Chapter 8

Technologies Supporting Agricultural, Aquacultural, and Fisheries Development

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Chapter 8

Technologies Supporting Agricultural, Aquacultural, and Fisheries Development

INTRODUCTION

Consideration of the ecological integration of island resource systems is integral to island renewable resource management and development and to optimum use of human and natural resources. Two other kinds of integration are important as well: 1) integration in the development of the various components of food and kindred products industries, and 2) integration of resource development with other forms of economic development.

Little is gained from increasing agriculture or fisheries production if what is grown or caught is not purchased, if a substantial part of it is lost to pests or deterioration before it can be purchased, or if no means exist to get it from the producer to the consumer. Thus, integrated development of food and kindred products industries requires that attention be given not only to the modes of production, but to preservation or enhancement of product quality and value (preservation and processing), fulfillment of product specifications determined by consumer demand (marketing), and product storage and transportation.

Conversely, integration of the provision of basic human services (e.g., water, energy, and waste treatment) with resource management and development is not a required component of resource development and is not commonly practiced on continents. However, such integration can provide "double-duty" from government infrastructure investments on small islands. Airstrips and even roads can be used as passive water catchments on water-poor islands. Residential wastes can be a source of nutrients for farms or forests. Aquiculture of certain plants can even aid water purification allowing reuse by humans. Development of tourist attractions could include efforts to preserve endangered species or habitats of critical importance to fisheries in multiple-use protected areas, and development of the handicrafts industry associated with tourism can provide a means for rural people to earn income and to maintain traditional skills.

Agriculture, aquiculture, and fisheries production systems also can be integrated with energy production technologies. For example, intensive mariculture farms need large quantities of seawater to supply oxygen to and flush wastes from ponds, and pumping is an energy-expensive operation. Such farms could be built around powerplants which pump large quantities of cooling water daily from the sea. In the future it may also be possible to integrate aquiculture with ocean thermal energy conversion (OTEC) systems, passive seawater energy systems, biomass conversion systems, and solar pond systems. On-farm production of energy from animal and/or crop wastes, using digesters, can reduce energy costs to farmers. Such systems may help islands reduce their reliance on imported oil.

Both of these forms of integrated development commonly involve comprehensive planning and broad government involvement, For example, development of the various components of food industries may require government incentives to entrepreneurs to enter lagging sectors so that their services can be provided to growing ones. Similarly, determining the potential for investments in large public infrastructure to provide secondary benefits probably will require considerable detail in project planning, specification of engineering design, facility siting, etc. Analysis of such factors must occur on an island-by-island basis.

INTEGRATED DEVELOPMENT OF A FOOD AND KINDRED PRODUCTS INDUSTRY

A commercial food and kindred products industry includes not only food and fiber production activities (see chs. 6 and 7), but also processing (the biological, chemical, or mechanical transformations of products subsequent to harvest), distribution, and marketing (figure 8-l). In the United States, before agricultural commodities reach consumers, they must be assembled, processed, packaged, warehoused, stored, transported, and distributed through the institutional food trade wholesale and retail outlets (93).

In a well-developed food and fiber industry, each of these components commonly is undertaken by different private individuals, businesses, or cooperative organizations. With each successive step, value is added to the product through transformation or distribution. Prices are raised, but revenues also are captured within the local economy. (For example, the nonfarm activities provide as much as 85 percent of the value added to the U.S. food and fiber system's output (93)).

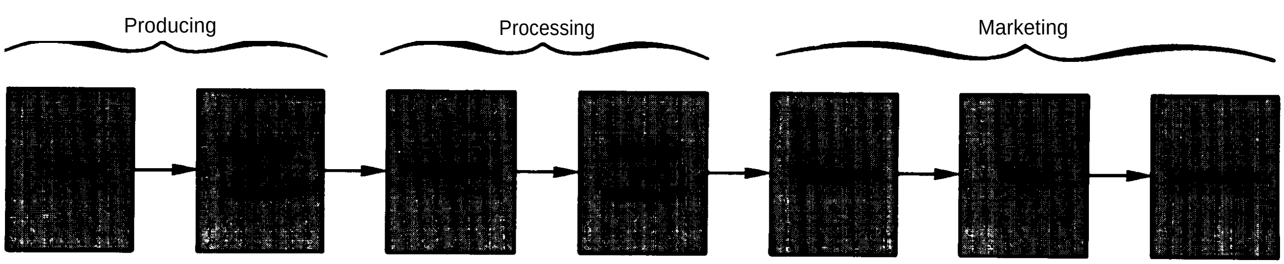
Food and feed processing technologies essentially transform raw materials into higher valued products with uniform marketing characteristics and longer shelf lives than the source materials. Such technologies tend to augment interdependence, encourage specialization, and are subject to economies of scale (82). They also promote the transformation from a barter economy to a cash economy. Finally, because convenience foods are preferred on many islands, increased local processing of foods has substantial potential to replace products currently imported.

On most U.S.-affiliated islands, fresh food is marketed directly by the producer (farmer or fisherman) to the public through roadside or harborside stands and open air markets. Thus, the producer is responsible for transporting, marketing, and maintaining the quality of the product. Some food may be sold to government food distribution centers, a small amount is sold to small retail stores, and still less is distributed to supermarkets or off-island (figure 8-2).

Only Puerto Rico's food industry approximates that of the United States or other developed countries. In the absence of complementary private sector development of the components of food industries, the processing, marketing, and distribution components can be centralized–through government-supported cooperatives or organizations—until private sector entrepreneurs take over (figure 8-3).

Besides raw materials, resources critical to processing include skilled people, information, and supporting infrastructure such as energy, water, and transportation facilities. Marketing, in particular, depends on reliable transportation systems.

