate types of energy
4. To transfer energy supplies from nonrenewable to renewable in the long term (i.e., sixteen years onward)
5. To encourage a framework for energy planning

It was clear that the immediate concern was utilization of the Maui gas field and that for the next ten years, on an annual basis, this would consume 10 percent of the country's annual investment. It was stated that the overall government energy research and development budget was to increase from $5.34 million in 1978 to $8.74 million in 1979. This report did not consider biomass vital in the short term (within five years) or medium term (ten to fifteen years), but to be brought in gradually from 1996 onward.

The report courageously included figures on the Ministry of Energy estimate for planning purposes on the future prices of crude oil (FOB, Arabian Gulf, quality of Saudi Arabian light):

	1979 SNZ/barrel
1979	18.00
1981	22.50
1985	28.00
1990	31.00
2000	33.00

By May 1980, the following prices (U.S.$/barrel) prevailed for export to the United States: Libya-$36.12; Algeria-$38.21; Mexico-$33.50; Saudi Arabia-$28.00; U.A.E.-$31.65. At the time, NZ$ = 0.95 U.S.$; the annual rate of increase in the consumer price index in New Zealand was around 18 percent. Allowing for these factors, the projected price in the year 2000 could be said to have been reached by mid-1980. These projections were being used for planning the timing of the development of indigenous resources which could substitute for oil.

It remained to be seen just how responsive the planning process would be to any errors in projections and assumptions. Proposals, however, were made for the Ministry of Energy to institute an annual energy plan. the first to be published in August 1980, which would continuously review needs and plan development according to the changing situation. Outside participation in the planning process would be provided through an Energy Advisory Council.

PHASE 4: EVALUATION, FOLLOW-UP, AND REFINEMENT

Evaluation

By the beginning of 1980, a program to evaluate production of ethanol from the country's most important forest resource, radiata pine, was well underway. Details for practical operating conditions were becoming established and results were matching those predicted by the computer simulation model. Experiments were now being considered to fine-tune the hydrolysis operation by reducing total cycle time and demand for water. A treatment method had been tested to improve the fermentability of the wood sugar liquors.

Laboratory investigations to ferment the residual pentose sugars to yeast had begun. Biological Oxygen Demand measurements of the effluent had been made and preparations for suitable treatment methods were under way. Completion of the radiata pine experimental program was confidently expected before the end of the year.

Future work would reexamine certain aspects of the kinetics of pine hydrolysis in the laboratory, and the pilot plant would be used to evaluate local hardwoods, beech and eucalyptus, paper wastes, and, for the country's contacts in the Pacific, coconut. Coconut had already been examined and gave yields of ethanol compatible with other hardwoods, that is, 20 percent lower than softwoods.

In the longer term, it was intended to examine the production of fermentation products from the residual pentose sugars, including acetone, butanol and butanediol, and possibly ethanol. A joint project with the Biotechnology Department of Massey University was organized.

With repeated operational experience on the pilot plant, it was becoming possible to specify the requirements for a prototype production-scale plant for accurate capital cost and operating cost estimates. Before the experimental program was completed, a project with this objective for plants with the capacity of 30,000 liters per day and 90,000 liters per day was underway. The data summarized in Tables 3.4, 3.5, and 3.6 showed that actual plant costs were much less than had been predicted four years previously.[25] (The availability of Teflon linings for the corrosive applications in the process played a major role in reducing costs.) For blending purposes, a liter of ethanol is as good as a liter of gasoline. With the new prices for non-Saudi OPEC oil, ethanol at 37 cents per liter was directly competitive.

Another finding of the budget cost estimate for the commercial plants was the limited process-engineering knowledge of distillation systems using low alcohol feedstocks. Few process engineering and consulting organizations were in a position to design and construct such plants. In addition, international interest in alcohol fermentation and distillation plants from sugarcane, corn, and other crops was placing demands on such organizations and limiting their scope for involvement in novel technology. This operation, in the total ethanol-from-wood process, could be a limiting factor for rapid large-scale implementation.

Table 3.4 Capital Investment Estimates[a]

Item	30,000 liter/day plant			90,000 liter/day plant		
	Capital	Maintenance	Depreciation	Capital	Maintenance	Depreciation
Feed systems	418,000	24,500	7,000	844,500	49,500	27,500
Hydrolysis section	1,581,000	90,000	77,500	4,701,500	268,500	232,000
Filtration	237,000	18,000	6,500	682,000	55,500	19,500
Fermentation	199,500	9,500	7,500	435,000	21,500	15,000
Distillation	1,187,000	24,500	36,000	2,345,000	48,500	70,500
Effluent	65,000	3,000	2,000	110,000	4,000	3,000
Auxiliary	83,000	3,500	2,500	157,000	6,000	4,500
Ancillary	483,000	25,000	19,000	593,000	36,500	31,000
	4,253,500	198,000	158,000	9,868,000	490,000	403,000
Contingency @ 10%	425,500	20,000	16,000	987,000	49,000	40,000
Engineering fees @ 5% } capitalized	212,500	-	6,500	494,000	-	15,000
Commissioning costs @ 2-1/2% } capitalized	107,000	-	3,500	247,000	-	8,000
Total fixed costs	4,998,500	218,000	284,000	11,596,000	539,000	466,000
Working capital estimated at: one month raw materials storage,	114,000			460,000		
and one month production at operating cost (excluding depreciation)	195,000			601,000		
Total investment required	5,308,000			12,657,000		

[a]With 18% inflation and 20% interest rates, only the first year of operation is considered, revenue and costs being relevant for the first quarter of 1980; discounted cash flow techniques over total or parts of the project period are not considered valid.

True estimate allowances for depreciation and maintenance have been used, accelerated depreciation being relevant only for tax exemption purposes.

Table 3.5 Operating Cost Estimates
(based on first quarter 1980)[a]

Item	Cost/unit	30,000 l/day 10 million l/yr			90,000 l/day 30 million l/yr		
		Annual Quantity	Annual Cost $	¢/liter ethanol	Annual Quantity	Annual Cost $	¢/liter ethanol
Wood, in small form (fines, chips or hogged)	$10/m^3	92,600	920,600	9.2	-		-
	$15/m^3	-	-	-	278,800	4,182,000	13.9
Sulphuric acid, delivered	$75/tonne	1,990	149,300	1.5	5,970	447,800	1.5
Lime, calcium oxide, delivered	$80/tonne	1,990	159,200	1.6	5,970	477,600	1.6
Sodium sulphite, 0.05%	$350/tonne	200	70,000	0.7	600	210,000	0.7
Sodium phosphate, 0.006%	$540/tonne	24	12,960	0.1	72	38,880	0.1
Urea 0.02%	$350/tonne	80	28,000	0.3	240	84,000	0.3
Molasses 0.025%	$160/tonne	100	16,000	0.2	300	48,000	0.2
Water	$0.03/m^3	400,000	12,000	0.1	1,200,000	36,000	0.1
Power	$0.04/kWH	1,800,000	72,000	0.7	4,200,000	168,000	0.6
Labor and staff			623,669	6.2		717,202	2.4
Property taxes and insurance, 2% fixed cap.			100,000	1.0		232,000	0.7
Maintenance			218,000	2.2		539,000	1.8
Depreciation (straight line over total life of plant, 33 years)			284,000	2.8		466,000	1.5
Totals			2,665,729	26.6		7,646,482	25.4

[a]With 18% inflation and 20% interest rates, only the first year of operation is considered, revenue and costs being relevant for the first quarter of 1980; discounted cash flow techniques over total or parts of the project period are not considered valid.

True estimate allowances for depreciation and maintenance have been used, accelerated depreciation being relevant only for tax exemption purposes.

Table 3.6 Profitability Analysis[a]

Plant size, daily and annual basis.	30,000 liters		10 million liters	90,000 liters		30 million liters
Ex-works selling price, cents/liter	37	42	47	37	42	47
Annual revenue, $	3,700,000	4,200,000	4,700,000	11,100,000	12,600,000	14,100,000
Annual expenses, $	2,600,000	2,600,000	2,600,000	7,700,000	7,700,000	7,700,000
Annual profit, $	1,100,000	1,600,000	2,100,000	3,400,000	4,900,000	6,400,000
Return on total invested funds	21%	30%	40%	27%	39%	50%
Return on equity investment with 60:40 debt: equity ration; financing at 20% with roll-over.	26%	45%	69%	37%	69%	96%

[a]Inflation will have the effect of dramatically increasing profits for the "geared" situation, but if revenue and expenses move in line, this will not alter the profit picture.

Thirty-seven cents/liter represents the current value as a petrol substitute (retail pump price, forty-eight cents, less selling margins and road tax); 47 cents/liter is the current U.S. West Coast price; 42/cents/liter is a competitive price allowing shipping costs to major markets.

After four and a half years of activity proving the process a practical and viable route, it was possible to identify some of the positive and negative factors which had influenced the course of the project.

Some of the negative influences or problems included:

1. Raising general interest in the process.
2. The belief held by some that as the process had been practiced and established before, there was little purpose in performing an extensive research program.
3. The general complexity of the project, which took it outside a normal laboratory environment; included were pressure vessels, high pressure pumps, high temperatures, corrosive liquors.
4. The enthusiasm of the large pulp and paper industries was limited. The process may have been considered to add competition for the use of pulpwood, of which the pulp and paper industries purchased a major proportion of their supply from the New Zealand Forest Service.
5. Agricultural interests, for a time, believed that beet crops were simpler and easier to manage.
6. The FRI Forest Products Division had no previous experience in tackling a project of this nature.
7. There were long lead times in the acquisition of equipment and nobody responsible for expediting them.
8. The FRI as a government department was restricted by government policy at the time to reduce spending. Rapid expansion of staff levels was not possible. With the long-term nature of other projects, there was a general reluctance to transfer staff from other projects.
9. Because of the lack of experience with a project of this scale, it was difficult to predict financial requirements in advance.

10. The attitudes for support of research and development of biomass projects at the senior government level was not known by those directly involved.
11. There was only a small domestic market for established uses of ethanol. Production then would have to go for transport fuel or for export.
12. With transport fuel, the government held very tight control over pricing and availability. The price was constant throughout the country. The use of ethanol as a fuel made available through established distribution points as a gasoline-ethanol blend would depend on executive government approval.
13. During much of the project--until the end of 1979--gasoline imported directly or refined from imported crude was cheaper than the projected commercial price of ethanol from wood.
14. The FRI was located in Rotorua, close to the forest industries but distant from the influential centers of government in Wellington.
15. The objective of the FRI's Forest Products Division was to research alternative uses for forest resources. It was not in itself, nor through the NZFS as an organization, likely to develop the process through to a production scale.
16. The only country where the technology was established--the U.S.S.R.--was not keen to develop the technology in other countries.

Positive influences or advantages, on the other hand, included the following:

1. The FRI, while distant from the capitol, was close to the forests and the forest industry.
2. The FRI was an integrated operation with ongoing research covering the actual production of wood and all the alternatives for utilization.

3. The FRI was the research arm of the New Zealand Forest Service, the country's major forest owner and developer. It thus had direct access to national forest data and also had communication, and influence, on forestry operation and thinking throughout the country.
4. The Forest Service and FRI had good, if indirect, representation on the influential NRAC.
5. The FRI had an established carbohydrate chemistry laboratory with analytical services--support services unrivaled by any other research establishment interested in developing a biomass energy project.
6. As part of a large section at the research institute, it was possible to redirect technical staff to the project: that is, staff levels could in fact be increased without new employment, though this was not a routine procedure.
7. The process was essentially proven.
8. The process generated a large number of by-products, yielding a potential for diversity of downstream processing.
9. The price of crude oil was gradually increasing in real terms, with international forecasting unequivocably stating that shortfalls were sooner or later inevitable and alternatives had to be found.
10. Brazil was proceeding with its program to utilize ethanol as a major fuel, both as a 20-percent blend and a complete substitute for gasoline. By 1980, ethanol-powered vehicles were to come off the production lines.
11. The United States was encouraging its gasohol program; in 1979, the President set targets for 20,000 million liters of gasohol (90 percent gasoline/10 percent ethanol).

Follow-Up

During 1979, following the publicity on the project provided by the communications media, several individuals and companies from various parts of the country visited the plant and expressed interest in its application. The earlier published reports were freely supplied, but it was generally stated that another year would be required before practical operating data to provide the basis for plant construction would be available. There was little follow-up from these sources, probably because the process was technically detailed (requiring investigators to study the literature) and not readily understood.

One of the interested companies was located in Rotorua and specialized in project engineering. Adequate financial resources enabled the company to study the prospect of ethanol from wood. After six months of full-time investigation--examining the literature in detail, continually referring back to the project scientists at the FRI for clarification on several points, and finally performing a cost analysis--the company was convinced that the process was commercially attractive and would proceed with its development.

At this time, one of Rotorua's successful forest harvesting operations working in the state forest was, by requirement of the NZFS, moving milling operations from the forest to a permanent site. One of the requirements under the contract for timber removal was that the forest site should be left clean. The company was thus faced with a waste disposal problem. The forestry company and the project engineering company had business associates in common, and it was quickly realized that this was an ideal opportunity to construct a prototype plant to produce ethanol from forestry waste. The forestry company could provide the raw material supply and land next to the forest, with planning permission for plant construction and a demonstrated geothermal resource. The engineering company could provide professional input for civil and structural work and, more important, the necessary experience to organize the project and get it off the

ground. The scientific staff at the FRI were willing to provide the necessary technical input and backup, especially since the proposed plant was to be located only 20 km from the FRI.

The projected capital cost of the plant, with an output of 5 million liters per annum (to match the waste wood supply), was around NZ$2.5 million. As with any small enterprise, however, financing was the major problem. The government was approached directly with a prospectus and an offer of an equity stake in the venture, which was declined. The government-owned Development Finance Corporation was also approached for financial assistance; this feeler, however, was also not successful.

At this stage, the Ministry of Energy revealed that although consideration was being given to ethanol-blended gasoline, this was no basis on which to construct an ethanol production plant, and the product would have to compete in the market place. Fortunately, the U.S. gasohol program provided an almost infinite market for ethanol.[26] With a U.S. West Coast price of $1.70/U.S. gallon (NZ$0.48/liter), after allowing for transportation costs, the selling price was clearly adequate to support the project. It seemed possible that Japan might also adopt a gasohol fuel policy.[27] It was also felt possible that higher prices could be achieved by the time production was in progress.

Negotiations for financial support were thus begun with local and overseas merchant banks and one of the major multinational oil companies.

Refinement

At a latter stage of the experimental work, when the process design problems had been resolved, the lack of certain kinetic data which could have been determined in the laboratory was recognized. Before the plant was put into operation, it was felt that little more could be done on laboratory studies until the plant was operational. Afterwards it was realized that this was not the case, and with

enough forward thinking, useful work could have been done in advance of when required, thus shortening the total project time.

Serious problems were encountered with delivery of computer interfacing equipment for process control. It became apparent that a general shortage of knowledge in computer technology, hardware and software alike, existed in other government departments as well as the private sector of New Zealand. It was thus a lesson that computer equipment suppliers' promises had to be treated with great caution and reliance should be placed on straightforward assembly of imported units. Also, care would have to be taken over the use of computers for any critical process application.

It was also realized that special caution would have to be exercised over the ability of process plant fabricators to perform tasks of a given standard in a given time. One experience was particularly noteworthy. The hydrolysis reactor was fabricated from a special high-nickel, corrosion-resistant steel alloy, and the firm selected for this task was one indicated as having worked with this material before. There was considerable delay in delivery of the reactor with ancillary piping. On-site pressure testing revealed pipework weld leaks (which were repaired), raising some suspicions. After twelve months, the reactor was disassembled for inspection by the government pressure vessel inspector. Surface corrosion was revealed at some welds, indicating the need for an x-ray of the welds. When completed, this examination revealed all the welds to have been improperly performed. The vessel had to be completely cut down and rewelded. This was another lesson in the problems of introducing unfamiliar materials.

Shortly after the start of the commissioning period, the director of the Forest Products Division requested weekly meetings, with minutes, on progress. These provided an effective weekly diary of events and a chronological order of

problems. It remained to be seen, if similar projects were undertaken in the future, whether the cumulative experience gained in this exercise could be used.

At this writing, in fact, initial plans by the New Zealand Forest Service to build a pilot commercial plant if the laboratory pilot research program proved successful may not proceed immediately. This possibility emanates from a recent government decision to proceed with the installation of a methanol plant based on the Maui natural gas field discovered in 1979. The private sector, however, has evaluated the commercial prospects of producing ethanol from wood and it is likely that investors will proceed with the development of a plant.

In summary, the production of methanol from the Maui natural gas field remains the New Zealand government's immediate priority at this time. Nonetheless, ethanol from wood remains an attractive possibility for liquid fuel production. As the natural gas field is depleted over the next twenty to thirty years, forestry in New Zealand will climb to the position of one of the country's largest industries. Ethanol from wood will increase as a possibility for liquid fuel development, especially since it can utilize the vast forestry resources and residues and has the advnatage of being a totally renewable resource.

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ACRONYM KEY

CNG	Compressed natural gas
LPG	Liquid petroleum gas
DSIR	Department of Scientific and Industrial Research
FRI	Forest Research Institute
LFTB	Liquid Fuels Trust Board
NRAC	National Research Advisory Council
NZERDC	New Zealand Energy Research and Development Committee
NZFS	New Zealand Forest Service

CASE 4

ENERGY FOR RURAL DEVELOPMENT IN THE PEOPLE'S REPUBLI' OF CHINA

John N. Hawkins

with

the assistance of

Li Shengyun

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Efforts to transform rural China into a more productive, modern, and integrated sector of the Chinese economy have been a major priority of the Chinese government for the past thirty years. This has been the case despite the many factional disputes that have emerged among the leadership since 1949. Regardless of which administration holds forth in Beijing, broad economic policy guidelines have consistently reinforced the need to promote rural development through a policy of "walking on two legs," or, in other words, giving equal attention to transforming indigenous, small-scale technology as well as to introducing (or transferring) more modern techniques and technologies.[1] To be sure, at various times this policy has emphasized one "leg" at the expense of the other, and, as this case history will show, the development of small-scale hydroelectric projects has been no exception.

Several important research questions emerge when small-scale rural development schemes and their parallel training programs are examined in detail. In the case of the People's Republic of China, the political issue looms perhaps the largest. How is policy formulated? Who are the main actors? What are the constraints to planning, design, implementation, and maintenance? Questions can be raised about the respective roles of centralized decision making: What are the positive and negative aspects of each with respect to the effective design, selection, implementation, and evaluation of small-scale energy projects? In the field of energy policy studies, what can we learn from the Chinese experience about project planning, management, and training? Given the fascination many nations now have with the use of intermediate technology, what is the Chinese experience with this form of rural development? Finally, what important education/training lessons can be derived from focusing on a single rural development case? These and many additional related questions provide a fertile ground for exploration; hopefully, some tentative judgments can be advanced on the basis of this case study.

The descriptive data and analysis that follow were gathered during a five-week visit to the People's Republic of China during the summer of 1979. During this time, interviews were conducted and documents collected at the Electrical Engineering Department of Qinghua University in Beijing (a major research and development center for energy policy and technology), the provincial Department of Electrical Power located in the capital city of Henan Province (Zhengzhou), and the county seat of Linxian in northeastern Henan Province (a more detailed description of the project site in Linxian follows). A series of interview questions were formulated utilizing the integrated project cycle and the author's previous work in technology and technique transformation policy. The information thus obtained was organized around these questions and is presented in this chapter within the IPPMC framework.

Project Background

Although the Chinese government has included the development of energy resources as a priority in each of their six five-year plans, it was not until 1958 that the first major effort at rural electrification and mechanization emerged. This emphasis coincided with a massive development effort known as the Great Leap Forward. During this period (1958-1960), Chinese farms were reorganized into communes, numerous small-scale industries were introduced in most rural areas, and major efforts were reported in the development of small-scale hydroelectric projects. As was later revealed, this early effort was ill-conceived, poorly managed, and created serious economic problems for the Chinese government. Despite current revelations about the failures of the Great Leap Forward, however, Chinese energy officials still admit that this example of mass mobilization tactics had a residual positive effect. Literally millions of farmers were exposed for the first time to industrial activity, and many became semi-proficient in the manipulation of tools and mechanical devices.

A second important by-product of the Great Leap Forward was that the idea of small-scale industry caught on despite the failure of many of the projects. Petty officials and local administrative bodies became convinced of the value of small-scale industry; from 1959 on, this general sentiment has been echoed in policy directives from the ministries in Beijing. The commitment to small-scale industry is especially evident in the area of energy policy. Since 1959, energy supplies to the rural areas have increased twentyfold. Measured in millions of kilowatt hours, the trend has been as follows: 1953, 43; 1958, 142; 1965, 3,200; 1973, 12,800; 1975, 20,256. In 1975, rural sources supplied a 16.2 percent share of the total electrical supply.[2] The Chinese now report that roughly 70 percent of all rural communes are electrified; a significant factor in this electrification program has been the 87,000 (1978) rural small

hydroelectric stations scattered throughout the Chinese countryside.

In keeping with the overall development policy of having two major economic sectors, the Chinese are continuing to divide hydroelectric projects into those controlled by the central ministries and those owned and operated by municipal governments, counties, and communes (including production brigades). The national policy at this time is to promote energy faster than other branches of research and development. The current goal is to have 20 percent of all national electrical needs met by hydroelectric projects of all sizes and scales.[3] The Chinese are far from achieving this goal, however, and the present situation is much more modest. Industry and construction (which includes rural small-scale industry) consume about 62 percent of all primary energy supplies, followed by residential and commercial, 27 percent; agriculture, 6 percent; and transport, 5 percent.[4] The trend has been to reduce residential and commercial usage as a leading sector (before 1949). Transportation is continuing to grow and industry is the leading growth sector followed by agriculture. Again, agricultural electrification and mechanization increasingly rely on small-scale hydroelectric plants and continue to follow a policy of self-sufficiency. Personal consumption of electricity for rural households is low and controlled. The maximum permissable wattage per bulb is 25 watts, restricted to one bulb per room. Heating and cooking with electricity is not allowed.

In terms of China's primary energy mix, the situation has improved substantially since 1949. There is more diversification, as evidenced by the reduction of the share held by coal (95 percent in 1949; 66 percent in the 1970s) and the increase in the share of total energy supply by oil, gas, and hydroelectricity. In addition, the Chinese are pursuing a variety of alternative energy sources to increase supply, particularly for the rural sector (biogas, geothermal, windmills, etc.)[5]

More relevant to this case are China's policies toward small-scale enterprises in general and small-scale hydroelectric plants in particular. Especially since 1958, the Chinese government has promoted the development of intermediate and small-scale enterprises and has generated, at different times, criteria that must be met before an enterprise can qualify as a small-scale plant. In summary form, the following profile emerges of a typical small-scale plant in rural China. First, it must be located in the rural sector, most often associated with a rural commune or county seat. Second, the technology selected to operate the plant must be as uncomplicated as possible, utilizing discarded machinery as appropriate and depending upon local, indigenous resources. The emphasis must be on supporting the development of agriculture, which means that most enterprises fall into the category of supplying agricultural inputs of various sorts (fertilizer, electricity, cement, irrigation, etc.).

This picture of a small-scale enterprise appears clear and straightforward. There have been many problems associated with this approach over the years, however. Because of the decentralized nature of administration and control, local county and commune authorities have often been overburdened because of the rapid development of small-scale plants. There have been problems associated with diverting labor from agriculture to build, operate, and maintain the plants (currently this diversion is limited to 5 percent of the local labor force at the county level). During peak agricultural periods, small plants are often not efficiently run because of the reassignment of personnel back to agriculture. Finally, there have been some isolated cases of local small-scale industries competing with the more modern, urban sector for full resources and other materials, something they are expressly forbidden to do.

Despite these problems, the contributions of small-scale enterprises to the Chinese economy have been significant. Ninety percent of all small farm implements are produced in this manner, as well as 50 percent of basic farm machinery.

Fifty percent of nitrogen and 75 percent of phosphate fertilizers (by weight) are produced in small-scale fertilizer plants located at the county seat level or below. Fifty percent of the national output of cement can be attributed to rural small-scale plants. Twenty to 30 percent of rural electrical needs is accounted for by small hydroelectric plants (representing 5 percent of national consumption), and 30 percent of coal production comes from small plants. Finally, it is estimated that 15 to 20 percent of the national steel output is produced in small steel plants.[6]

These figures represent significant portions of total economic output and, since they are directed primarily toward rural development, allocation, and consumption, the impact of small-scale technology and techniques on the rural population is enormous. There have indeed been many fluctuations in China's policy and practice toward small-scale enterprises;[7] most analysts as well as Chinese officials themselves agree, however, that they have provided additional equipment and materials to the rural sector and that they have contributed to the steady increase in agricultural production. Small-scale enterprises have had a positive influence on the use of human resources in rural areas that otherwise would have meager alternative employment possibilities. Spatially, they have contributed to a more balanced rural-urban mix and have reduced other costs such as transportation and communication. Finally, they have contributed to the rural diffusion of construction techniques and technologies.

Where problems have been identified, these have been associated most often with the overzealous implementation of these policies during the late 1950s and late 1960s. Also, the modern sector has continued to lend some support to these efforts, and this practice has been a drag on their resources. On the whole, however, it can be said that China's efforts to promote small-scale industry, including hydroelectric power stations, has proceeded favorably and is projected

to remain an important component of overall economic planning for the next two decades.

The growth of small-scale hydroelectric stations has been no exception to the trend in favor of increasing small-scale enterprises in general. In 1978 alone, over 6,000 small stations were added to the rural sector, with a generating capacity of 950,000 KW. This represents a 28 percent increase over 1977 and brings the total number of small stations to over 87,000. The average generating capacity of these plants is about 200 KW, although the variation is substantial. There appears to be no firm definition of how much kilowattage constitutes a small plant, and reports indicate that some plants over 1 megawatt are still considered small-scale.

Overall policy regarding small plant use and construction is set by the Ministry of Water Conservancy and Management in Beijing, and small hydrostations are primarily an offshoot of water control projects. In legal terms, however, the ownership and management of the individual plants resides with the local unit that constructed the station (e.g., county, commune, production brigade). Before turning to the particulars of the project itself, a brief description of China's commune structure and rural administration pattern seems advisable, since much of the terminology used in the case refers to this social configuration.

Commune Organization

The people's communes (renmin gongshe) were launched in 1958 as a measure to rationalize land use. The Chinese were aware that underemployment was a problem to rural China and that many factors of production were underutilized. Communes were one device employed to maximize the use of the land, labor, and capital accumulated throughout the countryside.

In brief, the commune consists of four integrated units: commune, production brigade, production team, and household. Although the total number of

communes has varied; in 1974 there were a reported 50,000, and Chinese officials indicated that virtually all of rural China was organized according to the commune structure.

