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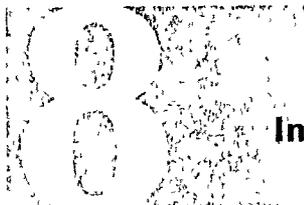
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INDUSTRIAL RESEARCH INSTITUTES:
Their Role in the Application of
Appropriate Technology and Development



THE REPUBLIC OF KOREA:
An Example of
Integrated Regional Development

Donald D. Evans

A series prepared by the
University of Denver
Denver Research Institute
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CASES IN THIS SERIES



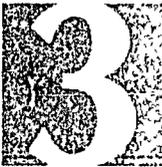
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THE REPUBLIC OF KOREA:
**An Example of
Integrated Regional Development**

Donald D. Evans

FOREWORD

This case history has been written to assist development planners, personnel of industrial research institutes, and USAID mission personnel in understanding the role that IRIs can and do play in the application of technology to development. This case history is one in a series of eight prepared by the Denver Research Institute under the sponsorship of USAID/Office of Science and Technology (contract AID/ta-C-1337).

The cases in this monograph series first appeared in another DRI publication, Appropriate Technology for Development: A Discussion and Case Histories, edited by Donald D. Evans and Laurie Nogg Adler (Boulder, Colorado: Westview Press, 1979). This book was sponsored by the USAID Office of Science and Technology in preparation for the United Nations Conference on Science and Technology for Development (UNCSTD).

INTRODUCTION

INDUSTRIAL RESEARCH INSTITUTES

In many countries the creation of a viable indigenous industrial sector has long been considered one of the key elements to economic development. Consequently, an industrial research capability is of significance in defining the industrial needs and priorities of a country or region and matching them with appropriate technologies. An industrial research institute (IRI) has been defined as a technical organization established to make direct contributions to industrial development in the private and public sectors¹. In this context an IRI differs from private research entities which have no proclaimed mandate or responsibility in the practical application or adaptation of technology to their countries' development needs. Frequently industrial research institutes are in some manner government funded and are therefore closely allied to the economic, social and political climate of that government. Ideally, IRIs play a supporting role in the design and implementation of national policies that reflect economic development and growth, while functioning autonomously. In reality, however, government usually plays a substantive role in research institute operations. In any case, compatibility and cooperation among government agencies should be preserved, and selection of industrial research programs should reflect needs of both the public and the private sector.

In many instances, the IRI acts as liaison between government and industry. Ideally and particularly in less developed countries (LDCs), the IRI acts as an intermediary in determination of the need for and the subsequent creation, adaptation or transfer of technology. In fact, the study of technological opportunities or the choice of appropriate technology for development is one of the major functions of the industrial research institute.

In comparison to other technologies, appropriate technology represents the social and cultural dimensions of innovation². As a mediator in an innovation process, a research institute's task is to identify the real needs of the local community, develop or introduce technologies and organizational means which can meet these needs and initiate a process of development based on the internal innovative forces of the local community³. In this manner, the IRI addresses the issue of appropriate technology and its role in the development process.

However, opportunities for innovation do exist in areas other than just industrialization--increasing agricultural productivity, developing

¹ United Nations. Industrial Research Institutes, United Nations Publication No. E.70.II B.21. New York: UN, 1970, p. vii.

² Nicolas Jequier, Appropriate Technology: Problems and Promises. Part I, The Major Policy Issues, 1976, Development Centre of the Organization for Economic Cooperation and Development (OECD). p. 9.

³ *Ibid.*, p. 36.

includes programs for producing a high-nutrition cattle feed, improved orange processing and shipping methods, design and partial testing of a small, wind-powered electric power generating system, and other technical and economic studies.

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rural technologies, and offering incentives for small industrial projects are also duties that a research institute is likely to perform.

The methods by which IRIs assess technological choice and stimulate innovation are varied. Most often development strategies would include a combination of the following:

- Survey, study and develop uses for local raw materials.
- Develop new processes and improve existing ones.
- Develop new products and recognize new uses for existing ones.
- Improve industrial and agricultural productivity.
- Study the technological and socioeconomic feasibility of industrial and agricultural projects.
- Develop standards and specifications.
- Determine choice of technology and scale of operation.
- Determine industrial location and site.
- Conduct marketing research⁴.
- Acquire and disseminate scientific and technological information.
- Systems design and management of development programs.
- Evaluate a chosen technology and its relationship to local economic and cultural traditions.