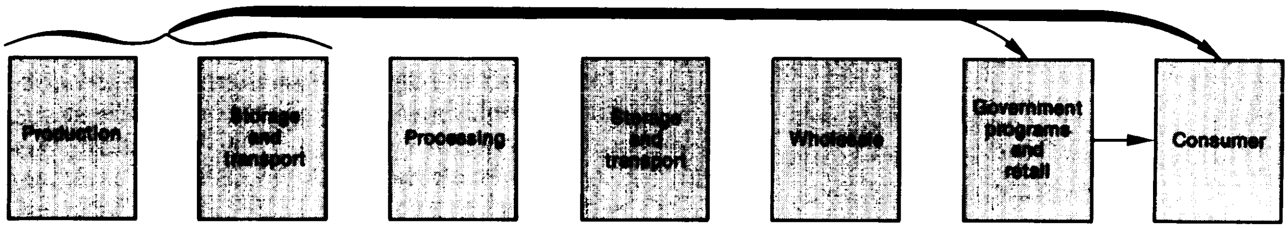
Figure 8-1 .—Modern Food Industry Components



In a well-developed food industry different private sector individuals, businesses, or cooperative organizations commonly are responsible for each segment of activity.

SOURCE: Office of Technology Assessment, 1986,

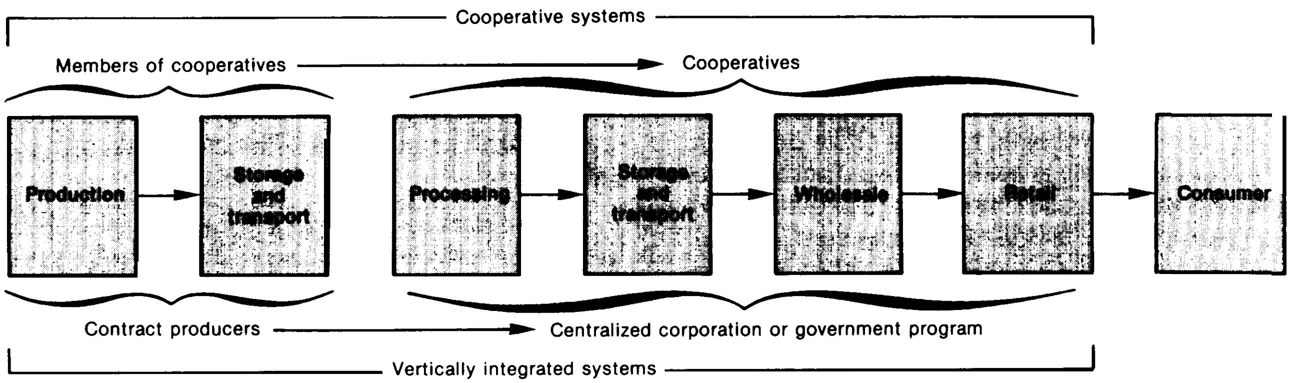
Figure 8-2.—Common Island Food Industry Systems



On most U.S.-affiliated islands, fresh food is marketed directly by the producer (farmer or fisherman) to the public through roadside stands or open air markets. A small amount is sold to stores for retailing. Little food is processed or exported (requiring wholesaling).

SOURCE: Office of Technology Assessment, 1986.

Figure 8-3.—Organizations Supporting Food Industry Development



In the absence of private sector development of the roles of food industries, processing and marketing components can be centralized, via cooperatives or centralized organizations, to provide these services until private sector enterprises can take over.

SOURCE: Office of Technology Assessment, 1986.

Food Preservation and Processing

Several methods of preserving and processing traditional foods for subsistence use exist in the U.S. Pacific islands. These include drying or smoking of fish, coconut meat, *Pandanus* fruit; fermenting coconut sap for coconut wine; and, in some areas, preserving breadfruit by storing it in the soil (2). The primary objective of traditional food preservation/processing was to ensure continuous food supplies during warfare, natural disasters, and off-seasons.

Today, the major goals of preservation/processing are to increase product storage life and quality, to minimize crop wastage and spoilage during peak production seasons, and to ease shipping and marketing (82). Food processing also may increase market demand (e.g., by increasing ease of food preparation). Furthermore, local processing of food may provide substitutes for products currently imported.

Primary and secondary processing and preservation methods range from simple and small-scale to complex, large-scale operations. Primary processing involves the preservation of crops and other products, whereas secondary processing deals with more complex processes such as extraction of plant oils, fermentation, or manufacturing of food products.

Food and feed processing methods throughout the U.S. Pacific territories are generally undeveloped. In Puerto Rico, the food processing industry is a strong manufacturing sector, primarily processing raw material imported from the United States and foreign countries (77). The strength of this sector may be due, in part, to the existence of a Food Technology Laboratory established at the University of Puerto Rico Agricultural Experiment Station.

Primary Food Processing Methods

Primary processing and preservation methods include refrigeration and freezing; dehydration (sun-drying, smoking, hot-air drying, and freeze drying); retort processing; irradiation; and hot-water bath treatments. Several of these processes can be combined or conducted sequentially.

Refrigerated Storage.—Proper storage facilities are needed to reduce postharvest losses from spoilage, insects, rats, or other pests. On most U.S. Pacific islands, storage facilities are inadequate because it is costly to provide modern storage facilities for the many small islands that are scattered throughout vast expanse of ocean. Low-temperature storage can provide protection from pests and spoilage and extend the shelf-life of perishable fresh products such as fruits, vegetables, and fish. However, low-temperature storage generally is not economical for most island crops because of the high energy cost. Furthermore, for most Pacific islands the use of cold storage is constrained by lack of or irregular power supply,

Refrigeration of foods for short-term storage (freezing for long-term storage) is nonetheless desirable, as it is safe, maintains flavor, and is suitable for many foods. Controlled atmosphere refrigeration (using carbon dioxide gas) can preserve certain fruits and vegetables for up to 21 days (82). Easy processing and packaging and acceptance of products worldwide make the potential for frozen tropical food excellent (cf: Bacardi frozen concentrate tropical fruit mixers).