Although it is difficult to describe a "typical" commune, some generalizations can be made based on evidence received from a variety of communes visited by foreign scholars in the recent past.[8] The most commonly observable unit in the Chinese countryside is the natural village. This unit and the property surrounding it constitute the production brigade and is the intermediate level between the production team and the commune. There may be fifteen production brigades to one commune (or fifteen villages), and each of these further subdivides into a smaller unit, the production team (about six teams to one brigade, or 100 to one commune). The production team is the smallest permanent production unit. The combination of the brigades and the teams then constitute the commune, which may have as its headquarters one of the larger brigades or villages. An average number of households per commune would be about 3,300, with a total population of 14,720. The total arable land area under the management of one commune would be about 5,000 acres (over 30,000 Chinese mu).

The commune is linked organizationally with higher levels of administration, especially the county level (xian); these relationships can be seen diagrammatically in Figure 4.1. The commune has a representative assembly and a management committee that allows it to communicate with upper levels, and although there has been an element of grassroots democracy built into the structure, during certain periods these levels have either been dysfunctional or manipulated by powerful interest groups (we will discuss later some of these management problems as they bear on the case history).

More important for the purposes of this study, however, are the various levels of ownership present in the commune structure. These levels correspond to the basic units of the commune, all of them collectively owned and managed,

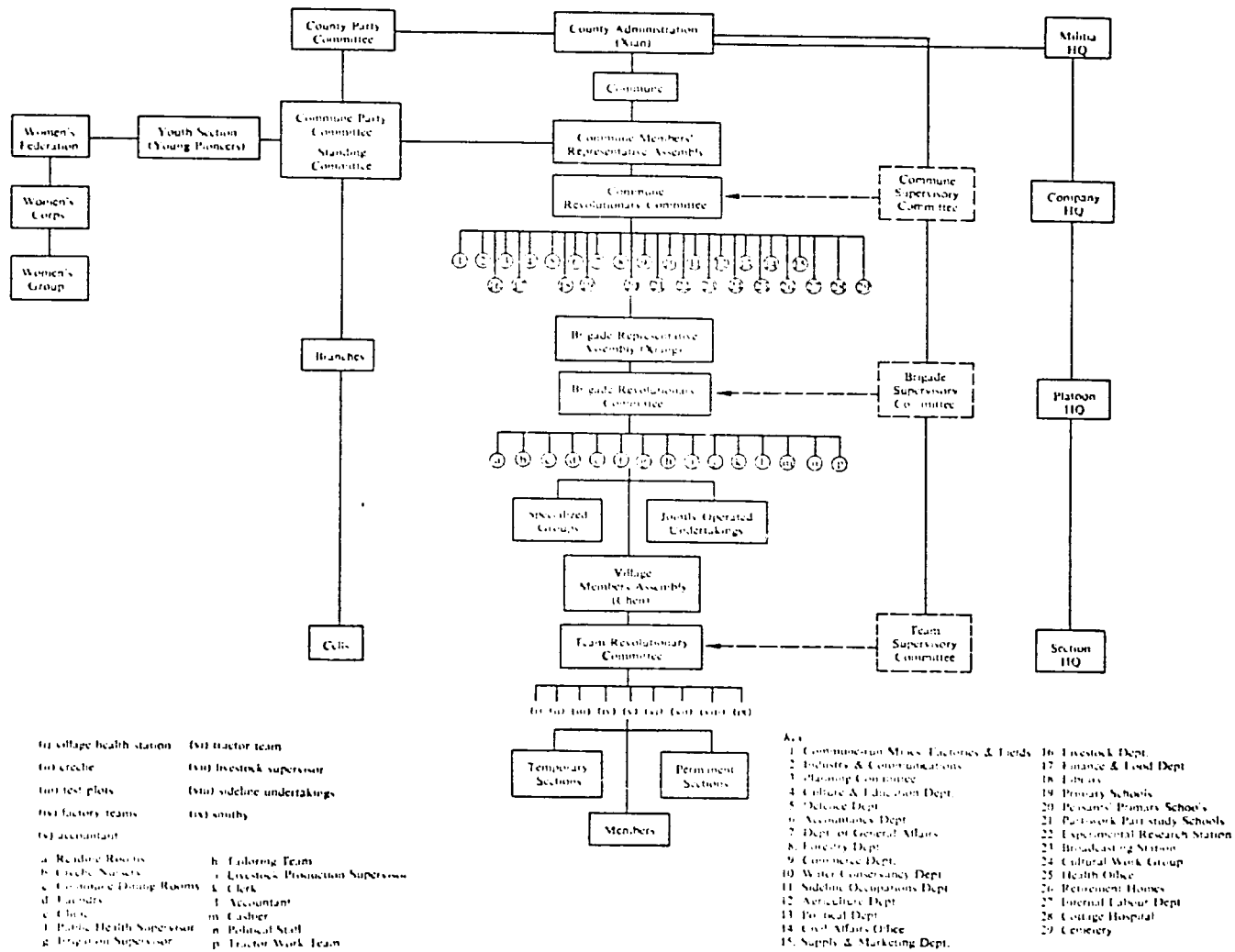


Fig. 4.1. Commune organization and management.

Source: Kieran Broadbent, A Chinese/English Dictionary of China's Rural Economy. Farnham Royal, England: Commonwealth Agricultural Bureaux, 1978.

with the exception of the household (and the private plots allowed each household). For the past ten years, the production brigade has become an increasingly important level of ownership and management. Among other enterprises, the members of this unit design, construct, and manage food processing plants, weaving shops, kilns for bricks, paper manufacturing plants, and small-scale hydroelectric plants. General water control falls under the production brigade as well (see Figure 4.1, section g).

The commune is responsible for larger-scale projects, such as experimental demonstration farms, agricultural extension work, larger industries such as cotton processing, grain processing mills, farm implements factories, light bulb factories, and larger hydro-power stations. A more complete list of the various functions of the commune can also be seen in Figure 4.1.

In overall management and administration, the communes have basically three types of relations with external agencies (e.g., county, province, state). The first is a hierarchical command-and-obey relationship, primarily in direct connection wtih national five-year plans. Certain elements of the plan are not negotiable (e.g., finances), although even here considerable political maneuvering takes place. The second type of relationship is more horizontal and is characterized by contractual agreements, often between two or more communes on joint projects (large waterworks, for example). Finally, communes enter into various forms of consultative arrangements, especially with respect to formulating the State plan and discussing with county and provincial-level authorities various sorts of development projects. When a commune realizes that it must receive technical assistance outside its own capabilities, it will enter into a consulting relationship with a higher level.

The point to keep in mind is that communes, production brigades, and production teams have a fairly substantial amount of autonomy and responsibility, especially

with respect to the planning, designing, constructing, implementation, and evaluation of small-scale projects. The general principle of "whoever builds it, owns it" is followed at the commune level, and recent figures indicate that in the agricultural sector, approximately 90 percent of all small enterprises are owned, operated, and maintained by communes and production brigades.[9]

While the foregoing brief description provides a general framework for understanding the commune organization and management system, we will discuss these relationships in more detail as we focus on the Linxian project itself.

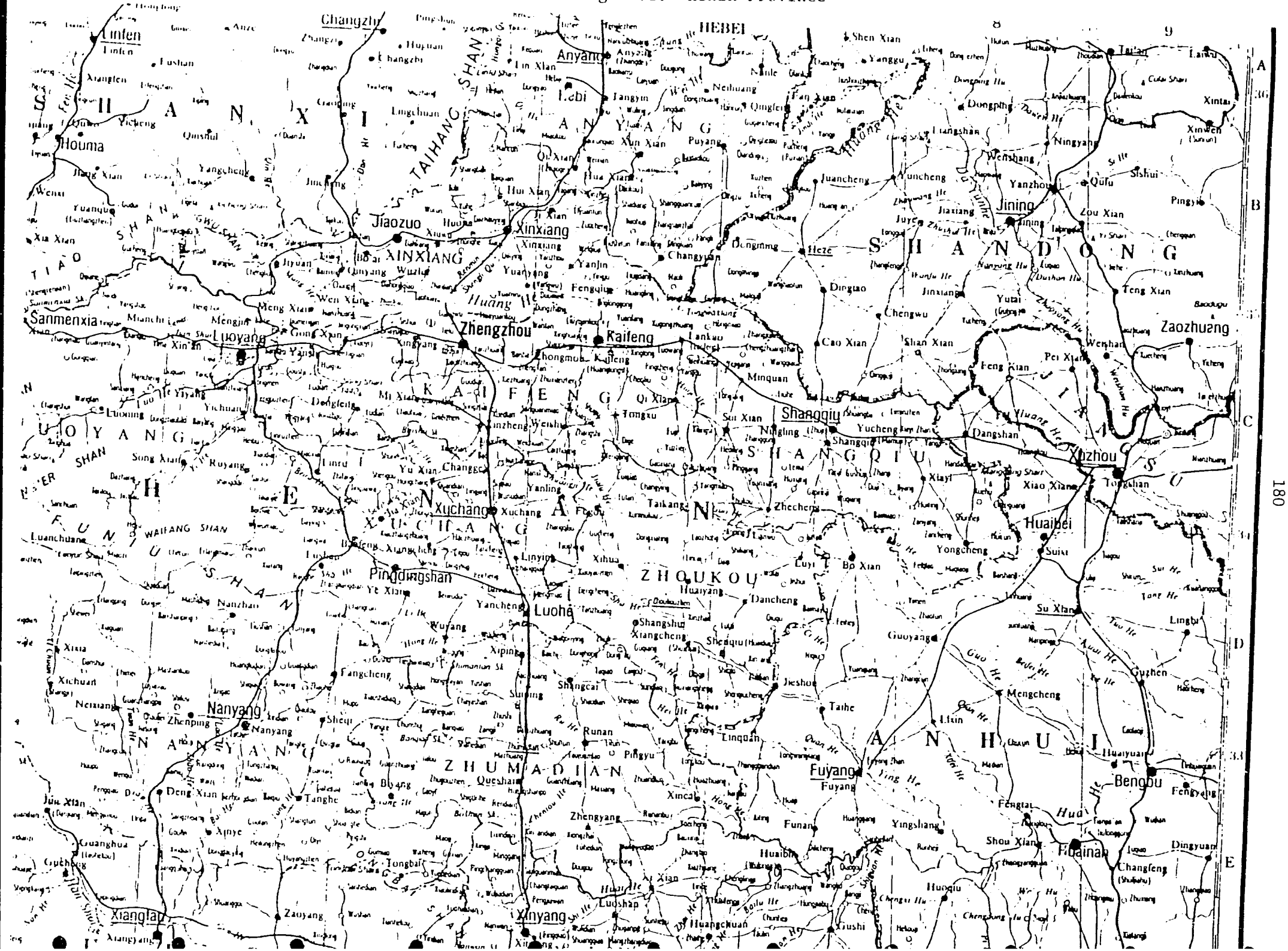
Project Site Background

The site chosen for this case history is in North China in the county seat of Linxian, located in the northernmost point of Henan Province (Figure 4.2). This is an area consisting of an extensive canal system from which numerous small-scale hydroelectric stations operate. Henan is one of four provinces classified by the Chinese as northern provinces (along with Hebei, Shanxi, and Shandong). This region, characterized by plateaus, mountains, hills and vast plains, has a long history of producing coal, iron ore, grain (rice, wheat, gaoliang), and cotton. A variety of industrial crops (sesame, peanuts, cured tobacco) and fruits (apples, pears, and dates) grow well in these provinces.

Henan in particular is considered to be in the temperate continental region, with an average annual rainfall of 700-1,000 mm. In the mountainous western sections of the province, elevations rise to 2,000 m above sea level and gradually decline toward the east to only 30 m above sea level. The province is quite mountainous, with mountain ranges covering over 25 percent of the total land area.

Objectively, Henan is rich in water resources, and Chinese energy officials estimate that the total hydroelectric potential is around 5 million kilowatt hours per year. The total wattage capacity for the province at this time,

Fig. 4.2. Henan Province



however, is 420,000 KW per year, of which 170,000 is from small-scale stations. Officials in Henan have defined small-scale hydrostations as those with one set of generators totaling no more than 1,200 each in output. At this time, Henan is utilizing only 10 percent of its potential in hydroelectric resources. In this respect, the county of Linxian, where this study was conducted, is not an exception.

Linxian is a county located in the north-central section of Henan, near the borders of Hebei and Shanxi. The county is bounded by the Zhanghe River to the north and the Qihe River to the south, both of which originate in the Taihang mountain range that traverses the area west and north (see Figure 4.2). The entire county is in the foothills of the Taihang range (Linlu shan) and averages 1,000 to 1,500 m above sea level. Linxian County consists of 15 communes, 526 production brigades, and 4,000 production teams. The total population of the county is 780,000 on a total land area of 2,046 km^2. Cultivated land totals 14,660 acres (890,000 mu). Despite the presence of the two rivers mentioned (there are two additional smaller rivers) and the annual rainfall of 700 mm, the county has been declared a drought-prone region for several decades. The major problem is that 60 percent of the rainfall comes in July and August and the remaining ten months are dry.

Because of the mountainous nature of the area, it becomes extremely difficult to extract sufficient water resources for the population of the region. During the two rainy months, the rivers in the past overflowed their banks so that the net result was ten months of drought and two months of flooding. A drought in 1942, for example, left 10,000 homeless and caused 7,000 deaths (due to what the Chinese call "water starvation"). Underground water has been explored, but is over 30 m below the surface. Over 300 of the 500 natural villages in the county had difficulty in obtaining sufficient drinking water, let alone water for irrigation. Given this general background, water management became a provincial and

a national priority after 1949, but it was not until 1957 that a full-scale water management project could begin (coinciding with the commune movement mentioned earlier).

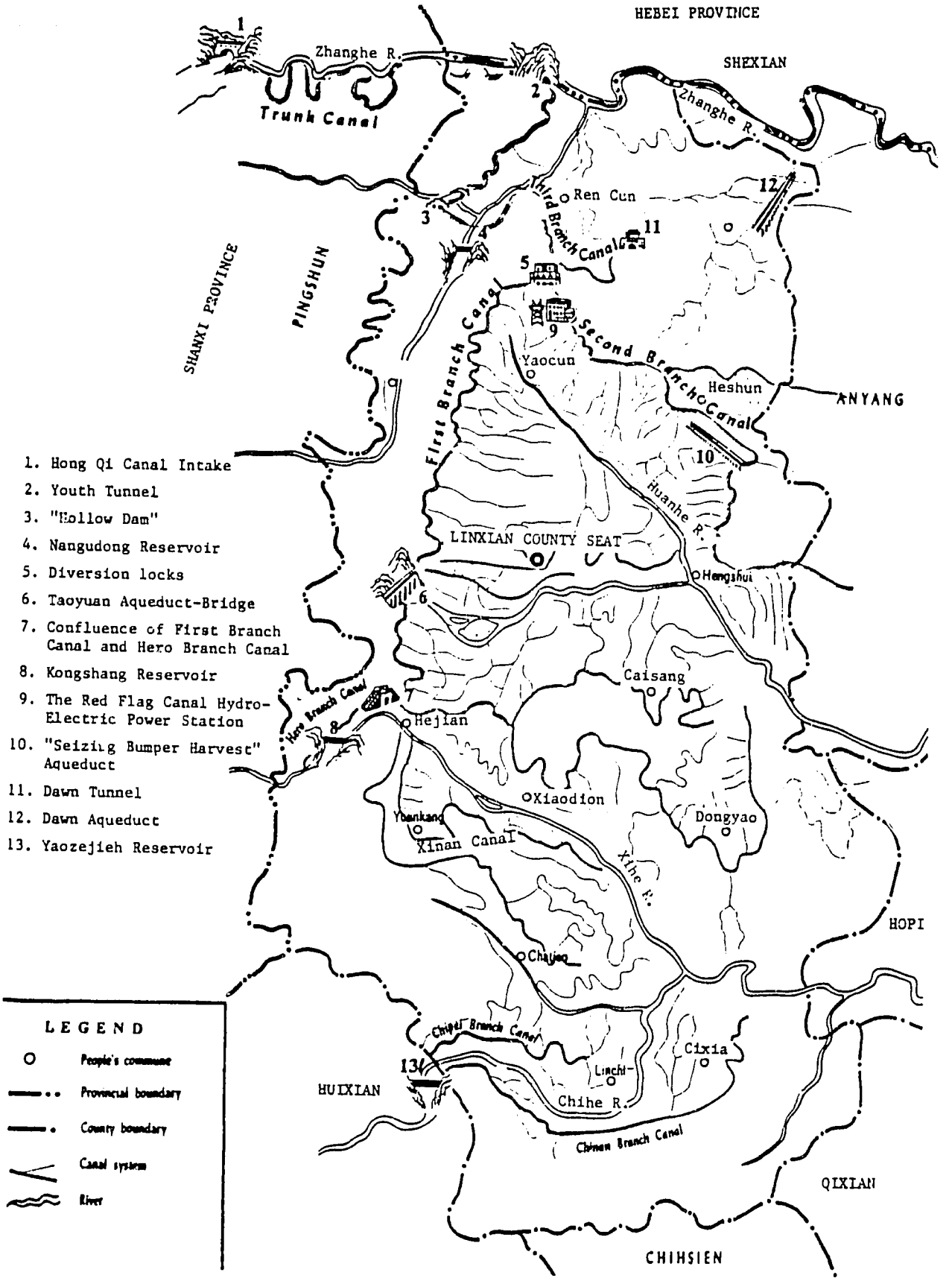
Construction of the Hongqi canal system, a massive construction project, began in 1957 and was completed in 1969. Eighty percent of the total investment came from local county sources in which over 70 million yuan (US $45 million, 1979 dollars) were invested: the remaining 20 percent was provided by central ministry funds in Beijing. The system consists of one trunk canal diversion, three main branches and 62 sub-branches. The system covers 1,500 km of waterways, 1,250 hills were excavated, 134 tunnels were dug, 150 aquaducts were constructed, and over 16 million m^3 of earth were moved. The Zhanghe River was dammed to raise the water level sufficiently to be diverted into the main trunk canal.

The entire system is located along the main range of the Taihang mountains (see Figure 4.3) and services each section of the county. At this time, there are 190 small and medium physical structures located along the canal (e.g., small enterprises, pumping stations, irrigation stations, small hydroelectric stations). The system provides irrigation for over 8,300 acres of land (500,000 mu) and over 10,000 m^3 of water are stored in 400 reservoirs. At this time, 83 small hydroelectric stations have been constructed, containing 135 sets of generators and with a total installed capacity of 17,000 KW. These stations provide the majority of Linxian's electric energy needs.

The overall development plan for Linxian specifies that investment efforts focus first on continued electricity generation; second, on coal extraction; third, on construction of fertilizer plants; and fourth, on agricultural machinery production enterprises. The electrical distribution policy is also rank-ordered, requiring that first priority go to agriculture-related machinery and industries,

Fig. 4.3.

LINXIAN COUNTY AND HONG QI CANAL



second priority to irrigation and power pumps, and third priority to household consumption (electrical lighting, power for radio sets, and the like). There are over seventy small factories in the county producing spare parts for agricultural machinery, processing grain and cotton, and producing electrical components.

The eighty or more small hydroelectric stations in the county were designed and constructed in integrated clusters. This case will focus on one such cluster of two stations, constructed during the period 1973-1977 and known as the Yaocun project. Three production brigades were involved (Rencun, Yaocun, Keguan), and the plant specifications can be seen in Figure 4.4. These two stations are representative of the many found in the area, and the project manager for both stations was also in charge of the majority of the other eighty stations.

The project manager (also chief engineer for the county), Li Shengyun, and his assistant, Sui Shengpei, were interviewed on four separate occasions; their remarks regarding the development of these projects were recorded in notes and on tape. Further interviews were held with personnel working on the project sites and with energy officials in Anyang (a city nearby, responsible for energy distribution for the region) and Zhengzhou, the capitol city of the province. Unless otherwise indicated by footnotes, the information obtained on this case is taken from interview data obtained from project personnel.

Phase I: Planning, Appraisal, and Design

China's development efforts have consisted of a mix of centralized and decentralized planning activities. The important point, however, is that planning as a process is highly regarded and extends down to the production team level in the rural areas. The project manager of the Yaocun project, Li Shengyun, was the link between the more decentralized levels (commune, production brigade, and production team). His role in the design, construction, and implementation

	Plant 1	Plant 2
Canal intake measures	Reinforced concrete, 40 m long, 2 m at greatest diameter, narrowing to 1 m	Reinforced concrete, 30 m long
Number of units	3 turbines, 3 generators, 3 governors	1 turbine, 1 generator, 1 governor
Installed capacity	320 kW/unit = 960 kW	75 kW
Turbine type	PRC-produced Francis type	PRC-produced Francis type, produced in Wuhan
Capacity of generator	400 volts each	400 volts
Annual energy generated	5 million kW-hours per year	400,000 kW-hours per year
Number transmission lines	3 feeding into integrated system to Anyang (100 km distant)	1 feeding into integrated system to Anyang (100 km distant)
Transmission voltage	6,000 volts stepped up to 35,000	6,300 volts

Fig. 4.4. The Yaocun Small-Scale Hydroelectric Plant Project, 1973-1977.

of the Yaocun project was therefore extremely critical. He was assisted by Sui Shengpei, a young engineer recently graduated from the technical university located in the capitol city of Zhengzhou. Although many committee meetings, small groups, and other interest groups were involved at various stages in the project cycle, these two individuals carried the burden of project development.

Identification and Formulation

The identification and formulation of the Yaocun project was intimately linked with county, province, and national plans. The nature of these linkages, however, was part of a complex process. Before the construction of the canal system, the idea already existed of eventually constructing a complex network of small-scale hydroelectric stations, but it was clearly third in priority. Because the region was extremely drought-prone, the first two priorities were to provide drinking water and crop irrigation. It was specified that the trunk canal was to have no hydrostations in order to assure an even flow for irrigation. The first branch of the canal system was also to be free of hydroelectric stations, and it was only with the design of the second and third branches that engineering decisions were made to provide enough water to allow the operation of small hydroelectric plants. The first hydrostations were constructed roughly 30 km from the second branch.

In one sense, then, the original intent to have small-scale hydroelectric plants came early and was already in the minds of the designers of the canal system (including Li), but it was not until the completion of the second branch in 1973 that Li's county energy office received instructions to actively "walk on two legs" (i.e., combine large-scale projects such as the canal with small-scale enterprises). These instructions were initially handed down from ministry authorities in Beijing.

The process of linking national planning with local project development runs as follows: At the central level, national plans are drawn up collectively by various administrative levels attached to the different ministries and are legitimized by these institutions. In theory, the final planning documents are presented before the National People's Congress in Beijing, to which Linxian and provincial representatives would be sent. During the period of the Yaocun project, however, the National People's Congress did not meet and all plans were approved by the State Council and implemented by subordinate institutions such as the People's Bank and the State Planning Commission (see Figure 4.5).

In the case of the Yaocun project, the Ministry of Water Conservancy and Electricity had included in its portion of the Fourth Five-Year Plan (1971-1975) a call for an increase in electricity generation for rural areas. Although this instruction was received by provincial water and power authorities in Zhengzhou and communicated downward to the county (Linxian) and commune revolutionary committees, national planning directives were not being treated seriously at this time because of the political turmoil in Beijing caused by the Cultural Revolution. This, of course, is now being blamed on the problems created by the "Gang of Four" (four top officials in Beijing, including Mao's wife, who were in virtual control of the State apparatus and who have since been arrested).

Whatever the cause, however, the net result was a lack of clear communication between central authorities and local provincial and sub-provincial authorities. More important for the Yaocun project were the local plans for agricultural development that had been initiated by provincial authorities in Zhengzhou. While the nation operates on five-year plans, the provinces function on three-year plans. In the early 1970s, these plans included a section on the development of small-scale hydroelectric stations and specifically singled out Linxian as a priority county in the region. Targets were proposed and handed down in draft form from

Commissions	Banks	Ministries
State Planning Commission State Capital Construction Commission State Price Commission	People's Bank of China Bank of China	Agriculture and Forestry Building Construction Coal Commerce Communications Defence Economic Relations with Foreign Countries Finance Foreign Trade Light Industry Machine Building (Nos. 1 to 7) Metallurgy Petroleum and Chemicals Railways Water Conservancy and Electric Power
Other special organizations under the State Council Birth Control leading group Government offices Administrative Bureau Scientific and Educational leading group State Bureau of Supplies (State Statistical Bureau?)		

Notes: 1. In the 1950s, there was a State Economic Commission responsible for annual plans, while the Planning and Capital Construction Commissions dealt with longer-term matters. Subsequently, the State Economic and State Planning Commissions were merged.

2. Some observers believe there still to be a State Statistical Bureau, but none of its personnel has been identified in recent years.

Fig. 4.5. Major planning agencies of the PRC.

Source: Christopher Howe, China's Economy: A Basic Guide. New York: Basic Books, 1978. Copyright Christopher Howe.

the Planning and Purchasing Agency in Zhengzhou to the communes, whose leaders in turn initiated discussions with county authorities (Li and Sui, in particular) and with production brigade leaders.

In a series of meetings held between these authorities, the major innovators were the leaders of the production brigades (Yaocun, Rencun, Keguan villages) and Li and his aides. All agreed that the construction of two or possibly more hydroelectric stations on their land would be beneficial to agriculture and productivity in general, but there was clear disagreement on funding and technical assistance. Because a general consensus had been reached and because provincial plans called for more construction in this area, a preliminary decision was made to proceed. The county administration, in conjunction with the revolutionary committees of the three production brigades, appointed Li as project manager. In fact, as the only qualified engineer in the area, his appointment was predetermined once the decision was made to proceed.

Li Shengyun had over twenty years of experience in leading project teams to construct small-scale hydroelectric plants, and the level of respect for his abilities was high. For this reason, support for the project idea was strong, but serious reservations were expressed by both production brigade leaders and county financial authorities. The production brigade leaders pointed out that besides the construction of two new hydroelectric stations, there might also be the necessity to construct another reservoir for storage, since maintaining a constant and even flow of water was essential to the successful operation of the plants. The alternative, they continued, would be to tap into an existing reservoir from another production brigade, and that would cause difficulty in obtaining agreement from all parties concerned.

The county-level financial authorities further reminded those at the meeting that the cost of generators, turbines, transmission lines, and the like was high

and that funds for these purposes were limited and, in fact, had recently been reduced. Funds for hydroelectric power were limited to only 20 percent of all funds available for energy purposes; if any additional funding were needed, it would have to come from the locality, that is, the three production brigades.

For his part, Li restated the general principle that "whoever builds it (e.g., a small-scale hydroelectric station), owns it and makes use of the output" and that it would be most beneficial for the three brigades to attempt to do most of the project financing themselves. He was also openly in favor of the project idea and eager to get started. This was his area of expertise and, as he stated in an interview, "business had been slow."