To establish solutions to identifiable problems, the research institute often adapts foreign technologies to suit local conditions and offers incentives to small industries to create new technologies. Technological innovation is accomplished in a variety of ways from actual adaptation of a chosen technology to training of researchers and engineers for institution building and infrastructural support, to establishment of extension services to help define and fulfill needs.

The creation of linkages between research institutes has allowed increased communication and the transfer of information and technologies, not only between developed and developing countries, but among developing countries as well. In a few instances, regional research

⁴ United Nations. Proceedings of the Interregional Seminar on Industrial Research and Development Institutes in Developing Countries, Beirut, Lebanon, 30 November-11 December, 1964. Vol. 1, New York: UN, 1966. p. 45.

institutes or networks of institutes have been established to facilitate development in common geographic and cultural areas. (ICAITI in Guatemala representing Central America is such an example.) Similarly, an international IRI organization called WAITRO (World Association of Industrial and Technological Research Organizations) has been created.

Industrial research institutes tend to become the foci for national S&T development and have offered essential infrastructural support. Research institutes, therefore, may play a very important role in mapping the future economic growth and development of a country. With this increasing responsibility, an IRI's task becomes more complex and difficult, particularly when original development goals are overwhelmed by other considerations. Factors such as politics, financial risk, societal or cultural considerations, legal restrictions, staffing problems, marketing problems, fear of change, and sheer inertia may impede or block the transfer process and thus weaken or negate its economic effect⁵.

CASE HISTORIES

Much can be learned about development from the investigation and analysis of industrial research institutes. The Office of International Programs (OIP) at the Denver Research Institute (DRI) has initiated linkage activities with a variety of research institutes worldwide over the last decade under the sponsorship of USAID's Office of Science and Technology. Through these linkage activities, choice and adaptation of technology, training of researchers and engineers, exchange of information and help in the management of research institute affairs have occurred. A dynamic process of communication has been established through DRI's relationship with each research institute, and much knowledge has been gained about the development process by all those involved.

Realizing the value of imparting research institute experiences to others in the development field, DRI has gathered several case histories of industrial research institutes' endeavors in the area of technology transfer. The cases were collected for the most part by OIP staff (often assisted by IRI colleagues) who acted as impartial reporters when collecting the information. The goal of the research was not to select cases that showed only successful adaptation of technology, but to show ways and means by which IRIs must operate to encourage and achieve progress in the development scheme. There are, in fact, examples where a transfer of technology is considered unsuccessful or unsatisfactory.

The case The Republic of Korea: An Example of Integrated Regional Development, written by Donald D. Evans, describes the Korea Institute of Science and Technology's (KIST) efforts to provide regional development on a 703-square-mile island. Research and Development

⁵ James P. Blackledge, The Industrial Research Institute in a Developing Country: A Comparative Analysis. Washington, D.C.: USAID, 1975. p. 19.

THE REPUBLIC OF KOREA: AN EXAMPLE OF INTEGRATED REGIONAL DEVELOPMENT

Donald D Evans

A concerted effort was made between 1975 and 1977 to examine systematically the environment and economic circumstances of a small, highly differentiated rural area of the Republic of Korea. A program to apply science and technology toward the economic and social development of this area was developed, involving the integrated efforts of the population, the local government, the national government, the local university, a national association of private firms interested in export development, and a technologically diversified contract research organization--all located in the Republic of Korea. The effort resulted in both successes and failures; it involved rural citizens interacting with scientists and engineers seeking practical solutions to significant problems affecting the lives and livelihood of a contiguous community of almost one-half million persons.