While refrigeration is common in the U. S.-affiliated Caribbean, refrigeration and food freezing facilities other than household refrigerators largely are limited to larger hotels and restaurants throughout the U.S. Pacific. An American Samoa tuna cannery has a large, commercial refrigeration and freezing facility.

Icemaking and refrigeration are essential if fish are to be sold at other than dockside locations. High temperature is the single most significant factor leading to loss of quality. Fish that can be stored for 2 weeks frozen may last only a day or two at 500 F. It is generally recognized that a large part of the growing demand for marine products must be met through improvements in fish utilization, not just expanded catches (54).

Losses of fish may be heavy even on board, and in the period after docking and before marketing. Keeping fish alive in "wells" until landing, shaded, or covered with wet seaweed or other such materials may also enhance preservation. Losses could be reduced from the beginning by keeping vessel surfaces clean and cooled with seawater, and by careful handling (48).

If transport to markets is required the catch is further reduced from exposure as well as insect infestation. For many fisheries use of ice during transport is not possible; icing can, however, be delayed up to about 6 hours if the fish is consumed soon thereafter. Rapid chilling can be efficiently achieved by layering ice (prefer-

Photo credit: Office of Technology Assessment

Packing fishery products in ice remains a primary preservation technique on many Pacific islands despite irregular ice availability. Shown here, fish are being removed from ice packing and displayed for sale in a local market.

ably in flakes or small pieces) and fish in a covered box or hold area. Only sanitary water should be used to make the ice, and ice should not be reused once fish have been stored in it.

Ice machines that do not require gasoline, diesel oil, or electricity are being developed in some areas. A low maintenance biomass-fueled icemaker has, for example, been developed at the Asian Institute of Technology in Thailand. Ice forms as heat is extracted from water in a closed container during the conversion of liquid ammonia to gaseous ammonia. A compact solar refrigeration system uses the same technology but the ammonia-water solution is heated in the pipes of a solar collector (48). Solar-powered zeolite refrigeration systems are now being developed and may have particular relevance for use in small remote island areas (86).

Dehydration.— Food dehydration is a common, relatively simple, and inexpensive primary processing technology. Depending on the product, sun-dried items can be placed on racks or on iron roofs. Sometimes wire netting is placed over drying racks or platforms to reduce dirt and insect contamination (82). Although sun-drying is simple, cheap, and easily transferable, it is limited by the availability of sunny days. In some areas, in fact, peak crop harvest coincides with the rainy season. Sun-drying alone, moreover, frequently will not reduce the moisture content of products to a level low enough to prevent fungal or bacterial growth (82). Thus, while sun-drying is suitable for home use, for initial preservation, or for nonfood items, handling and sanitation problems render it less suitable for most volume processing for sale (65).

Fish commonly are preserved in rural areas of the tropics by sun-drying, but significant losses result from spoilage, contamination, and insects. Drying on raised structures could reduce some of these losses. Solar fish dryers can be made simply and inexpensively with wood (to form a frame) and plastic or glass (to provide cover), A wide variety of solar dryers have been designed with these and other inexpen-

Box 8-A.—Zeolite Refrigeration Systems

Maintenance of food product quality and reduction of product loss might do as much for tropical island economies as expansion of agriculture and fisheries and puts no added pressure on scarce resources. Refrigeration would solve many problems of food preservation and storage on the U.S.-affiliated tropical islands, but the energy requirements of conventional absorption refrigeration systems pose a constraint to the application and use of this technology.

Solar coolers, using natural zeolite minerals as the adsorbant, are now being developed (86) that show promise for use on small tropical islands to extend the life and therefore the potential markets for perishable food products. Because of several unique, properties of zeolites, they can be used to provide efficient refrigeration with low-grade energy such as solar heat. Once fully developed and available for purchase, zeolite-based solar coolers have the potential to provide food refrigeration or freezing; refrigerated transport; and space conditioning (heating and cooling, depending on seasonal need) for livestock and for commercial and tourist facilities.

The solar refrigerator and walk-in cooler are the technologies of most immediate application and widest possible use. Coolers can be used onsite or installed on flat bed trucks or on boats for field use. One technology being developed uses waste heat from internal combustion engines, significantly reducing the weight of the system as compared to solar based~systems.

Zeolite solar technology is initially highly capital-intensive, thus those people who most need it probably cannot afford it without government or private subsidy. However, where such technology is used to market more produce than could otherwise be saved and sold, increased income can be expected to result, and low-interest might be repaid in a reasonable time. Nonsolar zeolite systems have low initial costs and can be used without subsidies wherever waste heat is available.

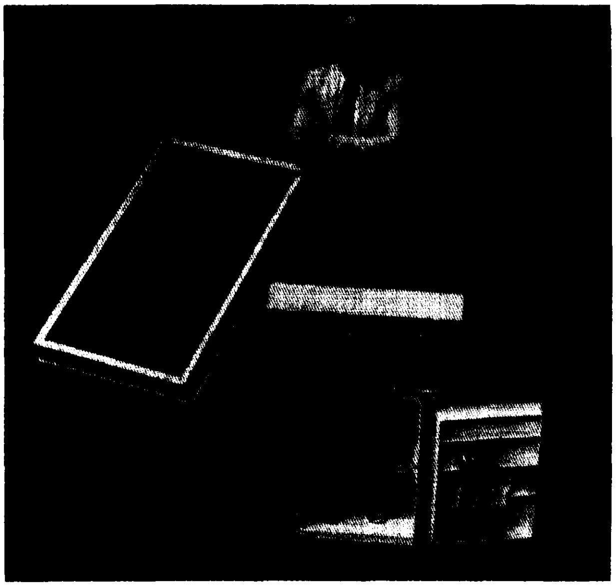


Photo credit: D. Tchernev

This small-scale solar-powered zeolite refigeration system may be particularly appropriate for remote areas or roadside markets where energy availability prevents the use of conventional refrigeration systems.

sive and readily available materials (including old oil drums, thin metal sheeting, and even sun-dried mud). Fish exposed to the flow of heated air in such structures dry very rapidly, and high temperatures reduce spoilage by mold and bacteria. Low-cost agrowaste-fueled fish dryers and combined agrowaste/solar dryers have also been designed and constructed in the Philippines (48).