This first meeting ended with an agreement in principle to explore further the idea of constructing the plants, a task which fell to Li and Sui. In practical terms, the reality of this meeting was for each interest group (production brigade leaders, county energy officials, county financial authorities, and Communist Party officials) to maneuver in an effort to gain the most advantageous position in authority and control of the project, funding, responsibilities, and political responsibilities for project success or failure. The first two issues were left unresolved, but the political responsibility for the project was clearly associated with Li and his county energy associates.

Feasibility Analysis and Appraisal

In China, feasibility and appraisal studies are linked to project-specific guidelines. In other words, projects focused on water and power needs have their own general guidelines prepared by the appropriate ministry, in this case, the Ministry of Water Conservancy and Power. The planning division of the ministry has regional subdivisions (e.g., Southwest, Northwest, Central, and so on), and feasibility guidelines are prepared to assist the regions in conducting larger-scale studies. The ministry also links up with an appropriate research and

development institution (such as Qinghua University's Department of Energy in Beijing) to obtain the best technical advice possible. Since the Yaocun project was local (e.g., subprovincial), there was no direct ministry input. The regional guidelines, however, were available and on file in the Linxian County energy office. Li had access to these guidelines, but utilized them only as a general model, preferring to develop his own feasibility criteria.

There were essentially two components to the feasibility process of the Yaocun project. The first was to review feasibility data that had been collected in the early 1960s, when plans were being drawn up to construct the canal system. This was a large-scale study that utilized ministry personnel and university expertise. The feasibility group at that time consisted of Ministry of Water Conservancy and Power investment specialists, the Secretary of the Linxian County Communist Party committee, local engineers, and county and provincial administrative personnel from the departments concerned with water and power. These documents were studied primarily to gain insight into the carrying capacity of the various sub-branches of the canal and to identify potential sites for constructing the two plants.

The second component of the feasibility study involved forming a feasibility team to conduct a new study specifically related to the Yaocun project. This team consisted of Li, representing the county energy office, representatives from the canal administration, technicians from the city of Anyang (drawn from the faculty of a secondary technical school specializing in small hydroelectric plants), and representatives from the three production brigades. This more specific feasibility study was conducted in six stages

First, the production brigade representatives took the lead in discussing the idea with local farmers and influential village personnel. The purpose of this stage was to obtain opinions from the local residents, sound them out about their attitude toward the project, involve them minimally in the early stages of

planning, and generally motivate them to support the idea; this technique is known in China as the "mass line" method,

In the second stage, an initial plan of the project was drawn up by the production brigade representatives in close consultation with county-level authorities, namely Li. This plan summarized the needs of the local region, how the project would benefit the area, and what some of the problem areas might be.

In the third stage, this plan and a short report were formally submitted to the county energy authorities through Li. The Linxian County office then revised the plan, made some further recommendations based on their knowledge of the region, and resubmitted it to the production brigades for their information. The production brigade representatives still had the option at this stage to make further suggestions and recommendations, but substantive changes were not allowed.

In the fourth stage, a final county plan was subsequently drawn up. This plan was finalized by Li and Sui, and their feasibility recommendations were included in a report sent to provincial energy authorities in Zhengzhou.

In the fifth stage of this study, provincial authorities made a careful study of the feasibility report and the plan, comparing it to national planning guidelines on hydroelectric stations on file in the provincial energy office. Highly skilled technical personnel reviewed the technical portions of the report and plan and made further recommendations. At this stage, however, provincial authorities were really only concerned with two issues: First, did the plan fit in appropriately with national and provincial plans? Second, would the project be low in cost and yield quick results? Agreement was reached on these two questions and the plan received the final signatures from the provincial energy authorities.

The sixth and final stage consisted of sending the finalized feasibility study and prototype plan to all personnel concerned with the proposed project. The

motive here, as explained by Li, was to assure those who would be involved in the project that upper-level authorities were anxious to keep them informed and participating in all project planning efforts. This again is part of the "mass line" technique.

It is important to point out that at this juncture the project was not completely approved and ready to be implemented, even though the feasibility study had been conducted, input had been received from groups and individuals who would be involved in the project, and upper-level provincial authorities had signed off on the report and plan. In fact, a much more complicated and sensitive task now faced Li Shengyun, who had thus far ushered the feasibility study through all the various stages. Because of the decentralized nature of small-scale project development, the key to project success or failure lies with the production brigade, who must bear the burden of constructing, managing, and maintaining such enterprises, but who also, in theory, reap the benefits derived from operating the enterprise. Production brigade leaders, representing the ordinary Chinese villager, are wary of county and provincial schemes, which at times in the past had been costly (both materially and environmentally), had diverted labor from agriculture to the enterprises, and in some cases had utterly failed (especially during the late 1950s). Li's task, now that the provincial authorities had legitimized the project idea, was to gain the active support of the three production brigades.

He and Sui began a process of open "argument" to convince production brigade leaders of the feasibility of the project and the benefits that would come from their support in constructing, managing, and maintaining the completed hydroelectric station. A series of meetings was held in each of the three production brigades, visits were made to the proposed sites, and visits were made to other production brigades that were currently successfully operating small-scale hydroelectric stations.

This last step proved to be the most critical in convincing brigade leaders to support the project. Li took them to a small hydroelectric plant that was used by another production brigade to provide energy for grain processing enterprises, and to irrigation stations. Production figures were displayed graphically to show how production levels had risen significantly since the implementation of the small-scale hydroelectric station. The leaders of this production brigade were questioned by Li and the leaders of the three other production brigades about the problems created by the construction, management, and maintenance of the plant. When they were satisfied that the benefits far outweighed the problems, Li finally received their approval to proceed further with the Yaocun project. The key element in obtaining this last measure of support for the feasibility of the project can clearly be attributed to the demonstrative effect created by visiting a successful project of similar dimensions. In fact, this was a technique that Li had perfected over the course of many years of project management.

Two final concerns were voiced by the production brigade leaders before Li could begin the design procedures. First, they insisted that the two hydroelectric stations be built on land that was neither under cultivation (or even potentially arable) nor occupied. Because land was in scarce supply and people were extremely unwilling to move, these were logical requests and Li readily agreed.

The second concern was more serious and substantive. After reviewing their financial status, the leaders of the three production brigades had concluded that they would provide, out of their own resources, the manpower, stone masons and other skilled builders, and raw materials to build the physical plant of the two hydroelectric stations. But, they indicated, they would not provide the investments needed to contract with the county for electrical engineers, technicians, and the hardware for the plants. This must come from the county and then be turned over to the production brigades upon completion of the project, with no additional cost to the brigades.

Since he did not have the authority to agree to such a demand, Li had to return to the county seat to discuss this problem with county authorities. He utilized a technique with county authorities which was similar to one he had found successful with the production brigade leaders. Li attempted to demonstrate to Linxian authorities how beneficial two more hydroelectric stations would be to the region, reminding them that the power generated would be fed into the Anyang network (rather than consumed at a local load center), which in effect would benefit Linxian, which received its power from the network, while at the same time benefiting the three product brigades. But, he indicated, this was only feasible if the county provided all the technical expertise and hardware to complete the project and then turn it over to the brigades. In addition, he pointed out, the brigades would provide all the resources necessary to build the stations. The county and brigades reached agreement and Li began to appoint his design group.

Design

During the period 1970 to 1976, the national leadership in Beijing had become increasingly antagonistic to what they considered an overemphasis on procedures, bureaucracy, and technical expertise, particularly in relation to designing development projects. Numerous statements appeared in the national press discouraging undue reliance on technical plans and technicians in constructing and completing development projects. One expression of this sentiment was a statement by a well-known professor of the Hobei Electric Power Institute, Song Zhiping, which appeared in the influential newspaper People's Daily in 1972. The professor described his efforts to avoid technical manuals in designing projects and instead "go deep into the scene to make designs."

The atmosphere which prevailed in Linxian at the time Li began to form his design group was expressed by the slogan "design while constructing." While

this sentiment was primarily pushed by provincial capitol political authorities in the Communist Party, it was also held by some politically motivated cadres in the production brigades involved in the project. Against this background, Li had to proceed cautiously to avoid a political showdown over his methods of designing the project.

He formed his design group, consisting of two teams of individuals. The first team was composed of provincial-level technicians from the city of Anyang, where the electrical network of the region was located, Linxian County political authorities, Li's own aides (Sui and two others), and representatives from the three production brigades. The second team, which was drawn almost totally from the three brigades, was composed of stonemasons who had experience in road and bridge construction, local cadres (the political support group), and survey personnel from the county. Li remained the coordinator for both groups.

The design procedure occurred in three stages. First, the second team (now called a "reconnaissance group"), visited the sites selected for the two projects (on the twelfth sub-branch of the second main branch) and compiled survey data, in addition to drawing detailed maps of the sites. The information was turned over to the first group, who used them to draw up blueprints for the physical plant, stone work, concrete specifications, and fittings to the canal. These blueprints were the responsibility of county-level engineers, and this activity completed the second component of the design procedure. The third and final component was the preparation of designs for the installation of the electrical components. This activity was the primary responsibility of the provincial electrical engineers from Anyang.

Two additional steps remained to complete the design phase of the project. The first was to review data sources to identify the appropriate technical components for the project. These sources are provided by polytechnical

universities and research and development centers such as Qinghua University in Beijing. Available technologies are listed, complete with specifications for various kinds of components, including new and experimental devices. Once the components are identified (turbines, generators, transformers, etc.), the second stage is to determine cost for the components and put through a purchasing request. Cost determination is fairly mechanical, as all prices for electrical components are listed in official price books that change only infrequently. Some prices are negotiable; in this particular case, however, all prices were fixed.

Having completed the initial design, Li presented the blueprints and other specifications to the design group, but with the assurance that during the construction phase there would be ample opportunity to revise and alter the initial designs. In interviews conducted for this study, Li indicated that privately he believed at that time that the designs were sound and that little alteration would be necessary or desirable during construction. To protect the project politically, however, and assure that it did not deviate substantially from the directive to "design while constructing," he continued to stress the flexibility of his plans. The project thus proceeded to the second major phase.

Phase 2: Selection, Approval, and Activation

Final selection, approval, and activation of the Yaocun project occurred in several stages, as will be noted. Since this phase of the project cycle is extremely critical from an administrative and policy point of view, however, some background on political events in China at this time (1973) is advisable.

During 1973, the first stage of the project was completed. The second stage occurred in late 1973, and construction began in early 1974. The national media had been reporting in January of 1973 that the economy was in serious difficulty, especially in terms of grain production. Economic sensitivity was

present in virtually all planning and policy offices, including those in Zhengzhou, Anyang, and Linxian. The political leadership in Beijing was divided, and this circumstance was reflected in confusing policy statements emanating from the nation's capitol. In April 1973, Vice Premier Deng Xiaoping reappeared in public after being in official disgrace for more than seven years. This was a signal to project leaders like Mr. Li that more centralized, pragmatic economic policies were likely to follow.

On the other hand, in August of 1973, a large-scale political campaign was launched by a more radical faction (later identified as the "Gang of Four") to criticize Lin Piao (a military officer involved in a military coup attempt a year earlier) and Confucius. The real target of this campaign, it was widely believed, was Premier Zhou Enlai and, of course, his more pragmatic followers, such as Deng Xiaoping.

These factional disputes had an impact on provincial politics, resulting in confusion regarding approval procedures and criteria for selecting appropriate projects. It was against this background that Li Shengyun sought final approval for the Yaocun project.

Selection and Approval

As noted earlier, basic agreement had already been reached among each of the major actors in the Yaocun project. What was necessary now was for Li and his aides to go through the paces of obtaining all necessary authorizations and signatures. He now had to enter the realm of bureaucratic and legalistic procedures, a realm that in China is highly sensitive and responsive to political pressures from all national administrative offices.

The various reports, plans, and designs already completed had to be submitted through a circuitous classification route where they received a classification (e.g., regulations, notification, method, and so on), were numbered,

circulated again through specified routes, filed, and acknowledged. The appropriate offices were then to respond in the form of work reports, statistical summaries, and authorizations. There exists, however, a complex set of rules surrounding this process which are highly rigid and created enormous access problems for Li. A 24-grade system for ranking cadres such as Li was in effect at the time, and each rank carries with it an appropriate clearance for access to officials, offices, and documents. Although Li was working at a level above his rank (due to his experience and standing in the community), he was not allowed access to certain offices and officials simply because his rank did not carry sufficient clearance.

The specific procedures Li attempted to follow involved three stages for approval. The general rule of thumb for obtaining approval for hydroelectric projects was that if the generators were 100 KW or less, or total installed capacity was less than 1,000 KW, then all that was necessary for approval was the submission of blueprints, overall plan, and design to one office at the provincial level, and approval would be granted fairly swiftly. If, however, the total installed capacity was over 1,000 KW (the Yaocun proposal called for a total of 1,035 KW), then the three stages referred to had to be followed.

First, Li was required to prepare a detailed report that combined all the information so far obtained in the identification, feasibility, and design stages. As well as containing all technical data, this report was to specify exact timetables for completion and was to be submitted to the provincial energy authorities. Second, a full set of complete blueprints was to be submitted to the same office. Finally, and most troublesome for Li, the provincial authorities were to act on the first two sets of documents and assist him in preparing a revised set of blueprints which would then be approved jointly by the provincial, county, and production brigade levels.

Li prepared his documents but found it difficult to gain access to the appropriate officials to discuss with them the third stage. During 1973 and 1974, normal approval procedures, already complex and rigid, had been broken up by the numerous political campaigns that had trickled down from the national level. When he finally met with energy officials in Zhengzhou, Li found that the overall attitude was to shirk decision making and avoid taking responsibility for approval of development projects in general. Li realized that if he patiently waited for this process to work itself out, his project would be delayed perhaps as much as one year. He therefore simply bypassed this process, returned to the county level where his political support was high, and obtained final approval from the leadership of the local Communist Party committee. His strategy was that if by chance the provincial bureaucrats became upset over his unorthodox behavior, they would have to contend with the much more powerful and influential Communist Party. Since political relations between the bureaucracy and the Party were strained already, this strategy was successful. With Party leader signatures on his documents, he made one more trip to Zhengzhou to obtain funding for the electrical components. He reminded provincial authorities of the policy agreed to earlier and summed up at the time with the phrase, "if you have the nest, we provide the chicken," and funding for the electrical components was finally authorized.

The subsidies for the purchase of the electrical components were turned over to the county level, so Li had direct control over this level of funding. Funding by the three production brigades was raised by selling some surplus grain, hiring out construction teams to other production brigades in need of labor, and diverting some funds from the profits created by the sideline industries (small vegetable plots, handicrafts, and so on). The human resources were provided by the production teams associated with the production brigades. There

were twenty-two such teams between the three brigades, and each assigned ten workers to work on the project. The total manual labor work force was thus 220 workers, among whom were included skilled stonemasons, construction workers, and carpenters. The remainder were primarily young men and women who were engaged in agricultural activities but who were considered underemployed. With the funding and other resources in place, the project was now ready to be activated.

Activation

Fully activated in early 1974, the Yaocun project required about four years to complete construction and operationalize the equipment. Once all the paperwork had been approved and the funding structure established, Li proceeded to take command. From this point on, the project was organized in a paramilitary fashion. Li was in charge of "headquarters" (HQ) and his assistants from the county level (in consultation with production brigade leaders) directed the construction and later the electrical technicians. As far as construction was concerned, the production brigades were highly experienced and required little direction, nor, in fact, did they particularly care for much direction from county officials.

Two major concerns emerged at the time of project activation. First, the question of project inputs was raised. A recent directive from Beijing entitled "Build Hydroelectric Power Stations Self-Reliantly" encouraged local-level projects to acquire equipment, supplies, raw materials, and human resources from among their own resource base. Construction equipment was to be acquired locally and, if not available, constructed with local resources. Rather than buying new equipment, production brigades were encouraged to utilize old discarded equipment located in county and provincial storage areas. If problems in equipment were still present, they were to find a substitute. They were also encouraged to

start new industries if a critical material was lacking (e.g., copper refining).

These were the broad policy guidelines Li had to operate within. No real problems emerged here, since the region was rich in stone building materials and reinforced concrete reserves. Because of the previous large-scale construction work on the canal, tools were present in abundance, as were other building materials. The only real object of concern was the supply of trained personnel from among the 220 project workers. Thus, a nonformal training program was established in which master craftsmen were assigned to small groups of young workers to gradually teach them stone masonry and other construction crafts. Another program assigned older skilled workers to younger completely unskilled workers to monitor their work and point out any shortcomings. The project technical personnel and the skilled workers met daily to discuss the overall progress and especially to begin the process of identifying the brightest, most innovative of the workers on the construction crew. The purpose of this procedure was to identify roughly thirty such young people to recruit them for a more sophisticated electrical technical training program to be conducted during the installation of the electrical components. (More discussion of this education and training phase of the project cycle will take place in the section on Phase 3: Operation, Control, and Handover.)

The second major concern emerged in the assignment of job responsibilities. Li followed a principle which stated that "those on the post must be held responsible." In practice, this meant that, depending upon the post a worker held, he would be assigned to a group of tasks which had to be completed successfully during a certain time frame. There was a daily duty roster, and workers tended to follow their job cards mechanically. In addition, there was some problem with overall coordination of the tasks, which resulted in some confusion. In short, the process was too inflexible and lacked clear leadership.

Early in the construction of the two hydroelectric plants, this problem emerged and Li took action to rectify the situation. Although more leadership was exerted over task coordination, the problem of workers sticking to their job card remained. With the exception of these two areas of concern, the activation of the project was smooth and it moved into its third phase of operation.

Phase 3: Operation, Control, and Handover

This phase of the project cycle spanned the years 1974-1977, during which time political events had a significant impact on the implementation and supervision aspects of the Yaocun project. The economy continued to worsen in 1974; in December, steel production fell for the first time since 1967. Widespread factional disputes were reported in several industrial cities, especially in the steel and transport industries. Events deteriorated so much that in mid-1975, the military had to be called in to settle disputes in the railroad industry; the city Zhengzhou experienced some of this disruption. The so-called moderates and pragmatists (Deng Xiaoping and Zhou Enlai) continued to call for centralization and tighter management by professional managers and technicians. The more radical faction expressed their view that experts play little or no role in the development of small-scale industrial projects and that the "mass movement" model should be followed in all project activities.[10]

On January 10, 1976, Zhou Enlai died. Three months later, Deng Xiaoping was purged for the third time in his career. It appeared the radical faction had won this political struggle, and project leaders like Li hurried to complete their projects before another mass movement could overtake ongoing projects. With the death of Mao in September 1976, however, and the rise to power of China's current leader, Hua Guofeng, the political situation was completely reversed. The four leaders of the radical faction were arrested and Deng Xiaoping was again reinstated. It was against this sometimes confusing political

background that the Yaocun project was implemented, supervised, and completed.

Implementation

Implementation procedures had already been specified in the initial reports and blueprints submitted to the provincial and county energy offices. Li pointed out that once the HQ had been established, actual construction, installation, and implementation was fairly smooth. He had been building small-scale hydroelectric plants for twenty years and could predict many of the commoner implementation problems. With respect to the scheduling of work activities and project tasks, Li was familiar with PERT as a program evaluation technique, but noted that this technique was only used on larger-scale projects and that the task-setting method described earlier in this chapter proved more effective for small-scale projects. When problems did arise, requiring a change in design, the standard procedure was to report such changes to the county and provincial authorities prior to making any alterations.

On the Yaocun project, three minor technical problems emerged during construction: The water storage area proved to be insufficient, the building was too small for the transformer, and, following the installation of the turbine, it was found that the ball bearings were heating up. Each of these problems was solved in turn. Another production brigade agreed to share its reservoir, an addition was made to one of the buildings to accomodate the transformer, and the ball bearing problem was a simple matter of making the lubrication and cooling system more efficient.

In each of these cases, the matter was not reported any higher than the county level, even though this practice was irregular. Li's rationale regarding such an apparent violation of standard procedure was that "the central level (province) did not know or care about our technical problems, so it would simply have delayed the project needlessly."

This break in the linkage and administrative procedures was typical of many such projects during this confusing political period. The lack of clear leadership in Beijing resulted in a kind of ripple effect at the provincial level. It was reported that in 1975 there was a serious struggle for control of the major bureaus in Zhengzhou, including the energy bureau, and that this struggle created a situation in which final authority for projects such as Yaocun were left to the county level.[11]

It was also during the implementation phase that Li began the gradual process of reorganizing his HQ. The county-level personnel remained unchanged (administrators and technical professionals); with respect to the production brigade representatives, however, some shifting of personnel occurred. Originally, brigade representation focused on recognized brigade leaders (e.g., members of the brigade revolutionary committees). As construction proceeded, the procedure of recruiting the brightest and most innovative workers for further technical training was extended to including a small number of these individuals on the HQ staff (in this project, the number varied from five to seven). These people were gradually groomed to take over the management of the completed plants and therefore were brought into project management fairly easily.

Even while professionals from the county level continued to receive their regular salary, the brigade representatives were given their usual number of work points plus an incentive subsidy for taking on more responsibility. Essentially, their task was to work closely with one of the more professional administrators, who in turn acted as a management instructor. Gradually they assumed more responsibility, and by the time the project was completed, they were sufficiently trained to trial-manage the completed hydroelectric station.

Supervision and Control

Throughout 1973, the general policy on overall supervision and control of small-scale enterprises was to focus such responsibility on the localities (sub-provincial units). The role played by central forces was thus played down, at least in the major media organs.[12] Precise relationships between "center" and "local" elements, however, remained unclear. This confusion was exemplified in an article that appeared in late 1976 but that contained policy directives which had been discussed at the county level since 1973.

In this article, the author suggests that all supervisory departments be put under the direct control of the Communist Party rather than exercising themselves any autonomous decision making power. The article recognized that there was no confusion regarding the reporting mechanism and supervision of small-scale projects and simply concluded that these projects should be "led by the masses."[13]

In discussing this article, Li admitted that this kind of policy vacillation created supervision and control problems on the project site, but that since he had already built into his HQ representatives from among the brigades, including young management trainees, he suffered little criticism for being "too elitist and technical."

This did not mean that personnel problems were absent. Basically, two arenas of conflict existed among personnel. While neither was detrimental to the successful completion of the project, they serve to illustrate the kinds of problems that emerge when lines of authority are not clearly defined.

First and most serious, was a conflict that arose early in the implementation of the project regarding the role of worker participation in project management. Although Li had recruited brigade representatives and young workers to his project team, they still represented "management" in the eyes of the other

workers. There was some sentiment among the ordinary workers that they be directly represented in the project management process as well and, in fact, that worker committees should exercise overall supervision of the HQ and Li. This latter demand did not win much support among the majority of workers on the project, but it was voiced and had to be discussed at length in a series of meetings.

Li utilized the method of face-to-face meetings in dealing with the worker committees, but continued to stress the need for clear supervision relations between his HQ and the workers in general. Some of the meetings were heated, and criticism flew in both directions. The issue was never totally resolved, primarily because there were no clear directives from upper-level authorities regarding these kinds of relations (except for vague directives such as "assure that opinions that conform to Mao's revolutionary line are accepted [by management] and acted upon").

In the end, the worker demands boiled down to the issue that personnel in the HQ should also take part in productive labor and not simply manage the project. Since Li required this of his staff anyway (and he himself assisted in installation of the electrical components), this request was easier to comply with.

Another aspect of this conflict focused on the currently popular slogan, "design while constructing." This directive encouraged workers on the job site to make suggestions for changes in the project design while construction was proceeding, and each suggestion had to be dealt with individually, usually by Li himself, in a patient and genuine manner. Since most of the suggestions involved minor alterations in the construction process (utilizing a different grade of cement, making use of discarded construction materials from previous projects, and so on), there was no need to deviate from the blueprints. Li

was proud of the manner in which he handled this relationship with personnel and of the fact that he never did have to alter his blueprints.

The other arena of conflict, which occurred within the HQ, was rather minor in comparison with the first. The procurement of project inputs and the budgeting process created a conflict between the county and provincial technical specialists and the representatives of the production brigades. The former group, which had not been involved in the budget formulation, was primarily concerned with obtaining the highest quality of equipment possible. After all, they were electrical technicians trained in formal technical colleges, and they were aware of the best equipment on the market, as well as recent innovations in hydroelectric components. In addition, since they were responsible for the installation and performance of the electrical system, they were anxious that the plant operate efficiently and well. It is also important to remember that this group, the technical experts, was constantly under attack in much of the press for their elitism, arrogance, lack of practical knowledge, and so on. If the plant failed to operate properly, it would just be further evidence that "experts" did not really know what they were doing and were, in fact, irrelevant to projects such as this one. Thus, the technical personnel were willing to allocate higher amounts of funding in order to obtain the best equipment available.

The brigade representatives, on the other hand, were interested in saving money on the project. Their interests could best be served by completing the project with recycled materials, discarded machinery, and secondhand materials purchased from a variety of sources. If the project could be completed on a "self-reliant" basis, brigade leaders would gain politically in the eyes of those elements in the Communist Party and upper administration who valued this approach. Also, if previously allocated funding could be saved on this project, there was every likelihood that it could be diverted or requested for use on some other village-level improvement project.

In all of this, of course, Li was caught in the middle. As a county engineer, he recognized the point of view of the technical specialists and respected high-quality technical equipment. To maintain the good relationships we had with the brigades, however, he also had to respect their point of view and, in fact, had the image of representing their interests to the upper levels. He chose the obvious course of compromise. Since two plants were being built, a mixture of new and used equipment was purchased and the second smaller plant utilized almost all new equipment. His reasoning was that if by chance the plant with used equipment failed to operate and the new one operated well, both sides would be protected, because both could claim success in at least one plant and funding would have been saved. In the end, the project was completed with a surplus of funding, and both plants operated at full capacity with few technical problems.

Exact supervision and control procedures for maintaining quality control were also unclear at this time. In the early 1960s, a precise method for measuring quality control was worked out at the ministry level in Beijing and consisted of over seventy rules for quality assurance. Infractions of the rules often resulted in fines handed out to those in charge and even to workers on the project. In the mid-1970s, this procedure was criticized and workers were encouraged to develop their own set of quality control guidelines.[14]

Although the provincial energy offices in Zhengzhou had a similar checklist for quality control related specifically to small-scale hydroelectric projects, Li developed his own set of guidelines (after consulting those offices located in Zhengzhou). He followed a more centralized method of maintaining quality control than allowing the worker committees to set their own standards, but fines were not handed out, nor were procedures unnecessarily bureaucratic.

Finally, to complete the supervision and control process, a procedure was developed to submit monthly reports to the county and the provincial levels. Even

though provincial affairs were in turmoil during much of the time of the project cucle, Li continued to follow this procedure to the letter. Each of the two main sections of the HQ prepared specialized progress reports. The first section, composed of the director (Li) and deputy director (Sui), reported on overall progress and problems related to the project, specifically work organization, coordination, budgeting, equipment procurement, and so on. The second section, composed of specialized groups under the supervision of either the technicians or brigade representatives (e.g., canal group, electrical power group, engineering group, and so on) prepared their reports and submitted them to Li again on a monthly basis. These reports were especially useful to Li and county officials, but were perfunctory for officials at the provincial level.