BACKGROUND

Cheju Island is one of fourteen provinces in the Republic of Korea. It lies approximately 100 miles south of the mainland of the Republic at latitude 33° 27' N., at the confluence of the Yellow Sea and the Sea of Japan. It is about 600 miles due west of the Japanese island of Kyushu and lies at the head of the South China Sea. Although it is located at a maritime crossroads of East Asia, it has never been highly developed or internationalized during ancient or modern times. The maritime climate permits growth of subtropical plant species of many unique varieties. Principal crops are sweet potatoes, used for starch production; barley, used in brewing; forage crops; and, especially in more recent times, oranges. The surrounding waters yield a variety of seafood, mostly for local consumption, plus mother-of-pearl, widely used as an inlay material in traditional oriental furniture. The volcanic core of the island, Mount Holla, rises to 6,400 feet and dominates the 706

square miles of the surrounding countryside. Many small villages and clusters of houses dot the landscape. These are built for the most part in characteristic Cheju style, which utilizes the native volcanic rocks for walls and rock-weighted, woven straw ropes to hold the thickly-thatched roofs in place against ocean winds. The mild climate, excellent beaches, and spectacular scenery have made Cheju in recent years a rapidly developing regional tourism center.

Local and national governments, recognizing the unique characteristics of the island and wishing to control its development in such a manner as to not destroy cultural or scenic values, yet seeking to improve the living standards and productivity of the province, had consistently sought to foster planned, organized growth that would lead to self-sufficiency.

During a visit to the island in 1975, the Minister of Science and Technology of Korea, Dr. H. S. Choi, met with the provincial governor, and the topic of Cheju's development was discussed. Minister Choi perceived the need for a comprehensive approach to the problem, utilizing the scientific and technological capabilities of the country to study the situation and develop a program of experimentation and application of appropriate technology. Subsequently, he presented his concept to the staff of the Korea Institute of Science and Technology (KIST), which initiated a preliminary feasibility study. This ultimately resulted in a proposal to the provincial government recommending a comprehensive study and development project.

In the meantime, the minister contacted the Korea Traders Association (KTA) at the suggestion of the President of the Republic, Chun Hee Park. The KTA, a private association of manufacturers and traders in Korea, fosters regional development as a means of stimulating production of exports that its members may market abroad.

Ultimately, this coalition of interests--the provincial government, the Ministry of Science and Technology, the KTA, and KIST--resulted in the initiation of a research and development project. It was funded at KIST through contributions of (Won equivalent) \$202,000 from the budget of the ministry and \$165,000 from the KTA and was launched with anticipation in April 1975.

DESCRIPTION OF THE PROJECT

As a result of the preliminaries, KIST submitted a proposal for evaluating and initiating research appropriate to the Cheju situation. KIST itself represented the concept of applying technology to achieve economic and social development in that it was conceived and created as an institution for the identification, selection, adaptation, development,

and application of technology in pursuit of national development goals. Based on the example of contract research organizations in the United States, KIST is a large, multi-disciplinary technological institute whose staff of 1,000 members represents a wide range of scientific and engineering disciplines. It was organized to provide research and development (R&D) services to industry (both public and private). Located in Seoul, the capital city, KIST is dependent on individual contracts with private and government entities for its viability. It receives no regular stipend or grant from the government, although government entities are a primary source of its support through R&D contracts. Based on its ten years of diversified experience, KIST was a good source of concepts and projects conducive to Cheju's development.

Realizing that no development project of the type envisioned would succeed without the agreement and participation of the affected population, one of the first efforts was to involve representative members of the Cheju community in planning and analysis. The provincial government officials strongly supported the effort from the outset and were effective in identifying local residents who were willing to participate. These persons were from the agricultural cooperatives of the island and from the fishing villages along the coast. Faculty members from the national university branch located on the island provided useful intermediary functions and interpreted local conditions in terms that were understood by KIST investigators.

In the planning stage, KIST personnel met many times with island residents to identify those areas of activity that might benefit most from development efforts. It was ascertained that the following subject areas afforded the highest probability of benefiting from the project: (1) feed for livestock; (2) development of the orange-growing and processing industry; (3) supplying electric power to remote areas; (4) development of marine resources; and (5) exploitation of plant resources unique to the island.

These were arranged in three primary categories: (1) those to receive commercial development as a result of preliminary study and evaluation; (2) those to be studied as "basic" research subjects, to be pursued possibly later as development subjects; and (3) those to be "policy studies," to be described and qualified as a guide for authorities who would frame policy for Cheju's progress.

Livestock Feed Project

The volcanic soil of the island is of such recent origin that it has not weathered into the rich support for plant life that characterizes older soils from volcanic sources. Consequently, although it can help support a livestock industry

with forage crops, it is not sufficient by itself to provide all the nutrients and energy needed by cattle.