Hot-air drying and smoking are accomplished by placing the product on drying shelves or racks in ovens using natural-draft smoke or forced hot air. Hot-air dryer designs vary depending on the crops, on the types of dried products desired, and on the type of available fuel (82). Hot-air drying and smoking may be limited by fuel availability and cost. Dryers can be made from simple wooden or bamboo racks, steel racks, or durable steel drums. Forced hot-air dryers have been used effectively for drying various island products such as copra, black pepper, chili peppers, and herbs.

Smoking is a traditional method of preserving fish products. Smoking dries the product, and certain substances in smoke kill bacteria, particularly in the presence of salt. Simple smokers consist of trays hung in the column of smoky air above a fire. A variety of ovens and kilns have been developed in Africa and the Philippines (48).

Smoking, hot-air drying, and sun-drying may be used in combination for drying products. Dehydration also is frequently combined with other processes such as salting (used for thousands of years to preserve fish) and sugar curing. Spices, seasoning, tropical fruit flavors, and other specialty products seem to offer primary areas for expansion of dehydrated products. In addition, byproducts and waste products of dried foods can be added to animal feed formulations (82).

Dehydration also may be accomplished by freezing and drying at the same time. Freeze-drying technology may be applied to selected, high-valued products, provided reliable electric power is available (82). Freeze-drying maintains the flavor and helps protect the cellular integrity of the food. However, this technology requires high amounts of energy and skilled labor, and therefore cannot be applied economically on many islands.

Retort Processing.—Retort canning or pressure cooking is a common method of preserving fruits and vegetables, and can be used on some fish and meats. The goal of such thermoprocessing is to heat the product to microbe-killing temperatures of around 100° F. Traditional canning equipment is readily available and systems have been developed for lesser developed areas of the world (82). Acid fruit products are easily canned without substantial health hazards as the acid level prevents spoilage by most toxic organisms. Retort canning of nonacid foods such as vegetables and meats, however, can be a health hazard if quality-control procedures are not followed.

The retortable pouch–a multilayer adhesively bonded package that will withstand thermoprocessing temperatures—may maintain higher quality foods than those retorted in conventional cans and may require less energy due to shorter cooking times at lower temperatures (97). Further, retort pouches have an improved product-to-package weight ratio compared to cans, providing savings in transportation. This saving may be reduced by secondary packaging used to increase product durability in transport.

Irradiation.— Irradiation for preserving food and crops has been used both experimentally and commercially in many countries (69). Irradiation is considered an alternative to chemical preservation of foods and crops, or where refrigeration and retort processing are not feasible (table 8-l). Low doses of radiation prevent sprouting of tubers, destroy insects, and inhibit mold on fruits and vegetables. Medium to high doses of radiation can preserve foods for long periods of time (69,70). Low doses of radiation for spices, hog carcasses, and some fruits and vegetables have been approved by the U.S. Food and Drug Administration (83). Use of high doses of radiation for control of insect pests on produce, and for preserving fruit and vegetables recently has been approved. Irradiated mangoes have been exported from Puerto Rico to the U.S. market (60).

Irradiation could reduce the use of pesticides and inhibit maturation and spoilage of crops, thus extending shelf life and possibly making some foods more available or less expensive. Application of irradiation technology, however, requires the availability of electric power, skilled personnel, and a high initial capital cost making it an unlikely prospect for use on most islands.

Table 8-1 .—Effects of Food Irradiation

Dose	Rads	Purposes
Low-dose	1-1oo kilorads	Control insects in grains and flour Inhibit sprouting in potatoes Sterilize trichina worms in fresh pork Inhibit decay, control insects in fresh fruits and vegetables
Medium-dose. . .	100-1,000 kilorads	Destroy Salmonella and other bacteria in meat and poultry
High-dose	1,000-3,000 kilorads	Control insects, micro-organisms in dried spices and enzymes used in food processing; destroy botulism spore

Dose: Dose is calculated by knowing the energy given off by the radiation source, the distance between the energy source and the target material (food and its packaging) and the duration of treatment. "Rad" stands for "radiation absorbed dose." 1 kilorad = 1,000 rads.

SOURCE: S, Sachs, "Q & A Irradiated Food at the Supermarket, " *USDA Food News for Consumers 3(1): 14-15, 1986.*

Hot-Water Bath Treatments.—Hot-water bath treatments are an alternative to fumigation or irradiation to eliminate pests, especially fruit flies, in fruits. It has been used as an alternative to fumigation with ethylene dibromide, which recently was banned from use on all fruit and vegetables for trade in the United States. Fruit, such as papaya, are immersed in water for 40 minutes at 108° F followed by a 20-minute immersion in water at 120° F. This treatment killed all eggs and 99 percent of insect larvae in commercial-sized lots of papaya in Hawaii. In general, hot-water bath-treated papaya maintains its quality, including the flavor, texture, absence of blemishes, and absence of hard spots on fruits (98). This method holds promise for wide application on islands because it is simple, inexpensive, and does not depend on expensive imported materials.

Secondary food Processing Methods

Secondary food processing systems, in general, involve more complex techniques, higher capital investments, and more energy-intensive technologies than primary processing. On U. S.-affiliated islands, secondary food processing systems include fermentation, oil extraction, and starchy crop processing.

Except for coconut oil extraction, commercial secondary food processing methods are undeveloped in U.S. Pacific islands. However, in Micronesia a traditional coconut wine (toddy) is made by cutting the stalk of a coconut flower and allowing the sap to drip into a container to ferment naturally. Secondary processing is common in Puerto Rico; for example, brine-fermented citron is one of the oldest fruit processing operations on the island (77).