Apart from these problems and issues, the operation and control of the Yaocun project proceeded smoothly. Deadlines were met, there were no snags in equipment procurement, and personnel problems (considering the potential for disruption) were kept to a minimum. Li remains convinced that an appropriate mixture of centralized HQ-type control and supervision with worker committee input is valuable. In addition, he believes, the HQ should reflect a representative mix of individuals to whom the project will be meaningful, not just those capable of technically assuring its efficient operation. The project management team can also serve as a training ground for future administrators and managers, even if this function slows down the project to some degree. In fact, this diffusion and training component proved to be most important during completion and handover.

Completion and Handover

The completion and handover tasks of the Yaocun project were carried out in 1977 in accordance with the principle stated earlier, that "whoever builds the project, owns, operates and manages it." Even though this project was a joint effort of the three production brigades, the county, and the province, it was

considered a brigade-level project.

The handover procedure occurred in three stages. First, before final handover to brigade personnel, the two plants were pilot-tested by county and provincial hydroelectric specialists. Turbines, generators, transformers, and other electrical components were testes for efficient operation and mechanical quality. Second, the plants were trial-run for two weeks. Again, this procedure was administered by county and provincial specialists (still under Li's direction) who also utilized this process to provide final training for the future managers and technicians of the plants (this process will be discussed in detail later). Third, a final report specifying technical performance was filed with the county and provincial energy offices, and the HQ was disbanded. The project was now considered completed and legally handed over to the production brigades.

The most critical phase, however, of the completion and handover stage in all development projects is the technical and management training component. Actually, as mentioned earlier, a process of worker identification began right from the start of the project to recruit bright and innovative workers from the construction crew and groom them for eventual technical and managerial positions in the completed plants. Their training actually occurred throughout the project cycle but culminated in this final stage. Thirty such workers were identified in the Yaocun project, were given informal on-the-job training as the project developed, and were also enrolled in short-term training classes located in the Yaocun brigade area.

This kind of training program was known at the time (1973-1977) as the "May 7 Peasant Colleges" and has now been renamed the "Yaocun Secondary Agricultural Technical College." Whatever the name, however, the phenomenon is the same. These institutions enroll at any one time 100 to 200 students who are in training in some area of agro-technical science. The course of study may range from two to three months to three years (although the latter is rare). Training is

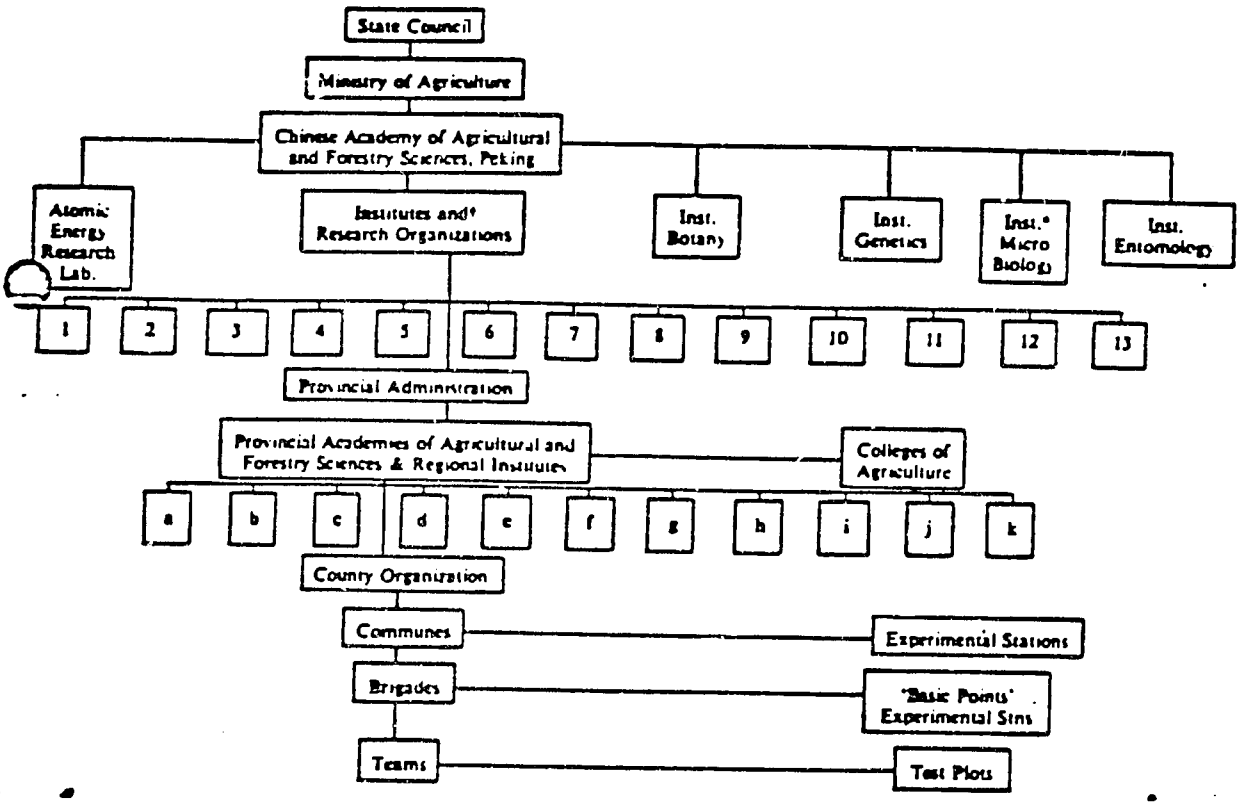
intensified and specialized. A two- to three-month course might focus on training tractor drivers, electricians, or paramedical personnel. Five- to seven- month courses are given for machinery repair, basic veterinary science, and water conservancy and power practices. More extended study (one to two years) would provide training in more technical matters such as plant protection, insect control, microbiology, project management, animal husbandry, and teacher education.

Management responsibilities for these colleges lie with county Communist Party committees in cooperation with commune and brigade revolutionary committees and linked horizontally with county and provincial agricultural departments (see Figure 4.6). Students are enrolled without age or educational restrictions, although the equivalent of a middle school (6 to 9 years) education is preferred. Once admitted, they are not required to finish the entire curriculum but may leave when they and their sponsors (in the Yaocun case, Li and his aide Sui) feel they have mastered the material. They may return when they need a refresher course or run into an unanticipated technical problem. The students continue to be paid in work points by their production brigade and work out their course of study so that they may continue to work during the day on their specific project.

The Yaocun student-workers, after their on-the-job training during the day, were released early from the project site to attend these technical training courses. Their course of study, as might be expected, focused on electrical engineering, water conservancy and power, and project management. These trainees gradually came to be considered the "backbone" of the construction crew.

When the project was completed, the plants were handed over to them. They were officially relieved from their work duties in agriculture by the brigade authorities, but retained their regular work point rate plus a subsidy which was borne by the county level.

Li recognized that this process of on-the-job training, using the demonstration method combined with short-term training classes, was time consuming and



* Includes former Institute of Applied Mycology

† Administrative control of research was decentralized during CR and many institutes were reorganized, moved to the provinces and placed under the supervision of the province to serve the needs of local agriculture. Locations are given where known.

1. Sericultural Research Institute, Chenchiang, Kiangsu
2. Institute of Agricultural Economics, Peking
3. Institute of Mechanized Agriculture, Peking
4. Institute of Animal Husbandry
5. Cotton Research Institute
6. Institute of Plant Physiology, Shanghai
7. Institute of Biochemistry, Shanghai
8. Institute of Plant Protection
9. Institute of Soils and Fertilizers, Nanking
10. Institute of Veterinary Medicine, Peking
11. Meteorology Research Laboratory, Peking
12. Institute of Pomology
13. Institute for Research into Oil Crops

a. Kirin Academy of Agricultural Science, Peking
b. Shensi Academy of Agricultural Sciences, Sian, Shensi
c. Central South Institute of Entomology, Peking
d. East China Institute of Applied Entomology, Shanghai
e. N/W Institute of Plateau Biology, Tsinghai
f. Nanking Agricultural Research Institute, Nanking, Kiangsu
g. Kwangtung Academy of Agricultural Sciences, Kwangtung
h. Liaoning Institute of Agricultural Sciences, Chaoyang, Liaoning
i. Szechwan Institute of Agricultural Sciences, Chengtu, Szechwan
j. Hunan Institute of Agricultural Sciences, Changsha, Hunan
k. Hupeh Institute of Agricultural Sciences, Wuchang, Hupeh

Fig. 4.6 Agricultural research in China.

Source: Kieran Broadbent, A Chinese/English Dictionary of China's Rural Economy. Farnham Royal, England: Commonwealth Agricultural Bureaux, 1978.

inefficient. Given the small pool of technically trained personnel in rural China, however, he and others feel that this method will continue to be used in the foreseeable future. A more systematic, formal training program is now being designed, he reports, but it will not begin to have an effect on the manpower pool for another generation.

Related to this technical training program was the dissemination and diffusion process that occurred after the plants were completed. Li's approach in the past had been to use one successful project to encourage another production brigade to begin a similar project. To do this, he made use of a highly effective extension and demonstration program. The basic goal of such an approach is to demonstrate innovative technical processes, such as small-scale hydroelectric plants, to production brigades and farmers in general. The mechanism used for this diffusion effort, called a "technical exchange station," was established by Li for the Yaocun project. The station serves primarily as a demonstration and consulting agency, operating introductory short-term classes to leaders from other production brigades on the development of small-scale hydroelectric plants. Field trips are organized to bring individuals from other brigades and communes to the project site to demonstrate the benefits of small-scale hydroelectric plants. In addition, the station publishes a variety of easy-to-read publications which discuss the project, the technical skills required to complete such a project, and generally, a how-to-do-it guide for other brigades and communes. The final activity of the technical exchange station is to sponsor forums and seminars for information exchange across brigade and commune lines. This activity continues for an unspecified period of time, generally until the target population has been reached.

With the establishment of the technical exchange station, the project was completed and fully operational. Li's county energy office remained available for consultation following handover and, as mentioned earlier, the brigade

technical school continued to provide short-term training for the new project management and technical team. The one remaining official duty for Li and his aides was to conduct an evaluation and refinement study of the project.

Phase 4: Evaluation and Refinement

In industrial and agricultural projects, the Chinese utilize a mixture of formative and summative evaluation. Moreover, during this period (1973-1977), the linkage between evaluation and policy refinement was strong, especially for small-scale projects. For small-scale projects, evaluation occurs on two levels: the project site level and the provincial level. At the project site level, formative evaluation occurs at each of the five project stages identified by the Chinese (as distinguished from the integrated project cycle format we have used in this analysis). These stages are: (1) feasibility analysis, (2) initial design (overall plan or outline of the project), (3) technical and final design, (4) actual construction, (5) design assessment. At each of these stages, summing-up meetings are held (termed "criticism, self-criticism" by the Chinese) to assess progress and problems. Rather than focusing only on problems, the meetings are designed to elicit "positive criticism." At the time of the Yaocun project, the notion of "design while constructing" was also being promoted, so recommended design changes at each of these stages were made fairly rapidly.

At the provincial level, monthly and annual evaluations of ongoing and completed projects are held. These evaluations generally take the form of conferences attended by provincial authorities and project leaders. The project leaders are required to summarize their projects and bring data to support their reports. Projects that appear to be functioning well are utilized as models for others to emulate and are promoted through a variety of official publications (e.g., trade journals, political reports, agricultural journals, and so on). Problems that are identified among project leaders are noted and summarized for

dissemination, with suggestions for correction and improvement. Because of the political turmoil during the period of the Yaocun project, provincial conferences were held irregularly and it was not until 1977, when the new government of Hua Guofeng and Deng Xiaoping was installed, that provincial-level evaluation conferences began again.

For most small-scale projects such as the Yaocun project, the more important form of evaluation was the ongoing, formative type mentioned earlier. During the course of the Yaocun project, regular meetings were held to assess each of the stages. Upon project completion, a final report was duly submitted to both the county and provincial levels. The final evaluation revealed six problem areas, some of which have already been discussed above.

1. A structural problem affected all small-scale hydroplant construction projects on the canal. Since the canal was originally constructed for water management and irrigation rather than to promote hydroelectric power, planning for this capacity was absent. The sub-branches of the canal were not structurally suited to be utilized for hydroelectric power plants, and therefore considerable reconstruction was necessary to make this adaptation. Each time a plant was built, a slightly different technique was used to cope with this problem, and each time the adaptation process became more efficient. These experiences were recorded and made available to future project leaders developing small-scale hydroelectric stations.

2. As noted earlier, the project met initial opposition from the "masses," meaning that local farmers associated with the three production brigades and their leaders were reluctant to engage in a new and possibly costly enterprise. Specifically, they did not want to divert human resources from agriculture to work on the hydroelectric construction crew and were reluctant to sink what amounted to risk capital into the initial project, the construction of the physical plant. Li was, as we have seen, able to convince them to proceed, and

the problems raised by the brigade members were recorded in the final report.

3. In view of the political events of the time, arbitrary orders were given by politically motivated cadres with little technical expertise, who were working on the project. Li and the other technicians, who had to take several political risks to protect the technical quality of the project, might have been in serious trouble if the political environment had not changed in late 1976. (This particular problem was not included in the final report.)

4. Some administrators associated with the Yaocun project (at the county level) were themselves politicians, having been promoted for aligning with the dominant political group at that time. They had little administrative experience and occasionally caused problems with the efficiency of the project, creating bottlenecks in the area of supply procurement and so on. In his final report, Li noted that this continues to be a problem and should be corrected in the future.

5. The assessment was made that the time expended in completing the project (four years) was unduly long. A project of this scale, Li noted, should be completed in less than three years. The reason given for the delay again related to the tense political situation, which on one occasion caused a complete halt in construction activities while numerous political discussions were held regarding a local investigation that was underway.

6. Finally, there were several efforts on the part of enthusiastic cadres to implement overzealously the principle of "design while constructing." Li, however, stuck to his blueprints while making some minor alterations in the overall design. He noted in his report that this principle should not be wholly discarded, but should be approached in a flexible manner. "Design while constructing" is actually a formative evaluation technique that can be used to great advantage. Mechanically following design plans that reflect only the advice and expertise of provincial and county authorities can cause as much

difficulty as constantly changing the plan. It was recommended that some balance be found between these two extremes.

As was the case with the evaluation procedure, the refinement process also occurred on two levels. First was the kind of policy and practice refinement th t resulted from the ongoing, formative evaluation that took place on the project site. This was a rapid procedure; a policy was either immediately altered or it was not. Once a recommendation was made on some aspect of the project cycle, it was acted upon at once. Because of the close relationship between the county-level authorities and Li, he was easily able to effect policy changes recommended by the formative evaluation of the project cycle. Also, local-level projects had a great deal of autonomy at this time because of the confusion over line and staff relationships at the provincial level.

It is in fact, at the provincial level that the second form of policy refinement takes place. In theory, provincial energy authorities still had overall responsibility for all energy-related projects, large or small. Provincial authorities state that they have the responsibility to assure that the principle "whoever builds the project, owns the project" is carried out correctly. Li noted that this slogan is somewhat euphemistic and actually means that provincial authorities have more power to determine energy-use factors than do the localities.

The Yaocun project is an example of this policy relationship. The provincial authorities indicated that there were two basic priorities for use of energy generated by small-scale rural projects: first, to allocate the energy to promote agricultural mechanization; second, to utilize the power to run local industries and sideline concerns. If there was a surplus of generated energy, then the provincial level would "assist" the commune or production brigade to channel it to the nearest network. The commune or brigade would then be reimbursed for such use by the electrical administration of the network.

Li stated, however, that although the administration in the locality of Linxian had been building small-scale hydroelectric stations for the past ten years, there was still a shortage in the region. The decision had been made to rationalize the complex of small-scale hydroelectric stations by pooling the electricity generated and sending it to the network in Anyang, the closest large city, about 100 km away. Linxian County, of course, would receive it back, but Li questions the equity of the policy. His recommendation, which is currently being reviewed by energy authorities in Zhengzhou, is to utilize the evaluation data from Yaocun and other projects in the Linxian area to consider revising current usage policy to assure that provincial authorities do not take advantage of their position to determine power usage inequitably. A major incentive in mobilizing farmers and workers at the production brigade level to engage in such projects as Yaocun is directly related to their perception that they will be the primary beneficiaries of the project. Should this perception be considered inaccurate, future development efforts would suffer.

What emerges in the Chinese case, then, is an emphasis on both local project evaluation and central (provincial and above) policy evaluation. At the local level, each stage of the project cycle receives some form of evaluation, even if only in the form of hastily called meetings. This form of evaluation is not formalized, does not utilize outside personnel, and is meant to result in immediate action. The evaluation carried out at the central level is summative in nature and focused on broad policy questions. The consequent refinement of policy hinges a great deal on the political relationships that prevail at the time.

During the course of the Yaocun project, the political instability that was present created an atmosphere of uncertainty and hence a lack of leadership ability, thus resulting in an ill-defined refinement mechanism. Toward the end

of the project cycle (1977), new rules and regulations were being formulated to clarify the policy refinement process. Government reorganization is currently underway and will have particular effect on the relationship between provincial and county-commune levels.

This massive policy refinement effort, along with a complete new set of national and local legal codes, has created an atmosphere of hope among project managers like Li Shengyun in China. The Yaocun project, as a microcosm of many similar small-scale energy projects, offers some lessons and generalizations for education, training, project management, and energy policy in general. It is this aspect that we will now examine.

Policy Implications of Small-Scale Energy Projects for Rural Development

This case history has features that are relevant for management, education, and energy policies. It should be recognized at the outset that this is only one case of a small-scale, rural development project out of literally thousands; whatever conclusions we can draw from the project, we must keep in mind that they are not necessarily generalizable. On the other hand, the author has visited a variety of such projects in diverse regions of China and, while each contains its own specific characteristics, there are patterns and trends that are common to many rural development projects in China. With these cautions in mind, we can proceed to summarize what might be learned from the Yaocun project.

On a macro level, it appears that the Chinese, despite numerous policy shifts, political struggles in Beijing, and corresponding political reverberations in the rural sector, have been making progress in the expansion of the role of small-scale rural development projects such as the hydroelectric project described here. The linking of small-scale projects with medium- and large-scale

enterprises in a rational and planned manner is a major goal of Chinese policy makers and one that, in the case of the Yaocun project, was successfully achieved.

As we have seen, however, it was achieved in an atmosphere of periodic confusion over the respective roles of central authorities and local subprovincial authorities. The issues raised here regarding contralization and decentralization are important. China, despite various efforts to "decentralize," remains a State economy in which the role of central authorities is preeminent. Yet the Chinese have recognized the need to bring local initiative into play in a way that does not conflict with overall national plans and goals. As the Yaocun project shows, there were several occasions where the commune and county authorities were in conflict with provincial and national authorities. These conflicts were often resolved because of the unique management and political skills possessed by the project manager, who was able either to persuade or bypass upper-level authorities in order to have the project continue on the path toward completion.

It is not likely that China (or, for that matter, many other developing nations) will abandon central-level planning for a more market-oriented form of decentralization. This being the case, the success or failure of a small-scale project such as Yaocun will often hinge on the special managerial skills of the project manager. Management training and education programs aimed at providing these skills will assume increased importance, then, in sociopolitical environments such as China's. It should be mentioned that Chinese authorities in the Ministries of Education and Industry are aware of this need and are beginning new management education programs directed toward this goal.

Related to the "centralization-decentralization" issue is the question of participatory planning. The Yaocun project has shown that early involvement of the recipients of development project outputs (in this case, the farmers of

the three production brigades) is a positive step in overcoming local-level resistance to change. It has become a truism that many development projects fail, not because the technology is inappropriate or because the project is not cost-effective, but because the local population either senses hazard or does not want to get involved.

As we examine the Yaocun project, we see that even in the feasibility stage, production brigade members were actively involved in data collection, discussions, and planning, remaining involved up to and through the handover stage. Participation of this sort can, of course, be manipulated and guided. When this is the case, however, the perception of this brand of participation becomes apparent and local-level involvement often ceases. Li was aware that people in the production brigades had to be genuinely involved in decision making, but also had to realize that there was a need for strong leadership on the project team. This mix between participation and leadership represents another area of success in the Yaocun project and perhaps offers some lessons for other projects of this type.

Finally, the critical stage of selection and approval revealed another management-realted problem, as the project manager and his team sought to move the project through the bureaucracy to obtain the necessary forms of approval. It is likely that in most developing nations, regardless of whether they have a socialist economy or a mixed-state economy, project managers will have to acquire the skills to successfully approach the bureaucratic apparatus and take the various political risks implied.

In other words, management skills alone are not sufficient to assure the successful completion of a project. The project manager must have an understanding of the political environment in which he is working and must be able to make appropriate judgments regarding timing and negotiation strategies.

Li acquired these skills due to his long experience in project management in a highly politicized environment. This level of training, which must therefore be considered a viable part of any overall management education program, represents an important research area for the future.

In the area of education and training, the Yaocun project reveals an interesting and important brand of nonformal education. During the activation phase of the project, the project team, in consultation with production brigade leaders, began the process of identifying bright, innovative, and committed workers on the project site. These individuals were thereafter cultivated, provided with specialized technical training, and gradually moved into leadership positions on the project site. This was an important step in making a smooth transition to the implementation phase. It is clear from studies of other development projects that a major problem in making this transition is the lack of skilled human resources. If the option is taken to rely on the formal school system to produce skilled middle-level technicians, a common problem is the appearance of human resource bottlenecks and the subsequent slowing of project progress as a result.

By beginning the process of training early in the project cycle, by having it occur on or near the project site, and by recruiting project workers into the middle-level technical ranks, several problems are solved at once. First, there is no need to rely on the formal school system totally for skilled and semiskilled human resources. Second, the possibility of upward mobility creates incentives among the project work crew. Third, on-the-job training results in a technical and management group that is intimately aware of all aspects of the project cycle and of the technology of the project itself.

As was evident in the Yaocun project, there are negative features to this training process as well. Two in particular stand out: the reluctance of skilled technicians from the county and provincial levels to play the role of instructors when they would rather just simply "get the job done," and the inevitable delays

that such an approach entails. For the Chinese (and possibly for many other developing nations as well), however, the benefits of this form of nonformal educational training outweigh the costs. The Chinese do not see this as a permanent sort of educational form and, in fact, are placing increased emphasis on the creation and expansion of "secondary technical schools" which will eventually take on the role of this form of training. Until this expansion occurs, however, the Chinese will continue to rely heavily on nonformal education. This also represents another important area for research.

Finally, the Chinese appear to be convinced of the utility of combining large-scale energy related projects with small- and medium-scale projects. Large-scale projects still remain an important component of overall energy policy in China because of economies of scale. It is still recognized, however, that large hydroelectric projects in particular present serious environmental and social problems; they are difficult to manage and demand a more advanced infrastructure to support and efficiently consume the electricity generated. Chinese officials also noted that large dams have major siltation problems which are avoided by the smaller-scale projects and certainly those working from a canal system.

Another advantage of small-scale systems such as Yaocun is the multiple use that can be made of the water resources utilized for electricity generation. As we have seen, the canal was constructed first to provide adequate water resources for drinking, cooking, farming, irrigation, and other such uses. The adaption of the canal system to accomodate small-scale hydroelectric projects was clearly an added advantage to the region, despite initial reluctance on the part of the local population.

In sum, the Yaocun project provided a certain amount of security to the region in at least two ways: First, the supply of electricity was clearly increased to consumers who were too distant from Anyang to benefit from the larger source of electricity. Second, the contribution of the small plants to the Anyang

network contributed to an overall savings, especially during peak demand periods. Given China's extensive water resources and the current problems associated with fossil fuels, it is likely that both large- and small-scale hydroelectric projects will remain a high priority for China's overall energy policy.

NOTES

1. For a more complete discussion of the transfer-transformation dilemma, see John N. Hawkins, "Technique Transformation and Rural Education in the People's Republic of China," Technology Forecasting and Social Change, Vol. II, No. 4, April 1978.

2. Christopher Howe, China's Economy (New York: Basic Books, 1978), p. 87.

3. Interviews with energy officials at Qinghua University, July 1979, Beijing.

4. United States Central Intelligence Agency, Seven Research Aids on the People's Republic of China (October 1973-May 1975), microfilm.

5. Additional information on the Chinese energy scene can be found in: Vaclav Smil, China's Energy: Achievements, Problems, Prospects (New York: Praeger, 1976).

6. United States Central Intelligence Agency, Seven Research Aids.

7. Howe, China's Economy; Jan S. Prybla, The Chinese Economy: Problems and Policies (Columbia, South Carolina: The University of South Carolina Press, 1978).

8. This summary of the structure of the commune is based on the author's own observations and those of others. See, for example, Prybla, The Chinese Economy.

9. Hongqi [Red Flag], No. 4, 1975.

10. Hongqi, No. 6, 1973.

11. Renmin Ribao [People's Daily], May 14, 1974.

12. Hongqi, No. 12, 1973.

13. Gong Xiawen, Xuexi Yu Pipan [Study and Criticism], September 14, 1976.

14. Survey of the People's Republic of China Magazines, No. 892 (October 12, 1976).

CASE 5

THE PHILIPPINES: TALOMO RIVER AND BALIGUIAN RIVER MINI-HYDRO PROJECTS

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INTRODUCTION

In the Philippines, waterways have always been of prime importance. The country is composed of about 7,100 islands separated by bodies of water and 172 principal rivers, streams, and lakes.[1] These water resources have served to transport people and cargo and have provided water for drinking, sanitation, washing, and irrigation; the development of towns and villages during historic times has usually centered around sites accessible to seas, rivers, and lakes.

Waterways were first used as sources of power in the Philippines during the early decades of the 1900s. The earliest known hydroelectric project was a small installation built in 1914 at an American base, Camp John Hay, Baguio City, in the northern Philippines. As of 1977, thirty known small or mini-hydro projects were in operation. Considering the country's abundance of rivers and streams, an enormous potential remains untapped.

In the late 1970s, the government of the Philippines developed a strategy to maximize use of indigenous power sources and hence reduce its dependence on imported petroleum fuel. Regenerative sources of power, such as hydro, geothermal, dendrothermal (energy plantations), solar and biomass, as well as finite resources, such as petroleum, coal, and uranium, are being harnessed to supply the country's energy requirements. According to the Ministry of Energy's Ten-Year Energy Program 1980-1989, government strategy is to reduce dependence on imported crude oil representing 95 percent of Philippine energy requirements in 1977 to 31 percent by 1989.[2]

In terms of the national energy mix, hydroelectricity's share of the total commercial energy requirement was 6.4 percent in 1979. This share is expected to increase to 12.8 percent in 1989. In volume, from an output of 5.84 million barrels-of-oil-equivalent (MMBOE) in 1979, the energy output from hydroelectric resources is expected to increase to 23.35 MMBOE. Of the non-oil

sources of energy, hydroelectric power is expected to represent the largest single energy resource in 1989. The significance of this figure lies in the fact that hydroelectricity is a regenerative energy resource.