For example, during the winter months when forage growth is slowed, cattle are undernourished to the extent that brood cows develop a deficiency disease. This interferes with their fertility, resulting in calving only every other year rather than annually. The energy and nutritional deficiencies in the available cattle feed are so pronounced that over the winter months cattle lose more than 15 percent of their weight when fed solely on local feed. Some feed supplements are imported but are very expensive, resulting in such high market prices for beef that sales are restricted. Further, it is not feasible to increase the amount of rangeland or to raise additional forage because land use already is intensive. Besides, other cash crops, including sweet potatoes and barley, are more profitable.

However, surveys by KIST food scientists showed that necessary nutrients and food energy sources were present in the Cheju environment if they could be made available to cattle. They existed in the form of cellulose, bound with lignin and silica, in the plentiful barley straw and of non-protein nitrogen (NPN) contained in poultry manure and other farm animal excreta. Important elements such as calcium, phosphorus, copper, zinc, manganese, and molybdenum were also present in the poultry manure.

The KIST staff knew of experiments in Europe and the United States where bacteria had been grown successfully on a substrate of poultry manure. The protein content of the bacteria was relatively high--and cattle could thrive on a diet of ordinary forage supplemented with this high-protein bacteria. The principal problem was that the manure had a highly unpleasant odor that repelled the cattle and raised questions of possible toxicity. The digestive systems of cattle contain a bacterium that also can utilize the poultry manure, if the cattle could be induced to ingest it. To gain the optimum utilization of this food source, however, significant bacterial growth on the poultry manure had to take place externally before cattle consumed it.

The odor problem could be eliminated through forced drying of the material and pelletizing as is done commonly in large-scale "chicken ranches" in the United States and elsewhere. However, in the Cheju situation this would have added an unacceptable cost to the process, given the high price of fuel and the requirement for additional equipment and labor. Consequently, a way to use the manure in the wet condition was sought.

A threefold problem was presented to the researchers:

- (1) Could barley straw be treated on Cheju farms so that the bound cellulose could be released

in sufficient degree to significantly increase the amount available to the digestive tracts of cattle, thus increasing the energy supply?

- (2) Could poultry manure be used as a substrate for growing bacteria so that, when used with other contained elements, the bacteria would meet the nutritional requirements for cattle feed?
- (3) Could both of these processes be adapted to the Cheju conditions, allowing farmers to produce their own feed supplements, and at a cost that permitted the product to be competitive with imported beef?

It was determined that the first problem could be solved if a strong base chemical could dissociate the silica and lignin, thus freeing the cellulose for utilization by the animal. Such a chemical was sodium hydroxide, which, when blended at a ratio of 3 percent by weight with chopped barley straw, accomplished the separation required to raise the available cellulose from 35 percent to 50 percent and more. The dissociation took from twenty-four to forty-eight hours, depending on the ambient temperature. Although highly toxic and necessitating considerable care in handling, sodium hydroxide was familiar to the Cheju farmer, having been used for many years (in a highly dilute form) for clothes washing. Also, it was cheap and readily available, even in remote rural areas.

The problem with the poultry manure was solved by a natural organic process. When air was effectively excluded from the manure, natural anaerobic bacterial growth occurred, converting the offensive uric acid to ammonia plus other, odorless, compounds. Also, the resulting bacteria were a highly available source of protein and other nutritional elements that cattle could utilize.

However, the anaerobic bacteria required yet an additional source of energy-yielding substance on which to feed. This was handily supplied in the form of rice bran cake (i.e., rice bran from which the oil has been extracted), which was essentially an agricultural by-product in Korea and was available in large quantities at low cost.

Finally, it was determined that the chemical treatment of the barley straw and the growth of anaerobic bacteria on the poultry manure could be accomplished simultaneously, thereby simplifying and accelerating the process.

The final "recipe" for the KIST-developed feed process was:

- (1) Mix 50 percent chopped barley straw, 20 percent wet (70-80 percent water) poultry manure, and 30 percent rice bran (or other type of bran) cake with 3 percent sodium hydroxide.
- (2) Place the mixture in fifty-kilogram plastic bags under a plastic "greenhouse" on the ground or in a plastic-lined, covered trench. Allow the mixture to stand until the manure odor has been replaced with the typical "sweet" smell of silage that is well known to the farmer. This will require from forty to sixty days depending upon the weather.
- (3) Feed the product in a ratio of one-to-one with normal roughage.