Fermentation.—Fermentation of fruits is a common method of preservation and flavor-enhancement, and is used in many cultures to derive alcoholic beverages. Fermentation of fish and shrimp was originally developed in Southeast Asia as a means of flavor enhancement. Since this generally involves hydrolysis in the presence of high salt concentrations, products (generally a liquid or paste) have good keeping qualities. Nutritive quality is maintained, and the process is simple (48).

Plant Oil Extraction Methods.—Chemical and physical extraction methods are available for extraction of oils from plants. Depending on the products, oil extraction ranges from simple, inexpensive, small-scale techniques to complex, capital-intensive extraction methods. Basically oil extraction involves drying the product, chopping it into small pieces for pressing and/or chemical extraction and fractionation to obtain the desired oil (82). Coconut oil can easily be extracted from dried coconut meat (copra), by pressing or boiling. This can be accomplished using common kitchen implements or in a factory setting with proper quality control and precise extraction procedures (67,82). Oil from the ylang-ylang *(Cananga odorata)* flower is extracted through similar procedures.

Starch-Crop Processing Methods.—A number of relatively simple processing technologies for making flour, chips, and pellets from common starchy island crops such as rootcrops, coconuts, breadfruit, plantain, and banana are available. These are relatively simple technologies which basically involve chopping and/or shredding the crop into small pieces and drying it or grinding it into flour. Flour may be processed into pellets and packaged in various ways *(21,77).*

A simple cottage-scale flour-grinding operation has been in operation for several years at Macheweichun Xavier Society in Truk. It involves the use of wood-fired dryers, a flour grinder, a drum shredder, and miscellaneous hoppers, trays, and containers (21).

Summary

Although U.S.-affiliated islands offer opportunities for food processing development, the pacific islands in particular are constrained by high energy costs, small markets, and relatively small and unreliable domestic production of raw materials. The energy requirements for certain processing technologies, such as freeze-drying, refrigeration or freezing, irradiation, and retort processing, can be substantial. This may seriously handicap application on U. S.-affiliated islands where energy is costly and irregularly available. Availability of fresh water may also be a constraint for resource poor islands such as atolls.

Although Puerto Rico has the capability for processing most food products, it is constrained by the limited quantities and the high prices of raw materials produced locally. Hence, food processing industries are forced to import raw materials from neighboring islands or from the mainland United States (77).

Establishment of regional or local cooperative food processing centers may overcome the constraints provided by the small size and fragmentation of islands of the U.S. Pacific territories. A processing center could provide a strong link between processing and production, and may provide technological support to producers and marketers thus facilitating commercialization of local products (82).

Cooperative processing and preservation centers could absorb crop surplus not taken by the fresh produce market, preventing waste and providing intermediate products for further food and feed formulations. Local producers might be encouraged to expand crop production if processing facilities guaranteed a market for excess products: sustained levels of production above local subsistence needs can take place when a stable cash market exists to absorb the surplus (70). It is estimated that between 30 to 50 percent of fruits and vegetables produced in the Commonwealth of the Northern Mariana Islands (CNMI) have been discarded because they have no market outlets (87).

Development of cooperative food processing facilities will require coordinated development of marketing services, island infrastructure, agriculture production, and managerial skills. Government cooperation and support probably is necessary.

Opportunity: Expand Research in Postharvest Technologies for Island Products

Postharvest technology research commonly is biologically or physically oriented, thus complementing production research. Some postharvest technology research focuses on the biological or chemical properties (e. g., composition, quality, safety, nutritional value) of products that affect the handling, storage, transportation, preservation, and effective use of such products. Other postharvest technology research focuses on the mechanical technologies used to assemble, process, package, warehouse, store, transport, and distribute products.

A 1983 OTA assessment concluded that public sector research in postharvest technology and economics can be justified because:

1. benefits are distributed beyond those who bear the costs, and substantial social advantages are derived from both public and private research;
2. in the absence of public sector support and guidance, postharvest research might be biased strongly toward mechanical and chemical technologies, since economic returns can be extracted in the short run; and
3. for those situations where private research might be detrimental to industry competitiveness, a mix of public and private research may best preserve competition or reduce market power.

Some areas of research, such as:

1. new food sources and their development,
2. naturally occurring food contaminants, and
3. yields in relation to productivity versus nutritional components, might best be undertaken by joint public sector/private sector organizations.

Three research agencies in the U.S. Department of Agriculture (USDA] conduct and fund postharvest research: the Agricultural Research Service (ARS), Economic Research Service (ERS), and Agricultural Marketing Service (AMS). Although ARS conducts some postharvest research, including some in Puerto Rico and the U.S. Virgin Islands (USVI), it is not organized to manage, conduct, or be responsive to regional research needs (93). ERS has International Economics Divisions which identify trends in food demand in foreign countries (on a regional basis) and draw implications for export markets in those countries. Its National Economics Division primarily assesses the organizations and performance of the major U.S. commodity subsectors (animal products; crops; and fruits, vegetables, and sweeteners).

AMS is an action agency primarily devoted to distribution of market news to the agricultural community, inspection and grading of food products, and other regulatory activities and some research. AMS has responsibility for the conduct of studies of the facilities and methods used in the physical distribution of food and other farm products; for research designed to improve the handling of all agricultural products as they move from farm to consumers; and for increasing marketing efficiency by developing improved operating methods and facilities (93).