In 1979, the National Power Corporation (NPC) operated seven major hydroelectric plants with a combined capacity of 899 MW. The NPC also operated small hydroelectric plants whose output represented a little more than 1 percent increased power capacity (9 MW). Estimated potential capacity for large-scale hydro projects along major water basins in the Philippines is 8,000 MW, so this means that only 13 percent has so far been developed. Approximately 50 percent of the hydro potential is targeted for development in the next decade. For mini-hydros, a total of 4,539 sites have been identified as potential sources of power. Of these sites, only 846 had data available in early 1980 for estimation of power potential. From the 846 sites, therefore, an estimated 843 MW can be generated. Two hundred and thirty-nine sites are programmed for development from 1980 to 1987 to increase capacity by 305 MW.

The Ten-Year Energy Program 1980-1989 indicates that hydroelectric development in the Philippines is increasing and will be site specific. Types of hydro projects selected for installation will depend on conditions in various regions of the country. In Luzon, which has distinct wet and dry seasons, storage and multipurpose hydro projects will be constructed so that water for irrigation is available during the dry months and flood control will be possible during the rainy season. In the Visayas, which has a multitude of smaller islands and no significant watersheds, the thrust is towards decentralized mini-hydro development. In Mindanao, where rainfall is even throughout the year (unlike Luzon), multipurpose hydro projects for flood control or irrigation are less of a requirement; hydro resources in the area can therefore be tapped principally for power requirements. The tremendous power potential in

Mindanao will be tapped mainly for large-scale power generation. As Table 5.1 indicates, the installed generating capacities for hydro and the other energy sources projected by region follow this pattern.

Table 5.1.

INSTALLED GENERATING CAPACITIES, BY REGION

	1979		1984		1989	
	MW	%	MW	%	MW	%
Luzon						
Hydro	546	17.44	1,255	31.51	2,617	43.20
Other resources	2,584	82.56	2,728	68.49	3,440	56.80
Subtotal	3,130	100.00	3,983	100.00	6,057	100.00
Visayas						
Hydro	3	0.74	30	2.75	170	11.16
Other resources	404	99.26	1,060	97.25	1,354	88.84
Subtotal	407	100.00	1,090	100.00	1,524	100.00
Mindanao						
Hydro	385	62.10	756	62.43	1,486	72.70
Other resources	235	37.90	455	37.57	558	27.30
Subtotal	620	100.00	1,211	100.00	2,044	100.00
Philippines						
Hydro	934	22.47	2,041	32.48	4,273	44.39
Other resources	3,223	77.53	4,243	67.52	5,352	55.61
TOTAL	4,157	100.00	6,284	100.00	9,625	100.00

Source: Ministry of Energy, Ten-Year Energy Program 1980-1989, Manila, January 1980, p. 63.

Mini-hydro projects are intended to make a distinct contribution to the energy development program. Although the total absolute energy contribution from the projects may represent minimal power supply in terms of megawatts, mini-hydro projects are nonetheless capable of supplying unique needs. For rural communities that have no access to the power grids of Luzon, Visayas, or Mindanao and are therefore energized through diesel generators or not energized at all, mini-hydroelectric plants are a blessing. The promise they bring is that of rural development and progress through a reasonably priced and dependable energy supply.

In July of 1980, President Ferdinand E. Marcos ordered an acceleration of the country's energy program, highlighting the immediate development of mini-hydro power as a secondary source of energy. The rural areas, therefore, would be the immediate beneficiaries of the accelerated energy program.

This chapter will examine two power programs initiated by the Philippine government to develop small water power resources. The first was a six-year small hydro program to develop 8 MW capacity through ten projects during the period following World War II. This program ended in the 1950s and resulted in many projects which are still providing electricity to rural areas. The subsequent program, a current one, aims to develop an incremental 305 MW capacity through mini-hydros by 1987.

Many agencies of the government have a role to play in the development of energy and the use of water resources. This chapter will focus on three principal agencies: the Ministry of Energy, which is charged with the overall planning and development of energy resources in the country; the National Power Corporation, a corporation under the Ministry of Energy responsible for development of power from hydro and other resources and distribution of that power; and the National Electrification Administration (NEA), in charge of

the development of rural electrification and recently designated the agency with primary responsibility to develop small hydro projects[3] for rural power. Letter of Instruction No. 892, issued by President Marcos in July of 1979, orders that the National Electrification Administration should be the agency of government to promote small hydro projects for rural power up to 5,000 kW; projects of over 5,000 kW were to be pursued after consultation with the National Power Corporation.

Small Hydro Program of 1948

A program to develop small hydro projects was pursued by the National Power Corporation, a government agency created on November 3, 1936 under Commonwealth Act No. 120 to undertake the development of hydroelectric and other natural sources of power generation. This program was started in 1947 and continued during the decade of the 1950s.

From the start of its operations in 1936, the NPC conducted surveys, investigations, and studies of river systems in the country and compiled all existing data on locally available power. The corporation initiated the construction of its first major hydro project--the Caliraya River Hydroelectric Project--with an initial 27 MW capacity in 1939.

After World War II, during which the country was devastated, all economic development plans for the Philippines advocated a shift of the national economy from purely agricultural to semiindustrial. Industrialization necessitated power development, hence the urgent need for tapping a known abundant power resource--hydro power. The government was interested in the development of power not only for industry, but to improve the quality of life of the population.

In 1947, a Philippine Power Program was prepared as a result of an agreement made in March 1947 between the Philippine government and Westinghouse

Electric International Company. The agreement provided that the latter was to undertake the preparation of a power program for the Philippines, as well as provide data necessary for securing loans to fund the execution of the projects recommended. The National Power Corporation cooperated in this agreement, and Mr. Filemon C. Rodriguez, then chief engineer and acting assistant manager of the NPC (later he became NPC manager), was designated Philippine representative to work with Westinghouse. In 1938, he was commissioned by Manuel Roxas, then secretary of the National Economic Council and later President of the Philippines, to chair a committee of specialists looking into the country's energy situation. In 1938, the committee came out with a comprehensive report, Power and Fuels of the Philippines, which contained the first total evaluation of water power potential in the country done from map study. The report also included chapters on power and fuel utilization in the country, diesel and gasoline power, steam and gas power, domestic coal and mineral oil supplies, the suitability of alcohol as motor fuel, and the use of vegetable oil as a motor fuel.

The Philippine Power Program was submitted by Westinghouse in January 1948. The program consisted of two parts: the long-range overall program for the installation of power plants in different parts of the country covering the period up to 1960, and an initial program identifying specific projects. Focusing on major power projects, the program covered the power requirements of the Baguio-Central Luzon-Manila area in Luzon and the Maria Cristina Falls area in Mindanao. The requirements for the rest of the country were indicated in the long-range schedule.

Because there was an immediate need for power in areas other than those specified for development in the Philippine Power Program of 1947, the National Power Board of the NPC approved a complementary program of small hydro projects

scattered over the Philippines. Funding for the project would come mainly from NPC financial resources. This small hydro program was expected to be operational in 1948, simultaneous with the major hydro program, therefore effecting a wide distribution of the benefits of electricity among the population.

Ten sites were initially identified in the six-year program of small hydro projects; six in Luzon, two in the Visayas, and two in Mindanao. A total of 8 MW capacity was expected to be developed, requiring a financing outlay of ₱10 million. A total of thirty-eight towns and cities were expected to benefit from this program. Figure 5.1 is a map showing the proposed development sites, Figure 5.2 depicts the schedule of construction, and Table 5.2 the installed capacity to be available under this program as of 1948. Although initially scheduled for the period 1948-1955, the flexible six-year program was expected to be modified yearly on the basis of new data and conditions. For example, the Peñaranda and Talavera projects, originally part of the program, were set back because major hydro projects on the Agno River were going to serve the same target areas more economically.

A majority of the projects scheduled for construction were completed under the small hydro program in the 1950s and early 1960s. Table 5.3 is a summary of the completed small hydro projects which were being operated by the NPC as of 1978.

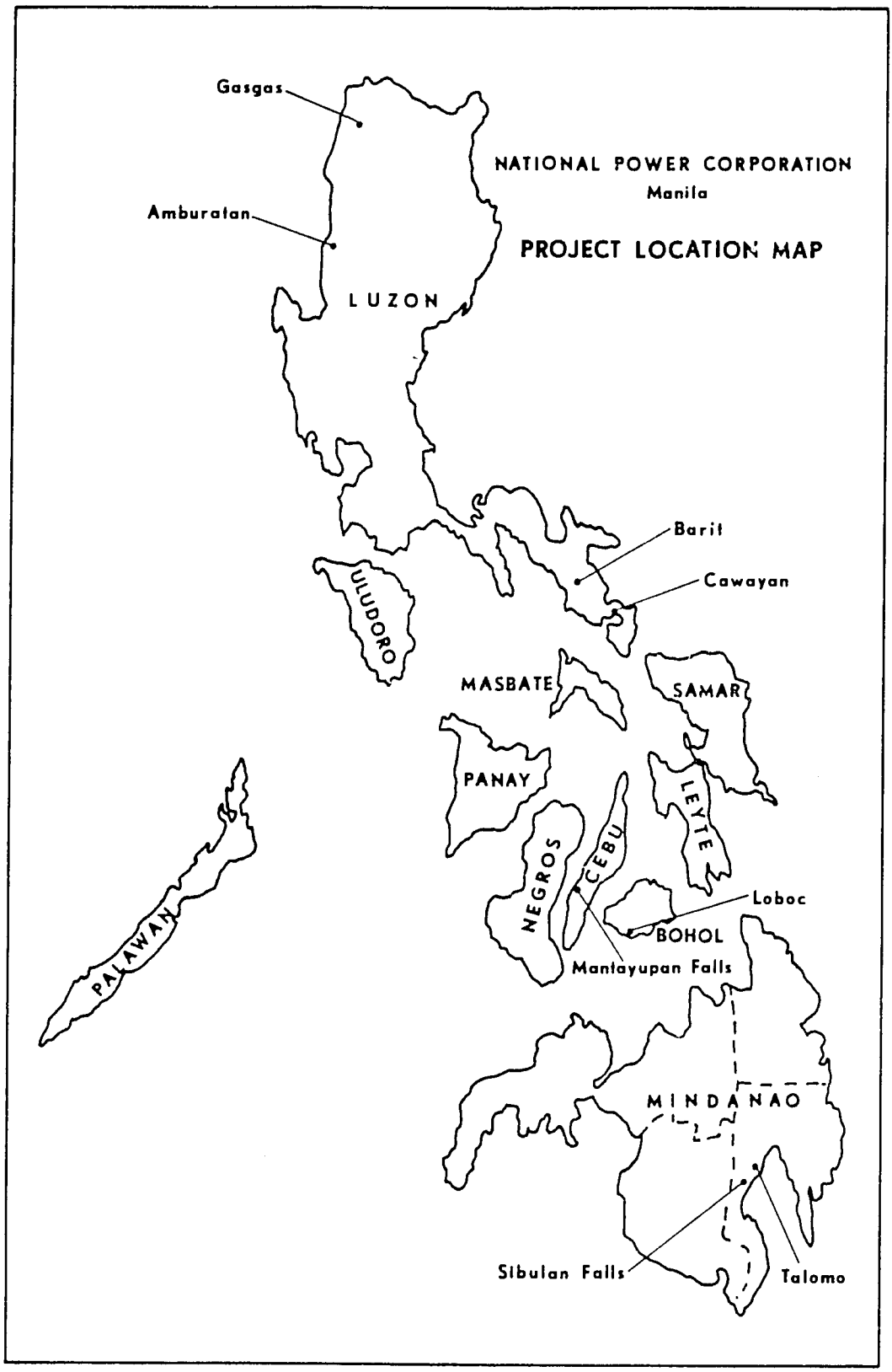
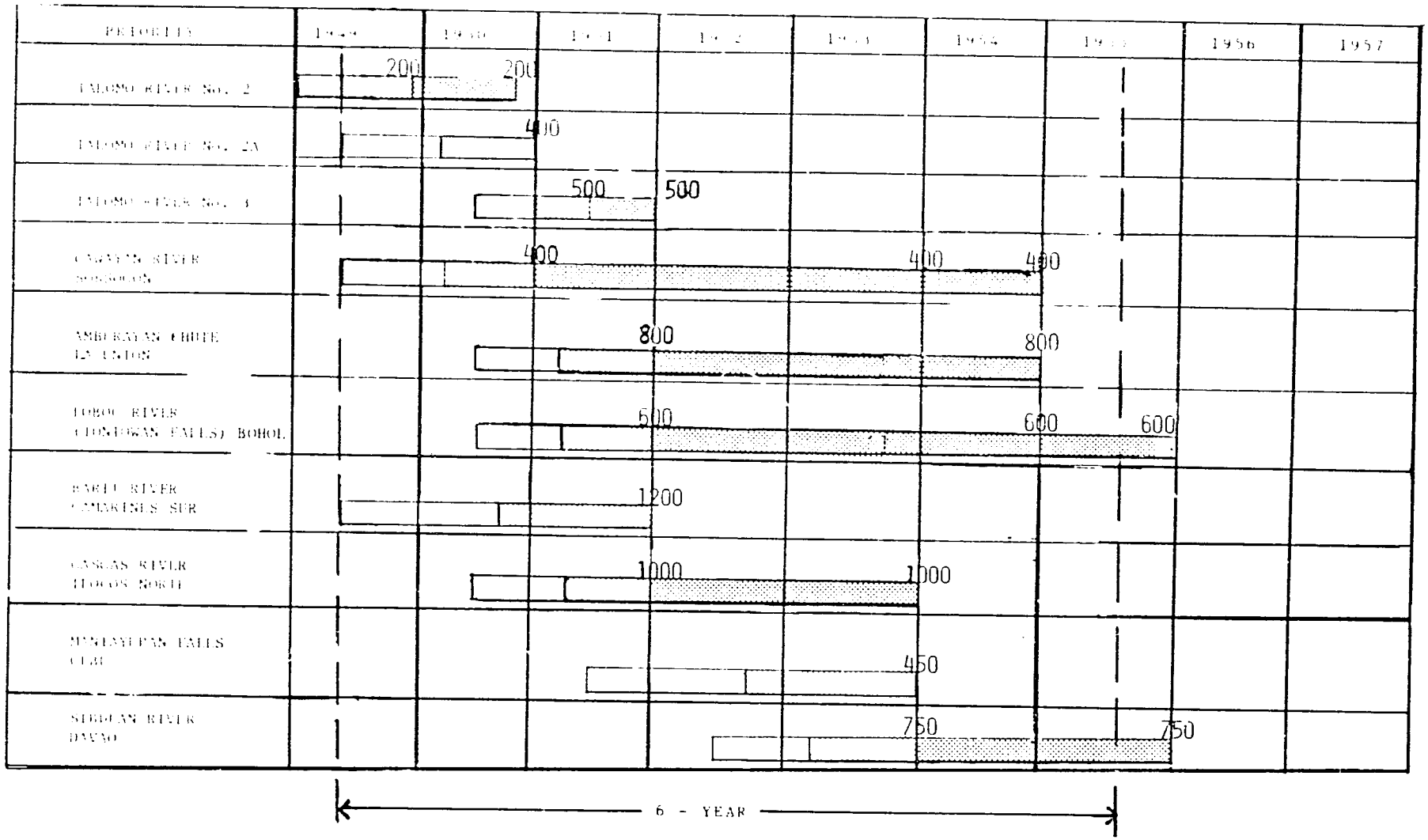


Fig. 5.1. Small hydro program 1949.

Source: National Power Corporation, Annual Report, 1949.



Surveys, designs - plans - specifications, estimates, advertisements, award of contracts, etc.

Construction period, initial generating station and limited transmission and distribution facilities.

Period of expansion of transmission and distribution facilities and Erection of Additional generating units.

Figures noted above each graph indicate the capacity in KWS installed at the end of the construction period and capacity in KWS added during and at the end of the expansion period.

Fig. 5.2. Small hydro program 1949: schedule of construction.
Source: National Power Corporation, Annual Report, 1949.

Table 5.2

ESTIMATED ANNUAL EXPENDITURES* FOR THE 6-YEAR POWER PROGRAM

(Pesos)

SCHEDULE OF APPROPRIATIONS

FISCAL YEAR	1949 - 50	1950 - 51	1951 - 52	1952 - 53	1953 - 54	1954 - 55	TOTAL CAPITAL INVESTMENT
TALOMO RIVER NO. 2	260,000						260,000
TALOMO RIVER NO. 2A	200,000	200,000					400,000
TALOMO RIVER NO. 3		500,000	600,000				1,100,000
CAWAYAN RIVER SORSOGON	150,000	200,000			160,000	170,000	680,000
AMBURAYAN CHUTE LA UNION		120,000	100,000			180,000	400,000
LOBOC RIVER TONTONAN FALLS, BOHOL		300,000	330,000			400,000	1,030,000
BARIT RIVER CAMARINES SUR	300,000	400,000	500,000				1,200,000 ANOTHER UNIT OF 1800 kw NOT INCLUDED IN THIS ESTIMATE
GASGAS RIVER ILOCOS NORTE		500,000	600,000	500,000	400,000		2,000,000
MANTAYUPAN FALLS BOHOL			150,000	300,000	300,000		750,000
SIBULAN RIVER DAVAO				300,000	300,000	300,000	900,000
TOTAL YEARLY EXPENDITURES	910,000	2,220,000	2,280,000	1,100,000	1,160,000	1,050,000	8,720,000

*AMOUNTS SHOWN IN PHILIPPINE PESOS.

Source: National Power Corporation, Annual Report, 1949.

Table 5.3

SUMMARY OF NATIONAL POWER CORPORATION"S OPERATING MINI-HYDRO PROJECTS

	Plant Capacity	Start of Construction
Luzon Plants:		
Balongbong Hydro	0.2	May 1954
Cawayan Hydro	0.4	October 1957
Lake Buhi-Barit	1.8	March 1955
Visayas Plants:		
Amlan Hydro	0.8	September 1958
Loboc Hydro	1.2	September 1955
Mindanao Plants:		
Agusan Hydro	1.6	May 1956
Talomo River Hydro	3.1	May 1949

Source: National Power Corporation, System Development Division, Statistical Data of NPC Operating Plants, Manila, January 1978.

In the 1950s, the NPC operations were greatly expanded. Laws were passed by the Philippine Congress authorizing the NPC to borrow money from international financing institutions to provide for the dollar cost of its projects. Many major hydroelectric plants, such as the 75-MW Ambuklao plant and the 100-MW Binga plant, were started during this decade. All the existing mini-hydroelectric plants of the NPC started construction during this decade (see Table 5.3), except for Talomo No. 2, which started earlier.

In 1962, the Philippine government, in a measure to stabilize the monetary situation, devalued its currency. The decontrol measures, however, resulted in a relative increase in the cost of imported goods such as equipment. As a

result, in 1962 the NPC limited its minimum requisite for development of rivers as hydro projects to 1,000 kW under favorable topographical conditions, available head, and river flow. Minor projects were considered uneconomical as a result of increased prices of materials and equipment.

In 1963, the NPC gave more emphasis to the investigation, planning, and construction of major projects. The corporation still responded to requests from provincial and municipal governments to investigate small streams for possible development by another agency, the Electrification Administration.

Because of budgetary constraints, the NPC used a criteria to limit and select the number of rivers and streams to be investigated. The criteria developed included: economic feasibility, service to the most number of people, and equitable distribution of power projects among the various regions of the country.

The NPC program in the 1960s and 1970s, then, concentrated in large part on major power projects. These projects tapped hydroelectric, diesel, thermal, geothermal, and presently under construction--nuclear--sources of power. The majority of the projects are in Luzon, where the capitol and a large percentage of the population are located.

Mini-Hydro Program of 1979

During the 1960s, many rural areas in the country had little or no power. Some rural cities had small generators capable of supplying only lighting requirements. Because one government thrust was to develop rural areas, and in recognition of the fact that electrification played a very important role in rural development and industrialization, a government agency was set up to undertake rural electrification. The Electrification Administration was created in 1962 under Republic Act No. 2717. This agency eventually became the National Electrification Administration in 1969 when President Marcos

signed Republic Act No. 6038, abolishing the Electrification Administration and creating this agency in its stead.

The primary objective of the NEA is to undertake the rural electrification program on an area coverage basis with electric cooperatives as the primary medium. The electrification program aims to bring the benefits of electricity to the rural areas by providing needed power for income-generating industries and irrigation systems for increased agricultural production. The long-range objective of the NEA is to attain the total electrification of the country by 1990 and to provide electrification to all barrios (small villages or communities) by 1984.

With the advent of the oil crisis and a rapid escalation in the price of oil, policy emphasis was placed on seeking indigenous sources of power. The economics of power production from streams and rivers were reexamined, and the NEA was given the mandate to prepare studies for and implement a Mini-Hydro Program under Presidential Decree No. 1645.

In 1979, the NEA 1979 Progress Report indicated that 36 mini-hydro project prefeasibility studies were completed. Other activities during the year included the acceptance of a grant of 5 million kroners from Norway for the preparation of studies on mini-hydro development in the islands of Bohol, Antique, and Mindoro, as well as visits to the People's Republic of China to discuss the mechanics for a joint Philippine-Chinese venture in manufacturing mini-hydro power plant equipment.

By early 1980, the NEA had loans available from France, China, and the Federal Republic of Germany, in addition to the Norwegian loan and its support from the U.S. Agency for International Development (AID) for the development of mini-hydro projects. The NEA identified specific projects to be funded under the loan agreements and prepared a map showing the proposed development of sites under the various loan packages.

The NEA has also planned for the development of local expertise in the technology of mini-hydros. Aside from encouraging local innovation and design, the agency has negotiated with the People's Republic of China for the transfer of technology in the fabrication of generators and hydraulic turbines. In April 1980, President Marcos gave approval for a licensing agreement between Atlantic, Gulf & Pacific Company of Manila, Inc. and the China National Machinery and Equipment Import and Export Corporation to transfer technology for manufacturing mini-hydraulic turbines; a cooperative production agreement between Philippine Electric Corporation and the China National Machinery and Equipment Import and Export Corporation to transfer technical knowledge of mini-hydraulic generators; and an agreement of cooperation between the China National Machinery and Equipment Import and Export Corporation and the National Electrification Administration on the financing and supply of mini-hydro electric generating units.

The 1980 schedule for mini-hydro development indicates that a total of 305 MW in incremental capacity will be available by 1987 and will cost a total of ₱2.8 billion and $2.0 billion in foreign exchange. Table 5.4 projects the development plan for mini-hydro projects on a yearly basis up to 1987. Table 5.5 shows the development plan by region.

Table 5.4

PROPOSED SCHEDULE OF DEVELOPMENT FOR MINI-HYDRO PROJECTS
(in MW)

Year	Megawatts
1981	16.0
1982	29.0
1983	40.0
1984	45.0
1985	55.0
1986	59.0
1987	61.0
Total	305.0

Source: National Electrification Administration.

Table 5.5

THE PROPOSED MINI-HYDRO PROGRAM DEVELOPMENT BY REGION
(in MW)

	Number of Rivers and Streams	1981	1982	1983	1984	1985	1986	1987	Total
Luzon									
Region I	39	3.34	2.30	5.91	9.70	2.67	10.14	16.58	50.64
Region II	26	3.56	5.42	-	7.80	6.90	7.72	20.98	52.27
Region III	24	2.28	2.00	8.70	5.50	7.40	9.22	5.94	41.04
Region IV	19	-	2.50	2.70	3.70	9.35	5.60	3.16	27.01
Region V	16	-	3.54	3.54	4.10	0.80	-	-	11.98
Total	124	9.18	15.76	20.85	30.80	27.12	32.68	46.56	182.94
Visayas									
Region VI	24	6.03	1.98	2.50	1.50	3.50	9.06	8.10	32.67
Region VII	18	-	0.50	4.25	2.40	2.80	3.70	3.30	16.95
Region VIII	14	0.94	8.74	7.60	0.75	-	1.70	-	19.73
Total	56	6.97	11.22	14.35	4.65	6.30	14.46	11.40	69.35
Mindanao									
Region IX	5	-	1.00	-	0.51	-	6.20	-	7.71
Region X	11	-	0.20	1.80	2.80	6.20	-	0.28	11.28
Region XI	14	-	0.80	2.00	2.86	8.99	2.10	3.00	19.75
Region XII	16	-	-	1.00	3.55	6.56	3.88	-	14.99
Total	46	0.00	2.00	4.80	9.72	21.75	12.18	3.28	53.73
TOTAL	126	16.15	29.98	40.00	45.17	55.17	59.32	61.23	306.02

Source: National Electrification Administration.

The long-range objective of the NEA program is to supply the total energy requirements corresponding to residential, commercial, and small industrial loads of electric cooperatives in Luzon, Visayas, and selected Mindanao areas by the year 2000. This program is to be accomplished through three types of programs: dendrothermal, mini-hydro, and small water-impounding projects.

The Case Histories

This chapter will present case histories of mini-hydroelectric projects at two sites: the Talomo River in Davao and the Baliguian River in Camarines Sur. The first project is located in Region XI in Mindanao and the second is located in Region V in Luzon.

Each project represents an initial attempt by a new government program to develop power from small hydroelectric resources. The Talomo project, directed by the National Power Corporation, began in 1949. The Baliguian project, undertaken by an electric cooperative under the National Electrification Administration, started in 1979 and is thus newly operational at the present time. The cases highlight the concrete steps taken to develop local or indigenous energy resources in the Philippines under varying conditions. There is approximately a three-decade time span between the planning for these projects, during which time world conditions have changed, especially in relation to energy economics and technology. In the Philippines, these changes have been felt and rapidly acted on with new energy policies and programs.

TALOMO RIVER PROJECT

PROJECT BACKGROUND

Davao City is a progressive city located in Davao Province, Mindanao. About fifteen times the size of the city of Manila and said to be large than London and New York put together, its total land surface area is 244,000

hectares;[4] the city is the main port and commercial center of Southern Mindanao.

The municipality of Davao became a Chartered City on March 1, 1937 under Commonwealth Act No. 51. Before that time, it was a settlement under the Spaniards and later a municipality. The city is located in Davao del Sur in the region of Mindanao in the Southern Philippines. Davao is an area known for its abundance of natural resources. The province has numerous agricultural plantations that grow banana, corn, coconut, and abaca (hemp). Because of good soil fertility, a mild typhoon-free climate, and adequate rainfall, average yield for the crops is generally higher than in the rest of the country. The area is also rich in logging and forestry resources as well as marine and mineral resources.