The plastic bags or coverings serve not only to exclude the air, thus permitting anaerobic bacteria growth, but also to insulate the mixture, raising the temperature and promoting the chemical dissociation of the cellulose in the straw and the further growth of the bacteria in the manure. The plastic also may be used to cover and promote the growth of vegetable crops when not being used for feed production.

Feeding tests were conducted at the time of case preparation on sixty head of cattle in four controlled experiments. Instead of the weight loss normally encountered during the winter, the test animals gained an average of 500 grams per day on the 50 percent roughage substitution and 900 grams per day when the KIST mixture was substituted for 40 percent of the imported feed supplement that composed one-third of the diet of winter herds. The imported feed supplement consisted of ground corn, soybeans, domestic oil cake, and grain. When this mixture was fed alone at the one-third ratio, each animal in the test herd gained an average of 800 grams per day. Two- and three-year tests were underway at the time this case was prepared to determine the long-term effects of the KIST feed diet. Some Cheju farmers were feeding the mixture regularly to their herds and were pleased with the results.

It was found that the mixing process for the feed required the development of a special machine. The design consisted of a fixed drum with a set of rotating blades inside. It could be fabricated from locally available sheet metal and parts and was powered by easily obtained two-wheel tractors.

The cost of the KIST feed when produced on Cheju farms was less than \$100 per ton, which compared with imported feed supplement at over \$200 per ton--and the

KIST product gave better results. Thus, the Cheju farmers were provided with a new cattle feed supplement that they could produce economically directly on their own farms. The technology was simple, and beef production improved markedly.

At the time, KIST was planning to extend its program to the mainland by experimenting with the use of rice versus barley straw, since the latter was much more plentiful on the mainland. If the long-term feeding tests on Cheju proved the acceptability of the feed, then it was assumed that the process would be widely adopted. In discussing the project, Director D. Chun Su Kim stressed the importance of having involved the Cheju farmers at all stages of the development process, thereby overcoming their natural reluctance and suspicion of innovations.

Dr. Kim visited Australia, where the Commonwealth Scientific and Industrial Research Organization displayed considerable interest and was experimenting with the process. The West German government also showed interest in supporting the project, particularly in testing the method on the Korean mainland. Meanwhile, information arrived that similar experiments were being pursued in the United States and Europe; although, as Dr. Kim pointed out, each situation will require specific adaptation.

Orange Products and Processes

Historically, Cheju was the site of the casual cultivation of oranges, which grew well on the southern reaches of the island. In recent years successful efforts were made to commercialize their production, since a ready market existed. Oranges were an agricultural product well-suited to the Cheju environment, being fairly labor-intensive, of high value, and capable of being raised on land little adapted for other agricultural purposes due to soil characteristics and general rockiness. From 80 thousand tons in 1975, production was scheduled to increase to 300 thousand tons in the 1980s.

The KIST researchers were not plant scientists and could contribute little to the selection and propagation of orange trees; however, they believed that the need and opportunity to improve orange storage, processing methods, products, and packaging existed.

One of the main difficulties on the island was the absence of cold storage facilities for the orange crop, resulting in spoilage rates of up to 30 percent, plus the inability to hold the crop long in storage, causing market oversupply and reduced revenues. The best storage conditions were determined by experiment to be a temperature of 4° to 6°C with relative humidity of 85 percent. The KIST staff

observed that, although mechanical refrigeration was possible and might even be cost-effective, the temperature gradient of the island over a twenty-four-hour period during the harvest season showed nighttime temperatures well below those required to greatly extend the storage life of oranges. They decided to try to design a storage method that could average normal day-night temperature differences. The objective was a steady humidity and temperature condition that would "smooth the curve" of daily fluctuations.

By experimenting with a variety of storage house designs that incorporated a humidifier, ventilator, insulation and locally available materials, an efficient, low-cost configuration that was capable of being constructed with local labor was finally developed. The method did involve a relatively sophisticated temperature and humidity monitoring and control system that determined when the flow of humidified air through the storage house needed to be changed; that is, cool air introduced at night with sealing off during the warm daytime hours. Without these continuous monitoring provisions, the system would not function well enough. Purely unassisted human control of the process would not be adequate.