The Agricultural Experiment Station of the University of Puerto Rico has developed a Food Technology Laboratory devoted to fostering the development of processing industries. An associate degree in Food Technology is offered at the University's Utuado Regional College. Product research since its inception in the late 1940s has included: canned sweet potatoes, canned fruit nectars, frozen fruit concentrate, canned soups, frozen root crops, jams, jellies, and marmalades. Although many of these efforts failed to reach commercialization, and others failed to survive (primarily due to economic reasons), the food processing industry showed rapid growth between 1960 and 1970 in diversification and sales volume (77). However, because quantities of acceptable quality fruits and vegetables were not reliably available from local producers, the Puerto Rican food processing industry shifted to the processing of imported raw materials.

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Opportunity: Develop New Products From Extant Crops and Catch

Local processing of crops can provide higher returns to growers than exporting raw materials, and can provide import substitution opportunities. Major opportunities for development of new products from locally available crops are coconut oil products; fruit juices, jams, jellies, and marmalades; and animal feeds.

Coconut Products.—The major commercial crop in the U.S. Pacific is coconut, from which copra is made. Copra oil processing plants exist on Majuro, Moen (Truk), and Pohnpei. Yap is in the process of building a plant. The Pohnpei Coconuts Products plant has developed a line of products—laundry and bath soap, dish soap, cooking oil, body oils, and shampoo—for the local and tourist markets. Plants on Truk and Yap will offer similar products, mainly for import substitution. Copra oil also is a potential substitute for diesel oil, but its cost ($4.00/gallon) compared to imported diesel oil ($1.50/gallon) is prohibitive at present (73).

Fruit Products. —Surplus fruit crops can be made into jams and jellies, juiced and bottled, or used in production of fruit ices, currently popular in areas having refrigeration. Small-scale juicing machinery, suitable for small quantities, are available and are employed on some Pacific islands. Through a successful Yap government-sponsored radio campaign, coconut milk has replaced large amounts of imported canned beverages; similar campaigns could promote locally produced juices (73).

Animal Feed.—Another major avenue for substitution of imports with locally produced and processed products is animal feeds. Feeds for livestock come from a variety of sources depending on the kinds of livestock raised and the husbandry methods. Livestock feeds include green forage, pasture grasses, hay, silage, feed concentrates and, for some livestock such as pigs and chicken, left-over food or crop wastes, In Puerto Rico and the USVI, most cattle are raised on improved or unimproved pastures. Dairy cattle are supplemented with feed concentrates (5), and silage and green forage such as *Leucaena leucocephala* are used occasionally to supplement cattle feed. In Puerto Rico, hay is fed to horses and calves during the dry season. About 10,000 tons of hay are produced yearly on about 2,000 acres and another 4,000 tons are imported (101).

Although the demand for animal feed is high, practically all feed concentrates are imported to U.S.-affiliated islands. Pohnpei imports about 400 tons of pig feed concentrates annually (85) and Puerto Rico imports about 500,000 tons of raw materials for livestock feed concentrates annually. None of the latter incorporate ingredients that can be produced locally (5).

High costs of imported feed concentrates constrain development of livestock industries on most islands. Imported feed concentrates are expensive and may represent one-half to two-thirds of the total cost of producing meat and dairy products in the U.S. Pacific territories (38). Furthermore, unreliable shipping has caused shortages of feed forcing farmers on small islands to ration and substitute feed. Rationing and substituting local materials for feed have resulted in decreased livestock production and reduced feed conversion efficiency. Shortages may also cause a “feed shortage mentality” on the part of unsophisticated farmers resulting in rationing of feed even when an adequate supply of concentrates is available on islands (5).

Establishment of plants that process local raw materials for feed may minimize crop waste, provide a market for crop surpluses during peak production seasons, and make use of currently underutilized resources. Such plants could also provide substantial benefits to farmers by increasing market demand and absorbing supply not taken by the fresh produce market (38). Development of alternative markets can moderate supply fluctuations and contribute to increased market efficiency.

Many attempts have been made to produce feed concentrate from local raw materials. For example, a feed processing plant on Palau, using copra meal, fish parts, and imported rice hulls, grain, and vitamins, was established in 1976. However, the plant was forced to close when the copra oil mill closed down (45). In general, ingredients such as fish meal, vitamins, and mineral supplements still must be imported (5,85). An animal feed processing plant currently is operated on Guam, but low-quality feed hinders its ability to compete with imported products (65).

On U.S. Pacific islands, a variety of local raw materials offer potential as feed components, such as copra meal, breadfruit, banana, root-crops, and various agriculture wastes. *Leucaena* leaves, which contain up to 30 percent protein (49), can be dried and used as an ingredient of feed concentrate. Excessive feeding of *Leucaena* to nonruminant animals can cause hair loss and ill health and poor feathering in poultry, because it contains a harmful chemical called "mimosine" (49). However, the toxic effects of mimosine are reversible and can be neutralized when certain micro-organisms are inoculated into cattle feed (79). Mimosine content in *Leucaena* leaf meal also can be reduced by adding ferrous sulfate to rations, soaking it in water overnight, or boiling it for a few minutes.

In Puerto Rico, byproducts from local pharmaceutical companies, tuna or pineapple canning plants, rum breweries, and sugarcane refineries can be used as ingredients for animal feed concentrates (72). Quantities of these byproducts, however, are limited and only seasonally available. These products could substitute for only about 10 percent of currently imported feed concentrates (5) and are not sufficient alone to support a feed processing facility.

Although the use of local produce for ingredients in animal feed is technically feasible, it is seriously constrained by the high production costs for small-scale operations and by the unreliable and seasonal availability of local raw materials (5,67,82,85). Because of these constraints, local raw materials generally can only be used as an extender for imported animal feeds (67). However, in most cases it is cheaper to import finished feed from large foreign operators than to blend imported and domestic raw materials (5,67,85). High fuel costs, costly maintenance of equipment, and difficulty in getting spare parts are also major hindrances to operation of local processing plants in most U. S.-affiliated Pacific islands.