In the early 1900s, plantations were already operating in the Davao area, and plantation owners were in need of industrious laborers for their abaca crops. A certain Mr. K.S. Ohta, a Japanese merchant-cum-contractor, arranged for Japanese laborers--who had previously been brought to the Philippines by American builders of roads in the Mountain Province in Luzon--to work on the Davao plantations. Ohta eventually established his own abaca plantation; by the end of 1919, the Ohta Development Company operated thirteen other companies in addition to its original land holdings.

The Ohta Development Company operated a 260-kW hydroelectric plant at Mintal on the Talomo River to satisfy its power needs. This plant consisted of a low masonry diversion weir across the river, 2 m high and 85 m long; an open canal with three flumes at a carrying capacity of 3 m^3/sec, 2,006 m long, ending in a small creek; another open canal 1,080 m long, branching from the creek and conducting the water to the river bank at a point about 3 km downstream of the diversion weir; and a power plant on the river bed below the end of the second canal. The Japanese power plant had two units, one of 200 kW

and another of 60 kW. The turbines and generators were of Japanese manufacture.

The Talomo River, located in Davao City, is well suited to hydroelectric development. The river bed has a good shape. River discharge--in this area of rainfall well distributed throughout the year--is very steady. The river drains the northeastern slope of Talomo Peak, an extinct volcano, with a drainage area of about 175 km^2 of sloping land. It flows into Davao Gulf at a point a few kilometers west of the poblacion of Davao City.

PHASE 1: PLANNING, APPRAISAL, AND DESIGN

During World War II, the more than 22,000 Japanese planters and workers who lived in Davao joined the Japanese Imperial Army and became the occupation units controlling the city. Before American liberation, the Japanese army destroyed structures in the city, including the hydroelectric plant of the Ohta Development Company on the Talomo River. All the equipment in the powerhouse was destroyed, as well as the superstructure. The dam, forebay, penstock, and the powerhouse substructure were usable, however, although in need of minor repairs.

The property of the Mintal hydroelectric plant in Davao was considered part of enemy property turned over to the Philippine Republic. Immediately after the war, therefore, the management of the National Power Corporation requested the president to assign the plant to the corporation for rehabilitation and reconstruction so that power generated could be supplied to Davao City.

Preliminary Studies

The National Power Corporation was created by law in 1936 for the purpose of undertaking the development of hydraulic power and the production of power from other sources. This law provided, among other things, that the corporation

conduct investigations and surveys for the development of water power to any part of the Philippines, and that it construct and operate power plants and other works for the purpose of developing hydraulic power from any river, creek, lake, spring, or waterfall in the country to supply such power to its inhabitants.

Among the studies conducted were:

1. Compilation of all available data on existing power installations and on power utilization throughout the country to ascertain existing and future power demands.
2. Compilation of all available hydrologic and hydrographic data of the main river systems.
3. Preliminary map studies of possible power sites utilizing all available maps of the Bureau of Coast and Geodetic Survey, topographic maps of the U.S. Army, and other maps secured from different government bureaus; preliminary reconnaissance surveys--by air, small boats, and on foot--of streams that offered possibilities for immediate development. These studies showed that projects having an aggregate capacity of 1,600,000 hp were susceptible to development; that hydroelectric power could be produced at these sites at costs lower than the equivalent amount of fuel-generated power; and that in some of the projects the probable cost of power would be so low as to permit profitable operation of heavy power-consuming industries.

After the war, the NPC resumed its task of planning the hydroelectric development of the country. The Corporation was revived six months after the liberation of Manila, when the President of the Philippines appointed the members of the National Power Board, the corporate policy-making level of the National Power Corporation.

The investigation of rivers and streams for power potential, considered to be NPC's priority activity, was resumed. Among the rivers surveyed was the Talomo River in Davao, which already had an existing power structure to be rehabilitated.

In 1949, the NPC had formulated a large-scale power program geared to the proposed industrial development of the country and also aimed at the reduction, if not total elimination, of fuel imports for power generation. It had also evolved a continuing and complementary six-year program of construction of small-scale projects in different areas of the Philippines.

Identification and Formulation

Since the corporation had surplus earnings in the late 1940s, the NPC management decided to use these funds--supplemented by proposed bond issues--to undertake the development of ten small projects scattered in different parts of the country at an initial aggregate of ₱10 million over a six-year period. These projects, it was considered, would provide additional power load, provide income for NPC, and meet a major objective, that of providing as large a portion of the country as possible with the benefits of electricity. The construction of the major power projects was dependent, on the other hand, on loans to be granted, mainly from abroad.

The Six-Year Power Program for Small Power Projects included the following projects (per the 1979 revision):

1. Talomo River No. 2
2. Talomo River No. 2A
3. Talomo River No. 3
4. Cawayan River, Sorgogon
5. Amburayan Chute, La Union
6. Loboc River Tontonan Falls, Bohol
7. Barit River, Camarines Sur
8. Gasgas River, Ilocos Norte
9. Mantayupan Falls, Bohol
10. Sibulan River, Davao

Surveys of the Talomo River indicated that the river's maximum potential was much higher than the capacity of the existing Japanese plant. The Talomo project was therefore the first of a series of plants to be constructed on the river under the six-year continuing program of small projects development.

Design

No feasibility study was prepared for the rehabilitation of the original Talomo hydroelectric plant, designated Talomo River No. 2. Since this was considered a repair and rehabilitation project, only engineering drawings were prepared. Feasibility studies, however, were prepared for subsequent plants on the river.

For Talomo No. 2, the two damaged units were to be replaced with two 330-hp Leffel horizontal turbines coupled to two 200-kW Westinghouse generators. The canals and structures were redesigned to permit the use of at least 4 m^3/sec of water. Construction was expected to start in 1949 and end in 1950, and cost a total of ₱260,000. Energy available from Talomo No. 2 was expected to be 3,000,000 kWh.

PHASE 2: SELECTION, APPROVAL, AND ACTIVATION

Selection and Approval

The project's selection was assured, since it was not only part of, but in fact represented the first project in the six-year development plan. Because funding would come from internal sources, the NPC general manager had final approval. Filemon C. Rodriguez signed the drawings for the project on the recommendation of Jose O. Lahoz, chief of the Engineering Department in 1949 and later assistant chief engineer.

Organization

The National Power Corporation was created by Commonwealth Act No. 120, which also provided it with a governing body, the National Power Board. The

President of the Philippines appointed the members of this board, with the approval of the Commission on Appointments, for a term of three years. The chief operating officer of the NPC, its general manager, was appointed by the National Power Board, subject to the President's approval.

The NPC had four departments during the time of the Talomo project construction: Finance, Engineering, Power Utilization, and Auditing, with all department heads reporting to the office of the manager (see Figure 5.3).

Project development and management fell mainly under the aegis of the Engineering Department. Surveys and investigation of the rivers--including the Talomo River--were undertaken by the Investigation and Planning, Field Investigation, and Hydrographic Sections. The Designing Division prepared the technical drawings and design for the hydroelectric plants, including civil, mechanical, and electrical engineering specifications. The Construction Division was directly involved in the implementation of projects. In the case of the Talomo project, a project engineer was assigned to supervise the construction and installation of facilities. The Talomo series of projects had a total of three project engineers: Zacarias B. Baile, Teodoro C. Santiago, and Jose Marquez, who reported to the Construction Division manager. The Power Utilization Department took over the normal utilization of completed projects, as well as made plans and studies on the use of power.

No separate project team existed, therefore, for the Talomo projects in 1949. The project functions were accomplished by the NPC's regular departments. Only in the Power Utilization Department was organization on a project basis accomplished for the operation of specific power plants during the late 1940s. By the early 1950s, the Construction Division also set up project teams to handle the various projects and their organization. These projects were: Maria Cristina Hydroelectric, Maria Cristina Fertilizer Plant, Ambuklao Hydroelectric, and Talomo 2B Hydroelectric.

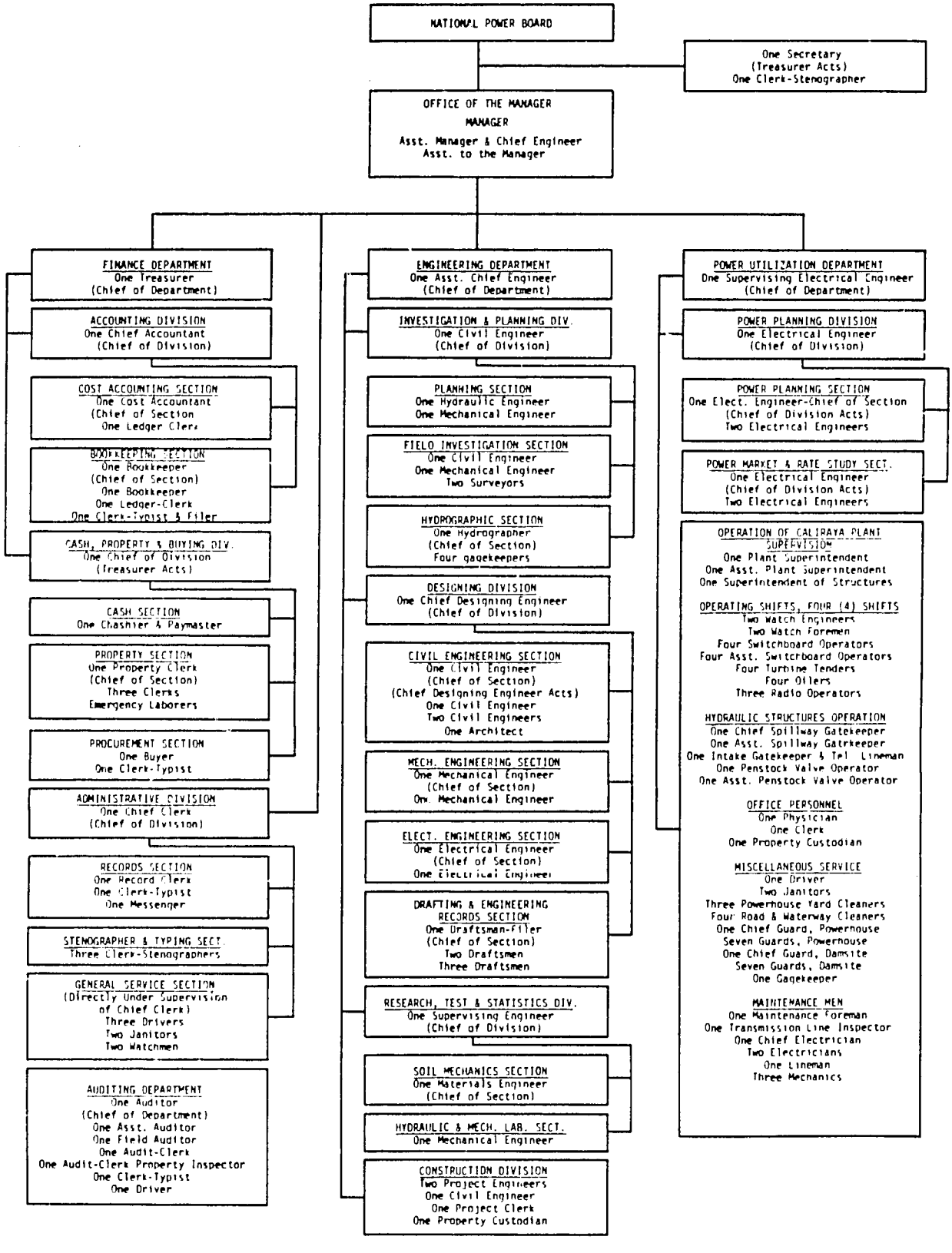


Fig. 5.3. National Power Corporation, 1948-1949.

Source: National Power Corporation, Annual Report, 1949.

Activation

The Commonwealth Act that created the NPC in 1936 provided in one section that all construction or repair work of the corporation involving an estimated cost of ₱3,000 or more would be let by the NPC manager, with the approval of the NPC board, to the responsible bidder making the lowest and most advantageous bid. The NPC followed this procedure in awarding contracts for the Talomo projects.

Late in 1948, the NPC issued an advertisement, instructions to bidders, and specifications for furnishing and delivering machinery, equipment, and spare parts for Talomo No. 2. Several contracts were signed to meet project requirements between 1948 and 1950.

Two contracts were signed with General Electric (P.I.) for the supply of the generators, switchgears, and power transformers for the two units of Talomo No. 2. The generators were 250 KVA, 514 rpm, 60 cycles, and 3-phase. The first contract, signed on January 22, 1949, amounted to ₱33,540; the second, signed on September 23, 1949, amounted to ₱25,280.50. Both contracts were for the delivery of equipment F.O.B. from New York City.

Two contracts were also executed for the purchase of hydraulic turbines and accompanying governor equipment. Supply of the equipment would be made from the United States through Edward J. Nell Co. F.O.B. from New York City. The first contract, signed on January 13, 1949, amounted to $32,056.55. On August 22, 1949, the second contract was signed for $30,453.53. The turbines purchased were manufactured by James Leffel & Co. and had a rating of 330 hp with a speed of 514 rpm. Other contracts were signed for the construction of the upper waterway canal and canal structures, as well as for the filling of low ground.

PHASE 3: OPERATION, CONTROL, AND HANDOVER

Implementation

The supervision of the Talomo No. 2 project was handled by the manager of the NPC Construction Division and the assigned project engineer. Project construction began in May 1949.

The plant site of the Talomo Hydroelectric Plant No. 2 is an irregularly shaped parcel of land situated between the populated section of Mintal and the Talomo River, approximately 17 km west of Davao City. A gravel surface road, extending some 600 m from the public highway, provides access to the site from the downtown area of Mintal. It contains the various structures erected: an administrative building, a powerhouse, and miscellaneous buildings. The plant site is approximately 24,000 m^2. The forebay and waterways are basically that of the prewar design. The forebay is an irregularly shaped piece of land situated south of the powerhouse, with earthen dikes forming the storage basin; its elevation is 512-545 m. The waterways are a series of open earthen canals and reinforced concrete flumes that convey excess water from Talomo No. 2 for a distance of 1.5 km.

The structures and improvements of this project as completed in 1950 included a powerhouse, office building, living quarters, and an access road. The reservoir, dams, and waterways for the project included a waterway canal, a forebay and earth dike, a concrete spillway with gate-controlled sluice pipe discharging into the Talomo River, a reinforced concrete intake structure, and the penstock unit with a 36 in diameter steel pipe, 65 ft long and 14 in thick, with a concrete anchor and sluicegate valve.

The equipment installed at the site was that discussed in the previous section--mainly, two generators and two turbines with accessory equipment, all of U.S. manufacture, for the hydroelectric plant's two units. Table 5.6 lists the technical aspects of Talomo No. 2.

Table 5.6

TALOMO NO. 2 HYDROELECTRIC PLANT, DAVAO CITY, 1951

General	
River basin	Talomo
Number of units	2
Installed capacity	400 kW
Usable storage	run-of-river
Powerhouse	
Floor elevation	500 m
Penstock	
Type	steel
Inside diameter	0.915
Turbine	
Number	2
Rating	330 hp
Speed	514 rpm
Manufacturer	James Leffel & Co.
Generator	
Number	2
Rating @ 80% p.f.	250 kVa
Voltage	2,300 volts
Phase	3 Ø
Cycle	60
Manufacturer	General Electric Co.

Source: National Power Corporation.

Project implementation started in May 1949 to install the first unit at the plant site. The capacity of this unit was 200 kW and that of the second unit was an additional 200 kW. At the start of construction, the project team in Mintal for Talomo No. 2 consisted of fifteen workers under the project engineer: four technical staff and the rest laborers. Work on the projects progressed smoothly, with a minimum of delays, although one stoppage did occur during construction of the canal structures when the stock of reinforcing steel ran out in Manila. The contractor subsequently requested and was granted a one-month extension.

To improve living conditions for the plant's operating personnel, the NPC undertook construction of additional housing facilities at the site. Seven units supplied with electricity and water were built, and athletic facilities were also provided.

Completion and Handover

The project was finally completed in November 1950 at a total cost of ₱434,320.15, approximately ₱174,000 more than the amount budgeted under the Six-Year Program. Table 3.7 shows the final cost breakdown for the project. Construction of the first unit was officially finished in April 1950, although some work was still done on the project until May. The second unit was scheduled for completion in October, but was finalized in November. The Talomo No. 2 project therefore had a plant capacity of 400 kW and annual energy capability of 3,000,000 kWh by the end of 1950.

In April 1950, the NPC started supplying energy to the Davao Light and Power Co., Inc., the holder of the utility franchise for Davao City. An agreement to supply power was initially signed in April but was finalized on July 27, 1951 to cover the sale of energy from the 400-kW capacity installation.

Davao Light then owned five diesel units with a combined capacity of 980 kW. The addition of the Talomo Plant increased the total capacity of the plants supplying electricity to Davao City and vicinities to 1,380 kW.

Davao Light and Power Company has used the energy from the Talomo No. 2 project from 1950 up to the present, as well as the energy made available by all subsequent Talomo projects. It should be noted that the NEA has included the Talomo River as a site for another hydroelectric project of 400 kW in 1983.

Ongoing Surveys

While the planning and construction of Talomo No. 2 were in progress, more studies were made on the river to derive data for future plants. Among the studies made were topographical surveys, location and profile surveys, and

Table 5.7

TOTAL PROJECT COST OF TALOMO PLANT
(as of June 30, 1951)

Production Plant		
Land and land rights		₱ 277.47
Structures and improvements		67,635.22
Reservoirs, dams, and waterways		117,662.37
Waterwheels, turbines, and generators		234,118.48
Miscellaneous equipment		2,337.71
Roads and bridges		1,734.35
	Total	₱ 423,765.60
Transmission Plant		
Substation		406.04
Power transformers		2,396.34
Others		221.14
	Total	₱ 3,023.52
General Plant		
Office furniture and equipment		862.46
Work, laboratory, and other equipment		4,854.05
	Total	₱ 5,716.51
Depreciation on general plant during construction		₱ 1,814.52
	TOTAL	₱ 434,320.15

Source: National Power Corporation, Annual Report, 1951.

cross sections of the river. Based on these surveys, the river was expected to have a power and energy capability of 2,000 kW and 16,100,000 kWh, respectively. The locations for the structures and requirements of the next hydroelectric projects were also determined.

Subsequent Projects

As a result of the success of Talomo No. 2 and the increased demand for power in Davao City, feasibility studies for the next plants were prepared by NPC engineers in the 1950s. They emphasized the technical aspects of the projects. The market for the power output was assured by Davao Light and Power Company, since demand in Davao City was increasing with the city's growth and the hydro plants could replace the old diesel units then in use. Energy sales were monitored on a monthly basis. The unit sale price, it was noted in June 1950, compared favorably with the cost of fuel generated power.

A total of five feasibility studies were prepared for the Talomo projects, designated Talomo Plant Nos. 2A, 2B, 3, 1, and 4.

The feasibility studies for Plants 2A and 2B were prepared in 1950 and 1951. The study for Plant 2A consisted of a general introduction on the area, background of the Talomo No. 2 Plant, the scheme of development, water supply and available power, investment and production cost estimates, proposed rate schedule, and a short assurance on the power market. It was a brief report supported by exhibits showing hydrographs of the river in 1949 and 1950, as well as a general plan and profile of development for the hydroelectric project. The estimated investment required was ₱405,000.00 (excluding transmission line costs). The study recommended a single 400-kW plant designed for remote control operation from Talomo Plant No. 2. No operating personnel, therefore, would be stationed at the powerhouse.

The feasibility study for Talomo No. 2B was similar in focus to that of Talomo No. 2A. Talomo projects 2, 2A, and 2B were in a cluster; 2B would be located between 2 and 2A where there was a substantial head, otherwise wasted, that could be economically developed. At this point, the study noted, the agricultural and industrial area around Davao City was growing at a phenomenal pace, such that power had to be provided in adequate increments if its growth was to be sustained. Financing for the project was expected to come from surplus earnings of the NPC as a part of its Six-Year Philippine Power Program. The feasibility study discussed the water supply in the river as indicated in the twelve year record of the Talomo River at Tugbok, located just upstream of the project. On the basis of studies, a plant with a maximum discharge capacity of 6 m^3/sec was recommended. Water diverted from the Talomo River, then, would be utilized successively by Plants 2A, 2B, and 2, and thereafter discharged back into the river for utilization in the proposed downstream plant--Talomo No. 3.

The feasibility study proposed a plant installation of 300 KW for Talomo No. 2B at a total investment cost of ₱330,000. Initially, the operation of plants 2 and 2A would be adequately suited for baseload operation for the power area. For this reason, Talomo 2B was planned to serve in the partial peaking of the system load by providing ample pondage. This study examined in more detail the power market in the area to use as a basis for proposed rate schedules. Based on the figures derived, the estimated average net income would be ₱40,000, representing a net return on investment of 12.1 percent.

In September 1956, the NPC Investigation and Planning Division completed the feasibility study for Talomo No. 3. This project was expected to be downstream from the Talomo 2, 2A, and 2B plants. The plant was needed, as stated in the study, to provide much needed dependable power in the fast

growing agricultural and industrial area around Davao City. The plant was expected to provide sufficient electric power to run the proposed ramie textile mill of the National Development Company to be established in Dalilao, Davao. It would be operated as part of the NPC-Davao Light and Power Company interconnected system serving the city of Davao and vicinity in order to make full use of its power capability and energy availability. The Talomo No. 3 plant would have a power capability of 1,600 kW and an annual saleable energy output of 12.0 million kWh. The estimated capital investment for the project was ₱2,000,000. Estimated annual revenues were ₱321,040.00, which exceeded projected annual expenditure by approximately one third, providing the economic justification for the project. The project feasibility study considered structures to be set up, consisting of diversion works, a waterway, forebay, powerhouse, and access road. The principal hydraulic plant equipment included trash racks, gates, penstock, turbine inlet valves, turbines, governors, generators and electrical accessories, and a transmission plant.

Two other feasibility studies were undertaken for projects that were not implemented. Talomo River No. 1 was expected to be the uppermost of the series of power plants on the Talomo River. The plan, prepared in 1951, was to set up a 200-kW plant in Calinan to serve the town of Calinan and vicinity. The major product in the area was abaca or hemp. Therefore, it was envisioned that the output of the power plant would be used to a great extent to power the abaca stripping machines. The plant discharge required to develop 200 kW was more than the estimated mean flow of the river, it was pointed out in the study. Furthermore, the load factor of the area was relatively low.

The other feasibility study, for the Talomo River No. 4 project, was prepared in 1962 and proposed for construction under the ten-year power program of NPC. The plan was to put up the most downstream plant in the Talomo River series

some 3 km downstream of Talomo No. 3. The plant was to have an installed capacity of 2,000 kW in two identical units and would be tied to the other operating plants of NPC in supplying power to Davao City and the ramie plant of the National Development Company. According to the forecasts made by the Davao Light and Power Co., they would need the output from the proposed plant by the end of 1962. By November 29, 1961, surveys for the layout of the different structures, access road, and right of way were completed. In addition, geological investigations at the proposed site were also conducted.

The feasibility study prepared for Talomo No. 4 was much more comprehensive than those prepared in the early 1950s. Included in the study were sections on stream flow, water and power availability, details of the project, estimated cost of development, power market, and economy balance. Eight charts and drawings covering plans of development, structures, electrical systems, and discharge and power duration curves were included. Total cost for the proposed development, including transmission tie lines, was estimated in 1962 at ₱2,840,000.

Implementation of the project was deferred when two basic assumptions on the market for the power output did not materialize: increased demand for power from the Davao Ramie Textile Mill (DARATEX) of the National Development Company and a contract for the output of the proposed plant by Davao Light and Power Co. Table 5.8 summarizes the technical details of the Talomo projects.

Table 5.8

TALOMO HYDROELECTRIC PLANTS, 1978

	Talomo 2	Talomo 2A	Talomo 2B	Talomo 3
River basin	Talomo	Talomo	Talomo	Talomo
Start of construction	May 1949	May 1952	May 1953	Jan. 1958
Date of operation	Nov.10,1950	Apr.14,1953	Nov.1,1954	Dec.4,1959
Number of units	3	2	1	2
Installed capacity	600 KW	600 KW	300 KW	1,600 KW
Usable storage	run-of-river	run-of-river	run-of-river	run-of-river
Effective head	14.3 m	14.9m	7 m	41.2 m
Discharge	5.3 cm	4 cm	5.4 cm	4.8 cm
Energy capability	5,820,000 kWh @ 67% pf[a]	3,000,000 kWh @ 85% pf	2,200,000 kWh @ 85% pf	10,500,000 kWh
Total construction cost	₱514,000	₱453,000	₱491,000	₱1,807,000

a. pf = power factor

Source: National Power Corporation, System Development Division, Statistical Data of NPC Operating Plants, Manila, January 1978.

Problems Incurred

Shortly after the Talomo No. 2 plant became operational, problems in pollution were encountered. The canal system of the plant was 4 km from the dam, passing through cultivated areas also used by the area's inhabitants to dispose grass cuttings, banana stalks, tree branches, garbage, and other refuse. Some of this matter was caught in the forebay, where it clogged the trash racks and sometimes got through to endanger the turbines. In 1952, a chicken wire screen was used to solve this problem, but it required continued vigilance to keep it clean. Three maintenance men were employed--one on each shift--to clean and watch this screen, and frequently the men, especially those on the midnight shift, got sick from a combination of pollution and chill from getting wet.

As a solution, NPC engineers designed and constructed a motor-operated revolving screen to use in place of the chicken wire screen.

Delays were encountered in the operation of Talomo No. 2A because of the late delivery of machinery and equipment ordered from U.S. manufacturers. The project was scheduled for completion in January 1952, but though the civil and hydraulic structures were completed by 1952, the project was only finally completed and commissioned into service on April 14, 1953.

A third unit of 200 kW for Talomo No. 2 was planned in the early 1950s to meet the increasing demand for power by the Davao Light and Power Co. This project was delayed, however, since the NPC considered the lowest bid for the civil work construction to be too high; subsequently, NPC had to postpone construction again because of the unavailability of funds. Construction finally began on May 27, 1958 and was expected to be finished in 200 calendar days. Because of the construction of a blow-off valve not provided for in the original plan, however, a 31-day extension was granted. The civil works for this project were completed under contract with the Philippine Grouting and Guniting Co., Inc. on January 8, 1959. Talomo No. 2 Unit No. 3 was finally completed on November 28, 1959.

Operation of Talomo Plant Nos. 2 and 3 was paralyzed for a while by a flood on September 4, 1963. In less than a month, however, the affected units, switchboards, and auxiliaries were dried and reconditioned: the two plants resumed operation on September 26, 1963.

PHASE 4: EVALUATION AND REFINEMENT

Reports on the progress of each project were included in the NPC's Annual Reports during the 1950s. They included the status of the projects, costs incurred, and problems encountered. Once a project was operational, monthly energy generation and income received would be presented in the reports.

This NPC monitoring system was effective in keeping department and project managers up to date on the performance of each hydro project. Targets set for the hydro programs would be reviewed and accomplishments were noted, as were delays and their causes. As a result of these reports, policy refinements or changes in procedure were undertaken. For example, in the early 1950s, delays in delivery of equipment from the United States (a result of the accelerated U.S. defense effort) were noted. This caused delays in NPC project schedules, and the NPC general manager urged the government to secure defense order priorities for these orders.