Additionally, the KIST food scientists were able to recommend chemical treatment for the oranges which essentially eliminated the spoilage caused by bacteria and other organisms that attack the fruit. Thus it was the combination of the improved storage conditions with the chemical treatment that resulted in a dramatic increase in the time which oranges could be stored and still retain their marketability.

The three-year development of orange storage facilities was perhaps the greatest immediate economic success of the KIST project on Cheju, promoting the preparation and distribution of a design and construction manual throughout the province. It was a prominent factor in an increase over a two-year period of about \$4 million annually in orange crop revenues.

Additionally, the packaging of oranges came under study. The customary method has been to utilize wooden crates, but they were expensive to produce and failed to adequately protect the product in shipment to mainland markets. Given the relatively high cost of oranges, savings in damage losses would yield a valuable reward to the processors. Ordinary cardboard containers also had been used in more recent years, but these were not durable enough.

The researchers and producers approached the problem from the standpoint of "containerization"--the complete orchard-to-market containment of the fruit. This involved the design of a packaging system using plastic wrapping and

boxes, which were then placed in large metal shipping containers for transportation to the final metropolitan distribution points. The recent introduction of container ships operating to the mainland appeared to make this feasible.

This system came to be used to ship approximately 40 percent of the crop to market. Reasons for its failure to capture all of the market were that many growers still preferred the older, initially less expensive method, although it could be shown that the new system was overall more economical. One factor inducing higher initial costs was the use of the special plastic containers, which had to be cycled through the system six or seven times to make them cost-effective. This required more systematizing and handling between the orchard and the market than smaller private producers were willing or able to undertake. Additionally, container ships were not always available at the desired times. Further, distributors had a preference for the cardboard containers, perhaps because they had other uses, while the expensive plastic ones had to be returned to the shipping depots.

As of 1978, 30 to 40 percent of the annual Cheju orange crop was being packaged and shipped in the KIST-designed system. This usage was primarily by the growers' cooperatives that the government had encouraged on the island and that generally were more progressive and development-minded than the independent producers whose individual growers were larger, but who tended to adhere to conventional methods and to resist change.

The research and development teams also made a laboratory study of orange processing methods for the production of marmalade, pectin, juice, and oil from orange skins. Although they felt that they had made some improvements in these products, the commercial processors on the island, in subsequent interviews with project evaluators, stated that "there was nothing new" in what they had been told as a consequence of the KIST experimentation.

A successful laboratory process also was developed for the production of an orange-based liquor, which it was believed would find a good market both domestically and abroad. However, the product evaluation report noted that there was consumer resistance to the taste, which apparently was too different from that of traditional alcoholic beverages (derived primarily from rice). In the meantime, the project exhausted its funding, and the liquor development effort was shelved. (Also, a surplus orange problem had existed when the research was started, but this later had been solved by increased fresh orange sales.)

Wind-Powered Generators

Cheju Island experiences year-round strong and steady winds near the sea, and seasonal winds inland over its expanse. Given the high costs of imported fuel oil used to operate the island's thermal-energy-powered generating plant, it was desirable to experiment with using the free, abundant wind to drive windmills and to integrate this source of energy with the use of electric generators. Additionally, the dispersion and small size of individual dwellings around the island made the use of self-contained, local generating sources even more practical.

Consequently, the electronics and mechanical engineering sections of KIST designed and built an experimental system for testing in the Cheju environment. The basic design for the windmill was adapted from a popular Australian commercial product that had been developed and long-used in the "outback," where wind conditions were similar to those at Cheju. KIST engineers ordered a three-phase brushless generator, manufactured in Korea, to be coupled to the windmill through a gearbox, increasing shift speed five to one. Its output ranged from 100 watts at a wind velocity of 4 meters per second, to a maximum output of 2 kilowatts in a fairly strong wind of 12 meters per second. Overspeed of the windmill at rates above this velocity was anticipated, and an automatic blade-feathering system was provided.

The feathering system used initially was based on the Australian design. It was comprised of three pivoted weights around the hub of the windmill's three-bladed propeller. When wind caused the rotational speed of the propeller system to increase to the critical point, the centrifugal force of the pivot-mounted weights overcame the effect of permanent magnets that held the individual blades in the attack position; and the individual blade was free to rotate into the feathered position until the speed was reduced sufficiently to allow the magnets to again return the blade to the attack angle.