Marketing Development

Opportunities for market development exist despite small local markets and highly competitive export markets. In addition to the small size of local markets, marketing on U.S.-affiliated islands is constrained by low levels of production, lack of marketing skills, and for small producers primarily on U.S. Pacific islands, by the inability to meet marketing demands (e.g., consistency in quality, quantity, and pricing). Under certain circumstances, however, cooperatives may overcome these constraints (102). Another way to facilitate marketing, is linking small-scale "satellite" farmers and fishermen to large-scale, well-established, producers. This system has been effectively instituted for ornamental plant producers in Puerto Rico (6). Although increased penetration of export markets is possible, it is considerably more difficult than developing local markets. In either case, government intervention may be needed.

Development of Local Markets

Farmers and fishermen use a variety of marketing methods to sell their product. In general, local markets are small relative to agriculture production potential. The absence of alternative market outlets, such as export markets and food processing plants, and inefficient distribution and marketing of fresh produce, lead to unstable prices, unnecessary product losses and spoilage, and inability to meet the demands of institutional buyers.

The local market in Puerto Rico, although relatively small for most commodities, is stable. Although local marketing methods in Puerto Rico are not as advanced as in the mainland United States, they appear adequate. Local produce such as plantains, bananas, pineapples, and others are sensitive to market fluctuations; even small surpluses can depress prices, since surplus crops cannot be readily exported off-island. Thus, some crops, such as coffee, are protected against competing imports by local

Photo credit: Office of Technology Assessment

Large open-air markets, where the majority of locally produced agriculture and fishery products are sold directly from the producer to the consumer, are typical of many island areas.

regulations (47). On the other hand, the local market for some crops is, in a sense, "protected" by relatively high transportation costs of imports from the mainland United States (about 2.5 cents/lb for grain and 6 to 7 cents/lb for refrigerated products) (101).

About half of the food tonnage consumed in Puerto Rico is produced locally (100). The percentage of the local food market that can be captured by Puerto Rican food producers is limited by local production potential and by consumer preference for supermarket convenience food produced mainly by mainland U.S. food processing corporations (40).

In the U.S. Pacific islands, food imports are substantial. However, imported commodities are mainly sold in the major urban centers (38). Only a small fraction of the urban populations consume imported fresh food. Therefore, only a small amount of imports can be substituted by locally produced fresh food. Opportunities to develop the local markets on U.S.-affiliated islands and reduce imports are based on the potential for supplying various sectors of the local markets such as government-sponsored programs (e.g., school lunch, food stamp, and old age programs), tourist, and military markets.

Currently, most food products for the military and tourist markets in the Pacific are imported from suppliers outside Micronesia, thus, the potential for import substitution is great, However, hotels and military facilities require regular supplies of high-quality produce currently unavailable on the islands. Even if only part of the fresh produce requirements can be supplied locally, it could make a significant difference to local economies.

Opportunity: Substitute Locally Produced Food for Imports in Federally Funded Food Assistance Programs

In American Samoa, Guam, and the CNMI, opportunities exist to increase gradually the use of locally produced commodities in federally funded food assistance programs. Part of block grant funds (e.g., for school lunch or old age programs), could be used to purchase locally produced commodities, including processed items, instead of imports. The CNMI Food Stamp program requires that 25 percent of food stamp expenditures go to the purchase of locally produced commodities. These requirements increase the use of local products and benefit local producers (38), Gradual increases in the required percentage could result in additional benefits to producers and consumers.

Opportunity: Develop the Tourist Market

Tourism represents potential demand for agriculture and fisheries products where significant tourist industries have developed, such as in Guam, Palau, the CNMI, Puerto Rico, and the USVI. For Puerto Rico, the impact of tourism on agriculture development is not known. In the USVI, however, certain small-scale agriculture ventures are directly dependent on the tourist industry (13). Tourism in the Freely Associated States (FAS) and American Samoa is hindered currently by weak airline linkages with major Asian/Pacific markets and relatively expensive fares (38), but has the potential to become a significant market as it develops. In Guam and the CNMI, tourism provides the major private sector income generating activity; about 450,000 tourists visit Guam and Saipan annually (38) and prospects for continued growth in visitors is high (3).

Although large numbers of tourists visit the CNMI and Guam, local producers can take little advantage of this market because of the monopolistic practices of tourist facility (e. g., hotel) operators. Japanese interests control most of the tourist industry and have set up a number of barriers for local suppliers to access this market. Only small amounts of commodities such as food and locally made handicrafts enter into the tourist market (102).

Opportunity: Supply Military Markets

The military presence on Guam and Kwajalein represents potential demands for local agriculture and fishery products. Military personnel and dependents in Guam make up roughly 20 percent of the resident population. In the Marshall Islands, the Kwajalein Missile Base has a population of about 7,500, most of whom are Marshallese employees and dependents living on nearby Ebeye Island (35]. Although these populations represent potential markets for fresh produce, most food is currently imported from suppliers outside Micronesia.

While local farmers could supply at least part of the fresh produce requirements, irregular and limited supplies of local produce make it impractical for satisfying the military markets (see app. c). In addition, accounting advantages accrue through military dependence on centralized supply of warranted products. Only if the centers do not carry a particular commodity, or fail to meet minimum quality standards, are local commanders encouraged to procure locally. A Department of Defense team recently was sent to Guam to evaluate prospects for greater reliance on local markets, particularly of fresh foods. However, only small amounts of local products are likely to be bought by military employees, dependents, and civilian employees in the near future (35).

Opportunity: Develop Interisland Markets

Trade in selected agricultural commodities within Micronesia also is possible. The potential for intraregional trade depends both on coordinated development planning and strengthening surface and air transportation services among the islands (38), The most direct step to developing markets for Micronesia crops would be to conduct a pest and disease survey of Micronesia to provide a basis for U.S. Federal quarantine regulations affecting Guam and other potential markets. If quarantine regulations were revised, some traditional crops could be exported to Guam and other areas where demand for traditional foods is unfulfilled (15).