The Talomo hydro project was built by a government agency, and the power generated was sold to the Davao Light and Power Company (DLPC), a private utility franchise holder. The dynamics of relations between public and private sectors in the development and distribution of power could be further explored. In this instance, the Talomo hydroelectric plants were operated by NPC and eventually leased to the DLPC in the 1970s. In a position paper dated July 1977, DLPC indicated it had been able to increase tremendously the efficiency the efficiency of the plants through careful supervision and monitoring of operations, the construction of a transmountain tunnel and diversion dam to divert the Panigan River into the Talomo River, and the improvement of plant equipment and facilities. It has since included several rural municipalities into its franchise area coverage. This sizable investment and efficiency of operation--accomplished without government subsidy--have resulted in expanded operations for the hydroelectric projects.

In recent years, more private participation in mini-hydro areas has been encouraged. The Center for Nonconventional Energy Development of the Ministry of Energy supports research projects by private groups in water power technology. The President has issued Letter of Instruction No. 933, setting up

an Energy Priorities Program under the Board of Investments to encourage the local manufacture of mini-hydro equipment. Other suggestions coming from the private sector include participation in the implementation of actual projects: that is, simplified guidelines and procedures for a private enterprise to set up a mini-hydro, and the possibility of a "wheeling" arrangement, whereby a private company sets up the mini-hydro at a feasible site for use by nearby communities in exchange for power at the site of the company from the NPC grid.

The succesful operation of the Talomo No. 2 project was noted in the Annual Reports. Before the plant's completion, construction of Talomo No. 2A was started. At the present time, Talomo No. 2 is operating and providing power with the later projects on the river to a growing population in the southern city of Davao.

BALIGUIAN MINI-HYDRO PROJECT

PROJECT BACKGROUND

The National Electrification Administration establishes and operates its electrification projects through a system of electric cooperatives. An electric cooperative is a nonstock, nonprofit, member-owned public utility enterprise designed to provide adequate and reliable electric service at reasonable cost to its members. These electric co-ops were patterned after the rural electric cooperative system developed in the United States. Arrangements have been made through U.S. AID for technical support from the National Rural Electric Cooperative Association (NRECA) of the United States in developing this system. The NEA provides technical support, training, and funding for the co-ops, and has adapted the cooperative system to suit the needs of the country. The Philippine electric cooperative system has been successful in bringing rural electrification to municipalities and barangays (small political community groups) in far-flung areas. From an established backbone network, there are

now electric co-ops in almost all islands in the country, totaling 117 in early 1980.

On October 8, 1979, Presidential Decree No. 1645 was signed to support the electric co-op's energy development projects and accelerate rural development. The decree increased the capitalization of the NEA and authorized NEA to invest or grant loans for the development of power generation industries or companies, including dendrothermal and mini-hydro power plants and associated facilities, such as alcogas (gasohol) and tree plantations, water-impounding reservoirs, and feeder roads.

The NEA, therefore, compiled data from other government agencies on mini-hydro potential in the country. These agencies were: the National Power Corporation, the National Irrigation Administration, National Waterworks Resource Council, National Economic and Development Authority, Bureau of Public Works, and the Philippine Atmospheric Geophysical and Astronomical Services Administration.

Even while the government mandate for the NEA to undertake a mini-hydro program was in the offing, the design of a project was prepared by the general manager of an electric cooperative. Engineer Percival Favoreal, general manager of the Camarines Sur IV Electric Cooperative, Inc. (CASURECO IV), prepared such a plan and brought it to NEA for approval and funding.

PHASE 1: PLANNING, APPRAISAL, AND DESIGN

Identification and Formulation

CASURECO IV covers nine municipalities in Camarines Sur. Three of these municipalities in the Caramoan Peninsula are not accessible by road to the "mainland," as the other municipalities are called. The three municipalities in the Caramoan Peninsula are Presentacion, Caramoan, and Gatchitorena.

Before 1979, there were two 100-kW diesel-powered engines generating power in Caramoan. Fuel for this power came from Barangay Sabang by motorized banca (a small dugout boat powered by a motor). The cost of fuel in Caramoan was about 20 percent higher than the fuel in Sabang due to the problem of transportation and double handling. The fuel would be brought to Guijalo by boat and then transported overland to Caramoan.

Percival Favoreal, the general manager of the electric cooperative in the area, CASURECO IV, was interested in finding ways of reducing the cost of power. His idea was thus to construct a mini-hydroelectric plant in the area if it was possible. In early 1978, he and his staff made on-the-spot inspections in the Caramoan Peninsula and found a waterfall in the municipality of Presentacion on the Baliguian River (Figure 5.4). Their investigations revealed that the measured flow of the river was 20 ft^3/sec with a head of 27 m. The height of the waterfall was 28.66 m. Based on Favoreal's computations, the potential of the river was 200 kW. Favoreal then proceeded to plan how to harness this waterfall for generation of electric power to serve the surrounding municipalities.

Feasibility Studies

The electric co-op is the organization that sells energy to the community. Generally, an electric co-op covers ten municipalities with a total population of 100,000 to 500,000 people. As such, the demand for energy is assured. In the case of CASURECO IV, nine municipalities are covered by the electric co-op, representing 8,610 house connections, based on 1975 population data. This means that approximately 51,660 persons benefit from power generation in the area.

The Caramoan Peninsula, however, represents simple fishing villages. Therefore, demand for power exists if power is priced at a level the people

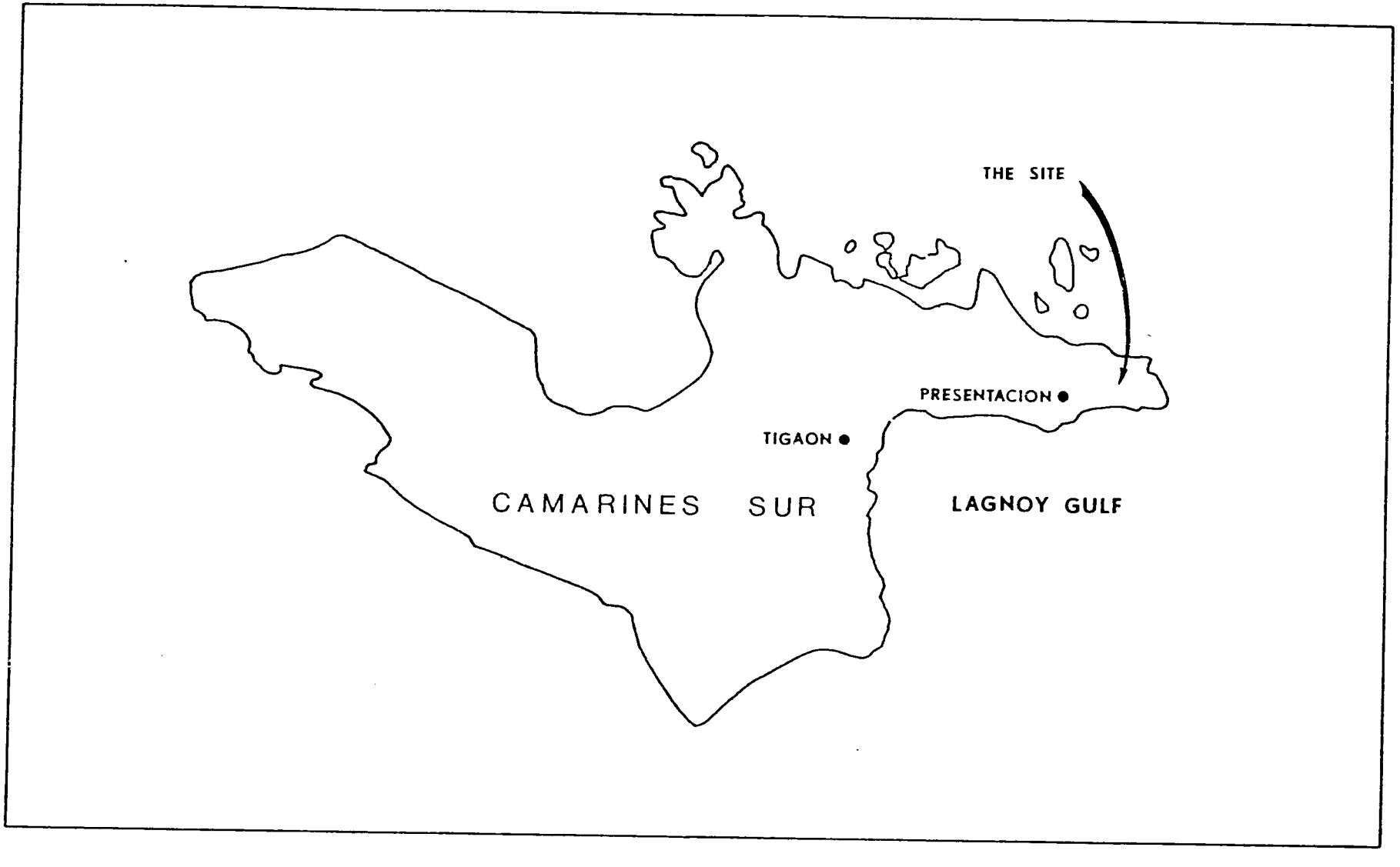


Fig. 5.4. Plant site: Baliguian, Camarines Sur.

can afford. Favoreal was interested in meeting the challenge of providing energy to help in the development of this rural, semi-isolated area at the lowest possible cost. He decided to look into possible ways of designing and funding a mini-hydroelectric project.

Favoreal made several trips to Manila to find out the cost of a small hydro plant. NPC and NEA data in 1978 indicated the cost was $1,000/kW for the mechanical and electrical equipment required. Next, he approached the board of CASURECO IV with a request to use some co-op funds for research and development. His main interest was to see if the equipment could be fabricated locally to reduce the cost. Early in 1978, the board passed a resolution approving an initial ₱10,000 for the research effort.

Favoreal began research on the project by looking at books and other material available at various agencies in Manila. He also requested the assistance of Francisco Dialogo, previously a mechanic at the CASURECO IV motorpool, who was interested in inventions. Dialogo became Favoreal's assistant in this project.

By mid-June 1978, the design for the mini-hydro plant was completed. Favoreal again requested the co-op's board to give its approval for him to go on with the project. Board approval was given, based on available funds.

In one month's time, Favoreal completed the design of a one-eighth scale model of a small hydraulic turbine. It was tested by simulating conditions at the proposed site of the project. The result of the test was satisfactory: the turbine was running and could control speed from 600 to 1,400 rpm.

Project Design

Favoreal's original plan was to use a locally fabricated propeller-type turbine that would drive a three-phase electric generator with a 100-kW capacity. Favoreal prepared drawings for the turbine.

In January 1979, after a satisfactory testing of the mini-hydro model he built, Favoreal informed the board of CASURECO IV of the need to build the actual mini-hydro plant. When the board granted approval, negotiations were made with a local machine shop that supplied spare parts to the co-op to fabricate the turbine, payable in three months' time.

Favoreal next approached Zenaida Santos, deputy administrator for Engineering and Materials of NEA, with a request for a loan of ₱42,000 to cover the cost of manufacturing the turbine. Both Santos and later Brigadier General Dumol, administrator of NEA, were willing to fund the project, because it would be an attempt at local fabrication of equipment that could serve as a model for future projects. Their main concern was expressed in the question: Tatakbo ba? (Will it work?)

Santos recommended that the proposal from CASURECO IV include the costs involved in installing the unit and making the plant operational. In February 1979, the board of CASURECO IV passed a resolution requesting a loan of ₱267,000 from NEA for the project. The loan was approved by General Dumol and released in mid-March.

CASURECO IV

The rationale for a cooperative organization for rural electrification is that the co-op, because it is nonprofit and service oriented, will extend service not only to the thickly populated town centers but also to the less profitable, remote barrios. Another advantage of the cooperative system is the popular support co-op activities generate, since the people of the community are themselves co-op members.

A co-op is governed by a board of directors who represent the municipalities covered by the co-op. Board members are chosen from a wider group of representatives from education, business, farmworkers, civic organizations,

religious groups, government employees, barangay councils, and youth sectors of the area. As mentioned in the project background, the NEA is the government agency which supports the development of cooperatives by training local leaders to organize a co-op, providing funding, technical aid, and training assistance to the co-op.

The Camarines Sur IV Electric Cooperative, Inc. (CASURECO IV) was organized through the initiative of the governor of Camarines Sur, Felix A. Fuentebella. It was officially registered with the NEA on February 18, 1977. The municipalities covered by CASURECO IV are: Ocampo, Tigaon, Caramoan, Goa, San Jose, Lagonoy, Gatchitorena, Sangay, and Presentacion. As of June 1980, co-op records indicate that it includes 7,614 member-consumers. The co-op provides energy for 9,034 houses, or approximately 25 percent of the families in the rural areas it serves, and lights 327 schoolrooms. Power generated by CASURECO IV is used to service ricemills, irrigation pumps, sawmills, a sugar mill, cottage industries, ice plants, bakeries, a batching plant, feedmills, a dressing machine, a palay (rice) dryer, and a paper pulp factory.

CASURECO IV has made such remarkable progress since the time of its official registration that it nas been dubbed the "fastest electric cooperative" in the country. In March 1977, the co-op was granted a loan of ₱13.9 million, and within a year the town centers of seven municipalities were energized. Since then, the co-op has inaugurated its first mini-hydro at Baliguian and the subsequent energization of the town of Presentacion. In early 1980, the co-op started another mini-hydro project, the Cayaoyao mini-hydro.

From the co-op's start in 1977, its general manager has been Percival F. Favoreal, a registered Philippine electrical engineer and native of Camarines Sur who has been involved in the operation of other electrical systems in Camarines Sur as assistant manager of the Buhi Electric System and as general

manager of CASURECO I. From May to June 1979, Favoreal made a two-month study tour of the operations of the electric cooperatives in the United States under the sponsorship of the NEA.

PHASE 2: OPERATION, CONTROL, AND HANDOVER

Fabrication of the turbine continued at the Luzonian Machine Shop in Naga City. Construction started in May at the site on the Baliguian River below the waterfall. Civil works construction began July 15, and the turbines were installed in August.

All building and civil works were done by the CASURECO IV administration. A local firm, DCCD Engineering Co., was hired to supervise the civil works. Reinforced concrete for the culverts which make the penstock were precast at the CASURECO IV headquarters in Tigaon. The generators were purchased from the municipal electric plant of the municipality of Ragay. These generators were then out of order and not in use, as the municipality was supplied with power by another electric co-op.

The project was built mainly by people from the area. A total of 70 workers were involved in the construction of the plant and other structures. Eighty percent of the people were from the barangay of Presentacion; the rest of the workforce were mostly technical personnel employed by the co-op.

The scheme of development for the Baliguian hydro project followed the principle that water, when scientifically released from an elevated reservoir, would become kinetic, creating hydroelectric energy. This process, applied to a turbine, creates electricity. The water from the falls would be stored in a rock-filled, reinforced concrete dam of 2.5 m in height and a pondage area of approximately 70 m^2. Water would pass through the penstock from the dam to the water turbine, causing the blades of the turbine to rotate and drive a three-phase electric generator.

Most of the components of the turbine were scrap materials such as railroad ties recycled and reshaped by the electric cooperative personnel. Metal shafting was done by the co-op crew using co-op lathe machines. Welding, which included cutting and assembling iron sheets and metal plates, was also undertaken by the crew. Secondhand bolts were used and pillow blocks were all locally made. Table 5.9 summarizes the technical details of the project.

Table 5.9

BALIGUIAN RIVER HYDROELECTRIC PROJECT

Location	Presentacion, Camarines Sur
Gross head	28m
Net head	27 m
Discharge	.6 m^3/sec
Capacity	100 kW
Type of turbine	propeller-type vertical shaft
Type of scheme	run-of-river
Distance from the electric cooperative	Co-op to Tigaon seaport: 12 km Seaport to site (by pump boat, 2½ hrs): 20 km

The NEA monitored the project as it was implemented and status reports were made by Favoreal and NEA Mini-Hydro Office teams.

Problems

The Baliguian River project encountered some difficulties in implementation, including the following:

1. All materials and equipment needed had to be transported by boat. The reinforced concrete culverts, which were precast at Tigaon, as well as sand, the turbine, and generators, had to be brought to Baliguian by barge or pump boat. All other equipment, materials, and supplies except gravel had to be ferried by pump boat or motorized bancas.

This became a problem during the rainy season, from July until the project was completed, as the seas were rough. Lagonoy Gulf, which had to be traversed, is on the Pacific Ocean; the trip to Baliguian from Sabang regularly takes 2½ hours by pump boat. The site of the project, moreover, was approximately 500 m from the beach.

2. Accessories and parts had to be designed and fabricated. The original design for the turbine did not include accessories and spare parts. As the project got underway and the turbine was tested, other items such as gear boxes had to be designed and fabricated.

3. Cost of the project was higher than estimated. As the project progressed, Favoreal noted that 30 percent of the total cost incurred was for freight and handling. During rough seas, the cost of hiring a boat soared.

Sometime in July, when the civil works of the project were 60 percent complete, the funds for the project were completely exhausted. Favoreal again approached Edgardo Piamonte, project supervisor for mini-hydro, and Zenaida Santos at NEA with a request for additional funding, bringing with him all the receipts for work so far accomplished. His estimate was that ₱102,000 would be needed to complete work on the project. This request for additional funding was again approved.

Completion and Handover

The project was completed in November 1979 and a test run was made. The plant was inaugurated in December when the Minister of Public Works, Hon. Alfredo Juinio, switched on the power plant, assisted by Camarines Sur Governor Felix Fuentebella.

The total cost of the project at the time of inauguration was ₱400,000 or ₱4,000 per kW. (A similar power facility with imported components would have cost from ₱40,000 to ₱50,000 per kW.) The final cost of the project,

based on Favoreal's computation by December, was ₱563,000, as shown in Table 5.10. The balance of the funding requirements was released by NEA in February 1980.

Table 5.10

TOTAL PROJECT COST OF THE BALIGUIAN PLANT

Site Development	
Area clearing/site improvement	₱ 12,825.00
Site selection/mobilization	71,104.00
Power Plant	
Powerhouse	146,118.85
Turbine, draft tube, and accessories	127,226.05
Substation/electrical equipment	13,978.85
Overhead	52,464.75
Civil Works	
Spillway and intake structures	27,891.60
Diversion (open flume)	6,200.00
Penstock	67,913.55
Tailrace	19,560.05
Surge tank	4,510.90
Overhead	13,481.40
TOTAL	₱ 563,275.80

PHASE 4: EVALUATION AND REFINEMENT

Post-Project Evaluation

The gift of electricity to a community spells opportunity and hope for development. For a community like the Baliguian barangay, an underdeveloped fishing village once part of a logging concession, the chance for development is even more significant. The area to be served by the hydro project is

mountainous, yet the mountainsides are denuded by past logging operations. The people plant camote (sweet potatoes) as their staple food. No paved roads exist in the barrios and travel to places outside the peninsula is difficult and expensive for the simple townspeople.

The mini-hydro plant has been operating since its inauguration in late 1979. Three local people operate the plant on a three-shift basis, one person per shift. The municipalities of Presentacion and Caramoan now benefit from the steady supply of electric power. As of early 1980, the co-op has built power lines extending 9 km to Presentacion, benefitting 300 families, and 16 km to Caramoan, benefitting 400 families. While operating, this mini-hydro plant provides the co-op a monthly savings of ₱30,000, equivalent to 15,000 liters of diesel fuel.

The NEA is monitoring operation of the mini-hydro project. Already teams of consultants and foreign visitors have been brought to the site. Through the NEA newspaper SINAG, information about the project has been disseminated to other cooperatives and interested parties.

Similar ventures are being encouraged. Favoreal, spurred by the success of the Baliguian project, is again planning a mini-hydro project in the area of his electric co-op. His proposed project is to install an additional unit at the foot of the falls by constructing a small water-impounding structure to supplement the power-generating capacity of the existing unit.

Policy Refinement

The Philippine government, as mentioned earlier, has accelerated its energy program in mid-1980 and is giving much attention to the development of mini-hydro projects for rural development. The Ministry of Energy administers this overall energy program, although the actual implementation of the mini-hydro program is carried out under an agency separate from the Energy Ministry,

the National Electrification Administration, which in 1980 was directly under the Office of the President.

Much coordination is necessary within and among the various government agencies for a program such as the mini-hydro program to be successful. Even in 1950, the chairman of the National Power Board, Prospero C. Sanidad, pointed out the need for coordination of this nature. Within the sphere of energy, the Ministry of Energy, headed by Minister Geronimo Velasco, provides the integrating factor: It provides logistics for research and development in energy; plans the development of the country's energy resources, setting the targets in coordination with the National Economic and Development Authority; and moderates energy utilization.

Outside the Ministry of Energy, however, government agencies such as those involved in irrigation programs, local government and community development, and the provision of basic services to communities all engage in development projects for rural communities. For hydro projects, which are usually complex undertakings, to have maximum impact on the rural areas, coordination is necessary among these agencies.

Under the present scheme--as the Baliguian project illustrates--the mini-hydro project is identified by the rural electric cooperative, whose main aim is the electrification of its franchise area. Hydro projects, therefore, may be planned to serve this single objective. The same project, however, could be expanded to service irrigation or flood control needs. Where a hydro project is developed in isolation, a multi-project approach can carry more potential impact in stimulating rural development.

Much as already been done to ensure that development efforts are maximized. Both the Ministry of Energy and the National Electrification Administration have taken stock of the hydroelectric resources suitable for development. The Ministry of Energy has indicated a general program for development of hydro

resources to maximize the use of water for various purposes. The NEA has classified water resources to be developed under its program as those for mini-hydro or small water-impounding projects and has planned the development of these resources in the 1980s.

In the area of research for new technologies, the Ministry of Energy's Center for Nonconventional Energy Development, as well as some other agencies, develops and tests inventions and innovations in the field of energy, including small water power projects. President Marcos, however, has designated lead agencies to implement the program at a pace determined jointly with NEDA and the Ministry of Energy. The government, therefore, has not allowed itself the luxury of multistudies, experiments, and multiagency conferences prior to project development that could bog down the implementation of the projects.

The Baliguian project is a remarkable example of a project initiated at a level close to the users, with full support from the central planners. The board of the co-op is composed of representatives from each of the municipalities under its area coverage. The unique needs of each municipality can therefore be readily recognized and considered. The NEA, on the other hand, has been able to respond equally to the needs of the co-op for funding--cutting through bureaucratic red tape--so that project approval to completion took less than one year. The NEA has proven that it can manage a centralized program of mini-hydro development and yet build in the flexibility to respond to requests from co-ops for support in innovative projects--a sort of centralized-decentralized approach that may prove effective in the mini-hydro program. The President, anticipating such an approach, has therefore given the mandate for the mini-hydro program to the NEA and its area coverage program through the electric cooperative network.

Rural development through electrification can readily be seen as a means of generating employment. A rural electrification co-op directly provides employment through its internal operations and indirectly, as a catalyst, through provision of power to industry. As a matter of policy, co-ops offer jobs at attractive, competitive wages to qualified permanent residents within the coverage area. A typical co-op in the late 1970s usually hired 350 workers during its organizational and construction stages, and around 100 full-time staff during actual operation. The co-op also provides employment opportunities indirectly through its impact on industry and trade. A study made of the Misamis Oriental Rural Electric Service Cooperative, Inc. (MORESCO) indicates that at least 400 new jobs were created by the founding of companies after the 1972 inauguration of MORESCO, benefitting about 2,500 family members, or 3 percent of the area's population. Other benefits come from the energization of schools so that evening vocational programs can be offered, as well as training programs sponsored by NEA and other agencies for linemen, electricians, and plant operators.

The mini-hydro program will provide additional employment in the rural areas. The initial Baliguian project resulted in employment for some 70 workers from the project area and the area covered by the co-op. It has given rise to actual equipment and parts fabrication for the co-op technical staff and engineering shop in a rural city. Its impact on indirect employment generation through industrialization cannot yet be measured; this effect, however, is probable and will be felt in coming years.

The two case histories, Talomo and Baliguian, demonstrate a shift in priorities for small hydro programs over the years. One of the main priorities of the government agency in the 1950s was profitability, or at least income from the project to justify undertaking the work, besides its other objectives

of providing electricity to as large an area as possible and improving rural conditions, industry, and the quality of life. In the present government program, mini-hydro projects are being pursued for rural development disregarding short-term profitability to the extent that subsidized financing is packaged into the program as an integral feature. This move is consistent with government belief that the key to rapid development in the 1980s lies in the availability of cheap and dependable power.

Use of these initial projects as training ground for project managers has been a part of the first small hydro and current mini-hydro programs. The NPC used the Talomo project to train bright cadet engineers in the management of hydroelectric projects, developing a pool of experts for future projects. To a more limited extent, the NEA has used the Baliguian project as a model in project management.

Rural development may come slowly to the municipalities on the Caramoan Peninsula. With rural electrification provided by the mini-hydro on the Baliguian River, however, prospects are good. Some evidence of progress is already apparent. Since the inauguration of the mini-hydro, "roads" or pathways have been cleared. Enthusiasm runs high in the barangays, where children can now read and play at night with light furnished by the Baliguian River.

NOTES

1. E. Yambot, ed., Philippine Almanac and Handbook of Facts, 3rd ed. (Quezon City, Philippines: Philippine Almanac Printers Inc., 1977).
2. Philippine Ministry of Energy, Ten-Year Energy Program 1980-1989, Manila, January 1980.
3. No official definition has previously been given to the terms "small" or "mini" in relation to hydro development in the Philippines. In 1979, the President used the cut-off rate of 5,000 kilowatts to distinguish the small hydro or mini-hydro projects.
4. Dean Damian Mercader, "Davao City: A Perspective," unpublished paper, p. 1.
5. National Power Corporation, Annual Report 1947, p. 4.

ACRONYM KEY

AID	(United States) Agency for International Development
CASURECO IV	Camarines Sur IV Electric Cooperative, Inc.
DLPC	Davao Light and Power Company
MORESCO	Misamis Oriental Rural Electric Service Cooperative, Inc.
NEA	National Electrification Administration
NPC	National Power Corporation
NRECA	(United States) National Rural Electric Cooperative Association

CONCLUSIONS: POLICY AND RESEARCH ISSUES

The purpose of this section is to examine and compare the planning and management approaches in the five case histories, providing a policy overview for the outstanding need to accelerate biomass and small hydro energy development. The need for pragmatic energy policies is increasingly vital to reduce dependence on imported oil. The case histories in this manuscript emphasize the use of small-scale energy technologies based on renewable resources, and also devote attention to further research needs.