However, in Cheju's occasional high winds, this system had to operate too frequently and cyclically. Under these conditions, the system's power output was too unstable. To overcome this difficulty, KIST engineers designed a wind velocity meter and small generator that produced an output voltage proportional to the wind velocity. This voltage was used to vary the field voltage of the main AC generator in the system so that as wind velocity increased, the axial (i.e., armature) resistance to turning was increased, thus providing greater rotational resistance to the wind. This not only (in most instances) damped the propeller speed sufficiently, but increased the power output of the system.

Energy was stored in ten twelve-volt automobile batteries, arranged in series. The test unit operated over a period of six weeks, generating five to six kilowatt-hours per day. It was later determined that one unit would serve four to five households under typical daily local conditions. Weather station records and on-site observations indicated that the design should provide sufficient storage capacity for up to three low or essentially windless days. For AC operation, (some households had small television sets), the system was fitted with inverters, yielding sixty-cycle current.

The first experimental installation was provided free of charge to a group of rural homes on the flanks of Mount Holla. The wind generator was mounted on a six-meter tower; service lines were run to each participating home from the battery house. Theretofore, some of the houses had had intermittent electric service from small generators powered by their three-horsepower garden tractors, but this was noisy and expensive, relied on imported fuel, and was not widely or consistently used on the island. The new energy source was used for lighting, for operating a small hotplate on occasion, and, in some instances, for powering television sets and radios.

The users were pleased at the outset with the free service that they were receiving and seemed content with the innovation. Then lapses occurred in the continuity of service because the KIST staff could not constantly provide the intermittent but frequent maintenance that the electrical and mechanical systems required. Such maintenance included lubricating bearings (on the KIST-designed models), tying down the propeller assembly when very high winds threatened, maintaining battery water level, and so on. Mr. Lo felt that if a number of such installations were operating, then the pro rata distribution of maintenance costs would lower the per-unit-cost factor drastically.

In fact, the small group of users ultimately became very insistent that the system be constantly operative and demanded that KIST maintain it. They complained about voltage drops but refused to become involved in the system's operation, even when threatening high winds necessitated shutting down the windmill,

It was, in fact, a high-velocity typhoon wind (it was never determined just how high) that forced a close to this initial experiment when the blades of the windmill literally were blown off. These original blades had a hollow form with double thicknesses of 0.5-millimeter stainless steel--and this obviously had been insufficiently rigid. The blades subsequently were redesigned in fiber-reinforced plastic (FRP), and the unit was moved to another, less-exposed location. However, not long after the new unit was installed, high winds blew off the new-design blades.

After this experience, one of the Australian commercial units (which was warranted to withstand 26 meter per second winds) was purchased and installed at the same location. Residents who used the system were charged Won 50,000 (about \$1,000) per household. It was felt that with such a significant financial involvement, the households might take more interest and even be willing to take a turn at routine maintenance. But this was not the case.

Although the third windmill operated successfully through subsequent high winds, it finally suffered a generator failure, putting the unit out of service. This happened coincidentally with the effective conclusion of the R&D project: contract funds were depleted and the system was deactivated. The residents were angry about this cessation of service just as they were getting to enjoy the convenience of electricity and were considering it a part of their daily lives. Although their Won 50,000 fees were returned to them, there was still much dissatisfaction with the entire program. One evaluator of the Cheju project observed later that resident users thought KIST had not been foresighted or properly attentive to the role of the consumer in the project and had been too occupied with the mechanical and electrical details of the experimental development.

When asked to comment on the relative economics of the KIST windmill system, Mr. Hong Jo Lo, one of the project leaders, noted that the installed capacity of the KIST system at about \$1,000 per kilowatt made the capital cost of this system about twice as high as the cost of a conventional fossil-fuel-fired central generating station. However, he thought that even with relatively high maintenance costs the windmill-powered system should ultimately be economically viable when the fact that its energy source was free was factored into the analysis.

At the time of this case preparation, the wind-powered generator project was inactive although the installation still existed on Cheju Island. Meanwhile, the West German government, in collaboration with the Korea Electric Company had agreed to sponsor a similar project on a number of other Korean islands that were entirely without power. These numbered in the hundreds, and it was part of the Korean governmental policy to assist the introduction of modern amenities to them. The new program was to incorporate German-manufactured generating units combining solar- and wind-generating capabilities in ten-kilowatt units.