The Case History Record

The research necessary to document each of the case histories clearly indicates the significance of both biomass and small hydro energy projects as viable sources of renewable alternative energy to reduce dependence on imported oil. When the world price of crude oil was less than $3 a barrel, it was probably not worthwhile to consider biomass energy projects on a global scale, but rather to limit the application to alternative energy systems for rural areas (for example, biogas digesters). Similar observations can be made about small hydro projects, either developing new ones or refurbishing old ones. Of course, this situation has changed dramatically and drastically in the past six years, reinforcing the outstanding need for international attention to alternative energy. Since we are clearly in a period of transition, policy and related decision making must result in a reasonable balance between the utilization of conventional or traditional sources of energy, and the growing possibilities for alternative energy, particularly the indigenous renewable systems. For example, if a society has limited oil but massive wood supplies and a demand for transport fuel, heat, and power, it would seem logical to reserve the oil for transport and use the wood to provide heat and power. The equation is not that simple, however, because attention must also be given

to the growing international debate on the use of certain biomass resources for food or energy.

Whatever the future use of biomass and small hydro energy may be in Asia and the Pacific, the ability to use and develop these resources for generating fuels for both electric and nonelectric uses has been amply demonstrated, and there are few situations in which lack of technical knowledge has precluded the use of these renewable energy resources. New and exciting techniques are constantly being developed to allow greater exploitation of the earth's plant and water resources for energy, but technology and its availability are not the main constraint on biomass and small hydro energy development in many countries. In our haste to achieve technical understanding, we have sometimes underestimated the difficulties that accompany the implementation of both old and new types of technology. Indeed, experience demonstrates that the fullest use of what is now recognized as important energy sources are highly dependent upon the ways in which projects for developing these sources are planned and executed. The five cases are vivid illustrations of the fact that resolving the policy issues and implementing the projects create common problems that cut across national boundaries.

Many of the serious problems the case histories reveal, it should be noted, arise from such issues as the legal status of indigenous renewable resources and the type of organizational channels through which these sources of energy can be developed most effectively. Each case presents important lessons in developing policies, methods, and systems to effectively utilize biomass and small hydro resources.

The four countries from which the case histories are drawn--China, the Philippines, Fiji, New Zealand--approach their energy problems through different policy-making procedures and government structures. The strategies each country

adopts to cope with its shortfall in energy have in common the fact that they are being determined to a large degree by decisions at the highest level of government. In China, major energy policy statements and decisions emanate from the Premier and appropriate ministries. However, implementation is the responsibility of the individual communes. New Zealand, which is centralized through its parliamentary government, has complete authority and control of electricity-producing energy sources. No private utilities are involved in electricity development or distribution in New Zealand. The government of Fiji is similar to that of New Zealand, with policy and decision making centralized through its parliament, prime minister, and his cabinet. The Philippines, with its martial law administration, receives direction from the central government, under whose auspices strategies, policies, and priorities are developed. Thus, each of these countries uses a policy decision-making apparatus that operates in a different way to cope with the complex problem of developing energy alternatives.

Biogas Development in the Philippines

The Philippine experience with biogas is a good example of a rapid national response to the increasing uncertainties of the world energy situation in the mid-1970s. The nature of the policy-making process in the Philippines, the numerous shifts in agency titles and responsibilities, and the action-oriented role played by the president all were important in understanding the speed with which the government responded to the current energy crisis. As such, this case provides a variety of policy issues related to national planning for nonconventional energy development.

One major policy issue revolves around the notion of "integrated national planning." In the Philippines, as in most developing nations, developing an appropriate policy for both rural and urban needs is a major priority and often

requires a great deal of experimentation. There are problems related to population demographics, and in the case of biogas, the ratio of urban waste to rural waste availability, dietary concerns related to protein levels, and so on. Given the scarce resources present in most developing nations, difficult choices must be made to equitably allocate resources such as energy in the form of biogas to both rural and urban areas. Related to this policy issue is another that focuses on establishing an appropriate energy mix, especially between nonconventional energy sources. The Philippine case discusses this issue and points out that unless the relationships between such nonconventional sources as solar, wind, and biogas are examined with particular attention to energy economics, serious cost problems can result. For example, if the energy expended to operate a biogas unit (pumping, stirring, maintaining heat levels) exceeds the output, then it obviously is not cost effective. However, if another nonconventional renewable resource is utilized for these purposes (e.g., wind), the expected savings will occur. In short, what appears to be a rather straightforward and simple answer to rural and urban energy needs may result in more expense if a national plan does not develop in an integrated manner. The Philippines seems to have made some progress in this area.

Once an integrated national plan is developed and a commitment has been made to utilizing nonconventional energy sources such as biogas, the next major policy issue has to do with institutional development, training, and dissemination. The Philippine biogas development experience in this regard clearly indicates the need for effective organization of resources for the production of biogas equipment, the development of training programs for middle level officials and technicians, and the eventual dissemination of technology and techniques to the project sites. Effective institutional

linkages are necessary here between research and development centers, extension programs, demonstration projects, government offices, management training programs, and the support infrastructure (repairs, supplies, etc.). In the Philippines, each of these problem areas was encountered, and in the case of the NIST Biogas program, serious problems resulted due to lack of coordination between agencies and problems of interagency communication.

It was found that especially for rural populations, conventional survey techniques involving complicated survey instruments and assumptions regarding technological sophistication will result in little or no feedback from the users of the equipment. This then results in the need to conduct face to face interviews which are time consuming and costly. It should be noted, however, that in the regional, metro, and BATEK biogas projects, the on-site seminars and training programs were successfully carried out and are examples of good institutional linkages.

Finally, one of the most important policy issues to emerge from the various national biogas development projects in the Philippines relates to problems of <u>scale</u> and <u>complexity</u> of development. In a general sense, difficult decisions must be made regarding priorities for allocation of limited resources. Should the national plan focus primarily on large-scale, commercial development, medium-scale rural development, or small- and micro-scale household or individual consumer development? As the Philippine case points out, there is an inherent contradiction here between the apparent "simple" technology involved in biogas systems and the related need for [illegible]atic, rigorous, and detailed training in order to keep the units functioning at full efficiency. For example, in the NIST biogas project it was determined that 64 percent of the surveyed units were inoperational, some of them for as long as one year. While not all of the technical problems could be traced directly to lack of

technical training, clearly this was one important factor.

Thus, the implications for choice of scale becomes important. If priority is given to individual household use, a rather extensive (and possibly expensive) training program will be required, regardless of the simplicity of the technology. A more effective approach would then focus on medium- to large-scale operations, where a technological staff can provide the required maintenance and attention to assume full efficiency of operation. Larger scale biogas projects can also more effectively integrate mixes of biogas raw materials (e.g., animal or agricultural wastes, fishery by-products, recycling sludge for fertilizer, etc.) than can individual households in most of the third world.

The Philippine Biogas Energy Program, as we have seen, offers several lessons for project managers and planners in other developing nations, particularly those where centralized planning and government control is a fact. Questions related to institutional linkages, integrated planning, and comparative economics are especially important; and as is noted in the case, despite a fairly high degree of centralization and commitment on the part of the government, personal relationships between institution heads and jurisdictional lines of authority remained important components of energy policy and practice.

Fiji Biogas

Perhaps the most innovative feature to emerge from the Fiji case is the elaboration of the concept of integrated farm systems. Two important factors are worth noting. First, integrated rural and urban development plans must be assessed in terms of agricultural priorities. If there exists an urbanization bias, there is the danger that agricultural production (the base for biomass inputs) will decline, thus detrimentally affecting the supply of biomass inputs and the adoption of the process on a national scale. Second,

once the decision has been made to promote integrated farming, it should be understood that in addition to the efficient economic outcomes of such a concept, there will also be sociopolitical implications. The Fiji case is a good example of the affects on rural life of the introduction of biogas and the implications for sanitation, education, recycling waste, food production, and so on.

Unlike the Philippine case, the Fiji case demonstrates the feasibility of providing biogas units for individual needs. The author agrees with the assertion that although the technology is relatively simple, it still requires detailed attention to assure efficient and consistent operation. However, he also believes that in a setting such as Fiji it is possible to provide adequate and appropriate training for individual households and that linked with the notion of an integrated farming system, such a project can achieve success.

Another point that emerges from this study is the recognition that policy makers and planners must assess and further develop integrated policy between the various decision-making levels (local population, middle level officials and technicians, central government officials), with the goal of creating a cooperative network of individuals directly involved in the development of biogas as an alternative energy source.

For island and village communities such as those in the Fiji case, new solutions to the endemic problems of food, fuel, and fertilizer supply must be found. It is clear that traditional methods are not going to be feasible in the future, and jumping to open farming techniques with high capital inputs is also not likely to succeed given the increasing costs in all areas, but especially fuel. The integrated farming concept discussed in the Fiji case raises the prospect of solving a variety of economic and social problems. The concept of self-reliance, usually just a slogan in many developing nations, is here given real meaning. At the very least, the case offers an example to

be experimented with and tested in other settings, as well as a challenge to more conventional rural development planning and policy models.

Ethanol From Wood

The New Zealand case history describes and analyzes the establishment of a new pilot project by the government to determine the feasibility of producing ethanol from wood on a commercial basis. New Zealand has abundant hydropower, geothermal resources, coal, and natural gas. The single energy problem is the supply of liquid fuel, which is essentially all imported. Attempts to utilize residues from the forest industry, coupled with the dramatic increase in oil prices, meant that a very significant step was being taken in assessing the potential energy options of New Zealand's vast forestry resources.

This case illustrates policy making processes and the resurrection and improvement of an old technology to develop an indigenous system for producing a gasoline substitute. As the case concisely notes, there were significant parallel events in the mid-1970s because of national concern for future secure supplies of fuel for transportation. Of particular importance was the energy scenario research conducted during the period 1974-1976, which not only clearly identified the supply of liquid fuels for transport as being the most critical energy problem facing New Zealand, but also demonstrated the potential for biomass energy development through energy farming.

A detailed analysis of the case uncovers a number of positive and negative factors which can be discussed. On the positive side, the pilot plant was successful in establishing the commercial feasibility of producing ethanol from wood. There are several key factors responsible for achieving this primary objective. First, the decision of the New Zealand Forest Service and other government agencies to undertake a variety of research and development projects regarding conversion of wood to ethanol as well as other liquid fuels

for transport was given high priority. A second factor was the position creation and appointment of a senior research scientist with established experience with fermentation technologies as well as demonstrated managerial capabilities. Indeed, much of the success of the pilot program must be attributed to the ability of the project director to improve upon the hydrolysis and fermentation processes as originally developed in Germany in 1926 and implemented in the Soviet Union in the 1940s.

A third major factor contributing to the success of the New Zealand pilot program was the fact that materials necessary for hydrolyzing wood and the subsequent ethanol distillation were readily available. For example, there already existed a well established phosphate fertilizer industry and the necessary sulphuric acid was manufactured extensively for the production of these fertilizers. In addition, the location of the pilot plant in Rotorua was a sound decision because the major source of the wood was located over a geothermal field of several thousand megawatts potential, thus providing more than ample hot water for hydrolysis and steam for ethanol distillation.

A final factor involved in the overall success of the pilot program was the wisdom of the appropriate government policy makers who supported this program to analyze the question of demand for ethanol to the year 2000 by means of long-range forecasting on the future prices of crude oil. Actually, by early 1980, the year 2000 price had already been reached by some of the oil-producing countries, and indeed exceeded by others. This, of course, had a major impact on the decision to accelerate the pilot project schedule to enable the initiation of plans for commercial operations.

Initial plans on the part of the New Zealand Forest Service to build a pilot commercial plant if the laboratory pilot research program proved successful may not proceed immediately. This possibility emanates from a recent government decision to proceed with the installation of a methanol plant

based on the Maui natural gas field discovered in 1979. However, the private sector has evaluated the commercial prospects of producing ethanol from wood and it is likely that investors will proceed with the development of a plant.

In summary, ethanol from wood is an attractive possibility for liquid fuel development in New Zealand, Nonetheless, the production of methanol from the natural gas field remains the government's immediate priority. As the natural gas field is depleted over the next 20 to 30 years, however, forestry in New Zealand will climb to be one of New Zealand's largest industries. Ethanol from wood will increase as an attractive possibility for liquid fuel development, particularly as it can utilize the vast forestry resources and residues and has the advantage of being a totally renewable resource.

Small-Scale Hydroelectric Project: The China Case

This case history has features that are relevant for management, education, and energy policies. It should be recognized at the outset that this is only one case of a small-scale, rural development project out of literally thousands; whatever conclusions we can draw from the project, it must be kept in mind that they are not necessarily generalizable. On the other hand, the author has visited a variety of such projects in diverse regions of China, and while each contains its own specific characteristics, there are patterns and trends that are common to many rural development projects in China. With these cautions in mind, we can proceed to summarize what might be learned from the Yaocun project.

On a macro level, it appears that the Chinese, despite numerous policy shifts, political struggles in Beijing, and corresponding political reverberations in the rural sector, have been making progress in the expansion of the role of small-scale rural development projects such as the hydroelectric project described here. The linking of small-scale projects with medium- and large-scale enterprises in a rational and planned manner is a major goal of Chinese

policy makers and one that, in the case of the Yaocun project, was successfully achieved.

As we have seen, however, it was achieved in an atmosphere of periodic confusion over the respective roles of central authorities and local subprovincial authorities. The issues raised here regarding centralization and decentralization are important. China, despite various efforts to "decentralize," remains a state economy in which the role of central authorities is preeminent. Yet the Chinese have recognized the need to bring local initiative into play in a way that does not conflict with overall national plans and goals. As the Yaocun project shows, there were several occasions when the commune and county authorities were in conflict with provincial and national authorities. These conflicts were often resolved because of the unique management and political skills of the project manager, who was able either to persuade or bypass upper-level authorities in order to have the project continue on the path toward completion.

It is not likely that China (or, for that matter, many other developing nations) will abandon central-level planning for a more market-oriented form of decentralization. This being the case, the success or failure of a small-scale project such as Yaocun will often hinge on the special managerial skills of the project manager. Management training and education programs aimed at providing these skills will assume increased importance, then, in sociopolitical environments such as China's. It should be mentioned that Chinese authorities in the Ministries of Education and Industry are aware of this need and are beginning new management education programs directed toward this goal.

Related to the "centralization-decentralization" issue is the question of participatory planning. The Yaocun project has shown that early involvement of the recipients of development project outputs (in this case, the farmers

of the three production brigades) is a positive step in overcoming local-level resistance to change. It has become a truism that many development projects fail, not because the technology is inappropriate or because the project is not cost-effective, but because the local population either senses hazard or does not want to get involved.

As we examine the Yaocun project, we see that even in the feasibility stage, production brigade members were actively involved in data collection, discussions, and planning, remaining involved up to and through the handover stage. Participation of this sort can, of course, be manipulated and guided. When this is the case, however, the perception of this brand of participation becomes apparent and local-level involvement often ceases. Li was aware that people in the production brigades had to be genuinely involved in decision making, but also had to realize that there was a need for strong leadership on the project team. This mix between participation and leadership represents another area of success in the Yaocun project and perhaps offers some lessons for other projects of this type.

Finally, the critical stage of selection and approval revealed another management-related problem, as the project manager and his team sought to move the project through the bureaucracy to obtain the necessary forms of approval. It is likely that in most developing nations, regardless of whether they have a socialist economy or a mixed-state economy, project managers will have to acquire the skills to successfully approach the bureaucratic apparatus and take the various political risks implied.

In other words, management skills alone are not sufficient to assure the successful completion of a project. The project manager must have an understanding of the political environment in which he is working and must be able to make appropriate judgments regarding timing and negotiation strategies.

Li acquired these skills through his long experience in project management in a highly politicized environment. This level of training, which must therefore be considered a viable part of any overall management education program, represents an important research area for the future.

Finally, the Chinese appear to be convinced of the utility of combining large-scale energy-related projects with small- and medium-scale projects. Large-scale projects still remain an important component of overall energy policy in China because of economies of scale. It is still recognized, however, that large hydroelectric projects in particular present serious environmental and social problems; they are difficult to manage and demand a more advanced infrastructure to support and efficiently consume the electricity generated. Chinese officials also noted that large dams have major siltation problems which are avoided by the smaller-scale projects and certainly those working from a canal system.

Another advantage of small-scale systems such as Yaocun is the multiple use that can be made of the water resources utilized for electricity generation. As we have seen, the canal was constructed first to provide adequate water resources for drinking, cooking, farming, irrigation, and other such uses. The adaption of the canal system to accomodate small-scale hydroelectric projects was clearly an added advantage to the region, despite initial reluctance on the part of the local population.

In summary, the Yaocun project provided a certain amount of security to the region in at least two ways: First, the supply of electricity was clearly increased to consumers who were too distant from Anyang to benefit from the larger source of electricity. Second, the contribution of the small plants to the Anyang network contributed to an overall savings, especially during peak demand periods. Given China's extensive water resources and the current

problems associated with fossil fuels, it is likely that both large- and small-scale hydroelectric projects will remain a high priority for China's overall energy policy.

Mini-Hydroelectric Projects in the Philippines

The Philippines case history examines two separate hydroelectric projects, one under the administration of the National Power Corporation (NPC) and one under the National Electrification Administration (NEA). The two projects are significant in demonstrating the nature of the policy making process in the Philippines, the creation of a new agency to accelerate rural electrification and development, the dynamics of public sector/private sector relations in the development and distribution of power, and the viability of electric cooperatives in furthering the growth of rural areas.

One major policy issue to be resolved in the need for rural development through electrification and water supply systems for both domestic consumption and irrigation was in connection with responsibility for accelerating small water power projects. The Philippine case discusses the rapid growth of the country's energy program, highlighting the importance given the small hydro program for rural areas. The presidential decree to give NEA primary responsibility to develop this program in consultation with the Ministry of Energy and NPC represents a beneficial move.

The Talomo hydroelectric project produced a number of positive factors. This project demonstrates vividly the ability to repair and refurbish an existing old dam and powerhouse to make a significant contribution to the energy needs of several rural municipalities. Of equal importance is the fact that the NPC used this project to train young engineers in the management of hydroelectric projects to develop a pool of experts for future projects. A third factor is the leasing of the Talomo power plants to the Davao Light

and Power Company (DLPC) in the late 1970s. This transfer from the public to the private sector is important in demonstrating the dynamics involved in further improving and therefore optimizing the efficiency of a badly needed water power system without any further government subsidy.

The Philippine government in mid-1980 has accelerated its energy program with particular emphasis on the development of mini-hydro projects for rural development. The Ministry of Energy manages the overall energy program, although the implementation of the mini-hydro program is carried out under the NEA, which is directly under the Office of the President. Coordination is necessary within and among the various government agencies for the mini-hydro program to be successful.

Under the present scheme--as exemplified by the Baliguian project--the mini-hydro project is identified by the rural electric cooperative, whose main aim is the electrification of its franchise area. Hydro projects, therefore, may be planned to serve this single objective, whereas the very same project could be expanded to service irrigation or flood control needs and thus carry greater impact in stimulating rural development.

Rural development via electrification can be viewed from the angle of employment generation. A rural electrification co-op provides employment directly through its internal operations and indirectly, as a catalyst, through provision of power to industry. As a matter of policy, co-ops offer jobs at attractive competitive wages to qualified permanent residents from within the coverage area. A typical co-op in the late 1970s hired 350 workers during its organizational and construction stages, and around 100 full-time staff during actual operation. The co-op also provides employment opportunities through its impact on industry and trade. A study made of the Misamis

Oriental Rural Electric Service Cooperative, Inc. (MORESCO) indicated that at least 400 new jobs were created with the establishment of companies after the 1972 inauguration of MORESCO, benefitting about 2,500 family members, or 3 percent of the area's population. Other benefits come from providing increased energy for schools so evening vocational programs can be offered, as well as training programs sponsored by NEA and other agencies for linemen, electricians, and plant operators.

The current mini-hydro program will provide additional employment in the rural areas. The initial Baliguian project has resulted in employment for some 70 workers from the area covered by the co-op. It has given rise to equipment and parts fabrication in a rural city for the co-op technical staff and engineering shop. The indirect employment generation through industrialization cannot yet be measured; however, it is probable this effect will be felt in coming years.

The discussion of the two case histories illustrates the shift in priorities and therefore policies of the small hydro programs over the years. One of the priorities of the government agency in the 1950s was profitability or at least income from the project to justify undertaking the work, in addition to its other objectives of providing electricity to as large an area as possible and improving rural conditions, industry, and the quality of life. Under the present government program, mini-hydro projects are being pursued for rural development, disregarding short-term profitability to the extent that subsidized financing is added into the program as an integral feature. This is consistent with the government belief that in the late 1980s the key to rapid development is in the availability of cheap and dependable power.

Policy and Research Issues

Each case documented and analyzed presents a number of extremely valuable lessons for policy makers, project planners, and project managers with respect to the future role of biomass and small hydro energy projects for rural development. There are thousands of terrestrial and aquatic plants (solar energy fixing systems), any one of which might be the ideal choice for a given application to a given set of circumstances. In addition, there are ample water resources for hydro power and irrigation in many regions of the world. These facts are of particular importance today because of the continued dependence on imported oil by many countries, with resulting disruptive effects on their economies, and therefore societies. The fact that the world price of oil increased from $13.50 per barrel in January 1979 to $30.50 per barrel in January 1980 reinforces the outstanding need to accelerate research and development of alternative energy sources.

A matrix showing the interrelationships of policy and research issues with the three energy sources covered in the case histories is shown in Table C-1. Some of these issues have been analyzed and discussed in the context of the individual case histories.

Perhaps the most significant and controversial research issue to emerge from the cases and literature on biomass energy has to do with the so-called competition between "food" and "fuel"--whether biomass resources should be set aside for one of these purposes or the other, or for what ratio of both. Depending upon the complex set of variables present in each national setting, a series of arguments can be made both pro and con around this question. Some examples of statements in favor of biomass development over investment in food resources are:

Table C.1

BIOMASS AND SMALL HYDRO POLICY AND RESEARCH ISSUES*

Energy Source	Policy Issues	Research Issues
Ethanol	Skilled manpower needs • Administration • Managerial • Technical Food versus fuel Land use	Inventory of local resources Cropping schemes Management needs Food versus fuel
Biogas	Public vs private investment for commercial production Infrastructure needs (transportation, power, water) Individual or community digesters Integrated systems	Energy efficiencies of conversion technologies Cost of delivery of plant material to energy generator sites New approaches to design of biogas digesters Use of digester sludge Public health problems
Small Hydro	Social and environmental factors Multiple purpose Land use Skilled manpower needs	Construction materials Packaged hydro units Post-Project Evaluation Procedures Retro-fitting existing units

*This overview is confined to the cases in this manuscript only.

1. That a substantial amount of energy goes into food production--i.e., transportation, fertilizers, production equipment, and herbicides--all mainly petroleum based. Biomass would provide for an energy tradeoff and replace much of the fossil fuels currently used, which have become increasingly costly since the 1973-74 oil embargo.
2. Proper management of agri- and silviculture biomass production should and can occur to alleviate current use problems such as depletion of forests or leeching the soil of nutrients. "Double cropping," for example, can be applied to areas which are unproductive for parts of the year due to the seasonal character of the primary crop. Furthermore, existing technologies may be applied for increased yields, superior genetic strains, and better fertilizers/irrigation.
3. Much of the feedstock used in many types of biomass production is total waste: i.e., human and animal excrement, or agri-waste such as corn cobs, bagasse, and timber-"slash," which leads us to:
    a. The main issue of food versus fuel seems to be involved with how the biomass energy compares with the food energy;
    b. And that the questionable--in terms of ethics--material seems to be the high quality grains used for the alcohol fuels as a petroleum substitute.

Similarly, statements can be identified that are equally persuasive in opposition to the development of biomass energy at the expense of food products:

1. That energy-consumptive countries such as the United States have a high energy per capita consumption and that biomass energy production (specifically alcohol fuels from grains) will take food from the mouths of the hungry, the need to fuel our cars taking precedence over the export of grain to countries in need of aid.
2. In most countries, a general shift toward urbanization and increasing population have reduced the amount of timber and agricultural land available for large-scale biomass production efforts.
3. Furthermore, that most countries have exhausted any virgin land (no new frontier) and that which exists is suffering from nutrient depletion and erosion problems.
4. And that marginal cropland (that which is often suggested for biomass production) requires greater energy input than prime land, thereby making the potential biomass fuel not economically feasible.

These are issues that defy simple solutions and cannot be resolved here, but they must be seriously considered by policy makers and planners involved in making the difficult choices referred to earlier.

There are additional policy and research issues that are common to both biomass and small hydro energy development. For example, as many of the cases illustrate, integrated national planning is a priority in most developing nations, and this raises questions regarding the identification of the appropriate mix between rural and urban energy needs and the roles to be played by biomass and small hydro systems as two forms of that energy supply. Related to this issue is the need to conduct more research on identifying and planning for

more effective institutional linkages. These linkages need to be on two levels: (1) the research links between central-level scientists and technicians and the local-level agro-technicians involved in implementation of new developments in technology, and (2) linkages focused on the organization of resources for production of technology and later dissemination.

Another series of research issues revolve around the comparative economics of both biomass and small hydro energy development. Economics of scale are important here, with questions focused on household, small farm, farm clusters, livestock farms, and large-scale commercial priorities. Policy regarding investment and allocation of scarce resources must take this dimension into account.

As is noted in the cases and the matrix, there is a complex set of issues focused on the relationship between the technology of both small hydro and biomass energy conversion and the related human resource development needs. What appears to be a simple technology can create a variety of implementation and maintenance problems if appropriate training is not developed in a parallel manner. The question of scale is important here as well, but whether it is large-, medium-, or small-scale, if the fit between technology and techniques is lacking, inefficient use of the resource is likely to be the result. Since there is a fair amount of disagreement over this issue, further research is warranted. With respect to small hydro projects, refurbishing old systems is perhaps one of the more critical research issues.

The issues raised here are not inclusive, but represent those that emerged as most important in the cases and much of the literature on biomass and hydro energy development. Despite the lack of agreement among many specialists in this area and the relative newness of the field, it is important to encourage further research in the policy areas mentioned. The cases have demonstrated

the great potential of biomass energy and the variety of methods and means with which it can be developed.

The world energy situation will continue to demand new and innovative solutions to the requirements of both developed and developing nations. Especially important will be those energy alternatives which offer the possibility of renewability and those which are capable of adapting to a closed system such as an integrated farming system. It is hoped that this series of cases has highlighted some of these solutions, suggested areas for further research, and provoked discussion on what promise to be two of the more exciting renewable forms of energy available.

NOTES

1. Walter Vergara and David Pimentel, "A Study of the Energy Potential of Fuels from Land Biomass in Five Countries," in Energy from Biomass and Wastes, Symposium Papers, Washington, D.C., August 14-18, 1978 (Chicago: Institute of Gas Technology, 1978), pp. 88-105 (p.100).
2. John R. Benemann, Biofuels: A Survey (Palo Alto, Ca.: Electric Power Research Institute, 1978).
3. Vergara and Pimentel, 1978.