OTHER RESEARCH SUBJECTS

KIST efforts included several other areas of investigation. One project, the production of starch from bracken species that grew naturally on the island, was a technical

success but a commercial failure. As noted previously, starch was a customary product of the island's sweet potato industry and was one of the principal exports to the mainland and to foreign users. However, the much higher yields of starch obtained from sweet potatoes made bracken an unattractive alternative, and the process was never commercialized.

The seas surrounding the island were found satisfactory for the cultivation of varieties of crustaceans, bivalves, fish, and seaweed. However, this research was undertaken only to provide useful information to others who subsequently might wish to go develop such industries.

Forty-nine species of indigenous plants were studied in the laboratory to determine their use as sources of oils and essences. The most promising was the wild rose, which grows profusely on the island and yields commercial grades of scent concentrates and pigment. The commercialization of this product was considered a good prospect if information was made available to domestic and foreign firms operating in this business.

Finally, a variety of fig that had been cultivated casually on the island and sold commercially to a limited extent was examined to determine its marketing possibilities. Improved preservation methods were devised, resulting in reduced spoilage losses--the principal detrimental aspect to the marketing of the fruit. This product also was believed to have good commercial potential if an interested producer/processor could be found.

POLICY SUPPORT STUDIES

The provincial government needed information and analyses of the island's economy to formulate developmental and regulatory policies. The KIST techno-economics section provided information on a wide range of related matters, including marketing channels for various products, price stabilization and support systems, and concepts for increasing farm income. Some of the study's recommendations were to develop better transportation systems both internally and externally, to subsidize the island's packaging industry, to increase the orange storage capacity on a schedule over the next several years, to further encourage the formation of cooperatives, and so on. These analyses and recommendations were used by the provincial government and formed an important part of the regional development plan.

PROJECT EVALUATION

The management of KIST wished to objectively evaluate the Cheju project, and assigned the task to one of the

Institute's social scientists who had a background in evaluation methods. Dr. Hong Ik Chung studied the documentation of the project (he had not been a member of the project team), visited Cheju Island to talk with various persons who had been involved, and conducted a similar series of interviews with participants at KIST.

Chung made several observations and recommendations. First, with regard to the utilization of the results of the study, the following were suggested:

- (1) The cattle feed project results should be dispersed widely within the country, and efforts should be made to seek the utilization of this technology in other areas of the Republic through demonstration projects and further research. (As noted, the intent had been to extend this research to include rice straw as well as barley straw, recognizing the much greater availability of the rice straw on the mainland.)
- (2) The information and the design for the orange storage facilities probably had application to other crops and other locations; therefore, this technology should be disseminated further.
- (3) More basic research was needed to support the findings of the Cheju project, and this "directed basic research" should be supported by KIST and/or others.
- (4) Notwithstanding the difficulties encountered and the doubt concerning economic viability, it was desirable to continue the wind energy research, especially considering the particular vulnerability of the Republic to interruptions in the supply of fossil fuels.

With regard to the conduct of the project itself, it was suggested that the quality and effectiveness of the integrated regional development study could have been upgraded by:

- (1) Limiting the number of research subjects undertaken. It seemed that too much was attempted, given the resources and sponsorship available.

- (2) Better overall management and project coordination would have been advantageous, especially considering the complexity of the project.
- (3) It would have been beneficial to have given appreciably more attention to the utilization of the research results--even before those results were achieved.
- (4) Dissemination to the public of more information on the project and its results would have been advantageous.
- (5) Most of the project results were useful and encouraging, and the experience should be conveyed to other countries where the same approach might prove beneficial.

The KIST staff offered the opinion that this project had been a very useful learning experience for the institute and that this type of coordinated effort would not only serve the interests of sponsors, but also would help to develop a greater feeling of unity and mutuality of interest among the KIST staff. It was hoped that other opportunities would be afforded to conduct similar regional studies in other parts of the country, because KIST was particularly well-qualified to conduct them and because such projects represented one of the most effective ways for science and technology to be applied for the overall benefit of the country.

PERSONS INTERVIEWED

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KIST

Mr. W.J. Lee
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Korea Traders Association

Dr. H.S. Choi
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