Development of Export Markets

Export potentials for the U.S. Pacific differ from that of the U.S. Caribbean islands, due to differences in geography, and the socioeconomic conditions. Puerto Rico and the USVI have ample opportunity to export fresh produce due to the cheap and frequent ocean transport to major east coast markets (60).

Currently Guam and CNMI have the best prospects for agriculture exports outside of Micronesia. Guam and Saipan islands have good air transportation links to Japan, a potential overseas market. Wide-body passenger aircraft serving Micronesia have the capacity to ship air freight containers. Japan seems to be the most promising export market, because of its high per capita income and already large volume of imported fresh produce. A recent study concluded that avocados and papayas had the best export potential in the Japanese markets, with other possible exports being tomatoes, sweet corn, bell pepper, melons, and ornamental plants (12). However, Japan's strict quarantine regulations preclude most fresh produce exports from Micronesia. Until the fruit fly is eradicated on Guam and the CNMI and effective methods for treating fresh produce are found, Japanese markets will remain closed to Micronesia exports. At present, only copra and green bananas can be freely exported into Japan (app. F, 65).

Removal of U.S. import tariffs on produce from Caribbean Basin countries as a result of the Caribbean Basin Initiative, has not seriously affected the local market for Puerto Rican products. However, import tariff reductions seriously hurt the potential for export of fresh produce from Puerto Rico (101). Exporting Caribbean countries have a competitive advantage in lower wage structures ($2 to $4 daily as compared to $16 to $26 in Puerto Rico), which results in lower product prices even after addition of transportation costs. To increase food exports, Puerto Rican producers must both reduce production costs and improve the quality of their produce, thus reducing competition between Puerto Rican products and foreign substitutes.

Integrated Production, Processing, and Marketing

Neither production nor marketing can be developed in isolation and one cannot be successfully developed without attention to the other. Without viable markets, production will stagnate or decline. Without regular and reliable sources of product, market development and expansion cannot occur. Many opportunities exist for integrating production and marketing to make these activities more efficient and mutually supportive. Such integration can remove certain constraints that affect each sector in isolation. For example, commercial small-scale operations may be handicapped by small and unstable markets or inadequate transportation services; small producers commonly are not able to produce uniform quality products, do not have access to adequate capital and, generally, lack marketing skills. Cooperatives and/or vertical integration of agricultural systems (linking smallholder farmers with large producers or processors) may help mitigate such constraints and provide enterprises capable of capturing economies of scale.

Cooperatives[1]

Cooperatives are known to be a useful way of organizing and mobilizing capital and people in developing communities. Cooperatives offer an alternative when conventional corporations are unable or unwilling to enter markets because of inadequate return, high risk, or lack of capital. A producer cooperative provides some economic benefit to individuals as they earn a livelihood. A consumer cooperative—in essence, a buying club—helps individ-

[1]This section is summarized from N. Nathanson, "The Suitability of Cooperative Enterprises for the Production of Food on the Territorial Islands of the United States, " OTA commissioned paper, 1986.

uals pool their resources to obtain products not otherwise available on acceptable terms. The return on the member's investment is almost always of secondary importance; the desire for a particular type or quality of product is paramount,

While small farmers face real difficulties purchasing small quantities of supplies competitively, and can ill-afford expensive equipment, farmer co-ops can competitively purchase supplies, services, and equipment and market produce for the benefit of the entire group. Groups of farmers may even purchase a sizable tract of land and work it together, either by subdividing the land or sharing in the production of the entire tract. The more highly organized food producer cooperatives provide fully integrated programs for their members. These may arrange bulk purchases of supplies, lease planting and harvesting equipment to individual members, process and market the finished product, provide financing for members, and even conduct research and development in new crops or techniques. Other co-ops are more limited in purpose.

Advantages and disadvantages to co-ops exist relative to capital enterprises. One major advantage is the built-in incentive for members to use services offered, increasing the cooperative's revenues, However, members generally lack incentive to purchase more than one share; this limits cooperative capital and can ultimately necessitate debt financing. There also is a danger of short-sighted decisions by members with diverse interests or limited knowledge of market economies. Some argue that not enough profit motivation exists in a cooperative organization to assure sufficient earnings for future growth. Nonetheless, the cooperative structure seems, in some cases, to be encouraging increased agricultural production on the islands.

In Puerto Rico and the USVI, some tradition of market-oriented agriculture exists, but there is little modern, competitive agriculture in the Pacific under the control of indigenous populations. Exceptions occur with the help of cooperative enterprises, whose member-investors have a direct need for the produce or service supplied.

A Successful Small-Scale Cooperative: SFCA.—Only about 5 percent of the land in the Northern Marianas is suitable for agriculture, and much of that requires irrigation. Public resources and private capital directed at the preparation of farmland have been very limited. Nevertheless, the Saipan Farmers' Cooperative Association (SFCA) is demonstrating that, with competent management, and a modest amount of public and private capital, small-scale agricultural co-ops can have a measurable impact on food supply. With nurturing, SFCA could become a model for agricultural development in other Pacific islands.

SFCA has 85 producing farmers as members. Its principal activity is the retail sale of member produce; a secondary activity is the procurement of supplies and animal feed for sale to members. Chartered in 1972, SFCA was nearly bankrupt by 1980, but since new management took over in 1982, it has been far more successful. Sales have increased from $133,000 in 1982 to $575,000 in 1984. The co-op has little capital but a $10,000 line of credit allows it to pay members cash for products.

SFCA does not guarantee members a fixed price, or purchase products that are below a market standard, but it has been able to purchase most of what its members produce, Most products sold are fresh fruits and vegetables along with some locally processed and baked goods, eggs, and honey. No meats or fish are sold. A major problem in earlier years was spoilage, but with more attentive management and a higher sales volume, this has been greatly reduced.

SFCA sales, while growing, still represent only a small fraction of the market potential. To serve more of Saipan's dispersed population, SFCA will need more retail outlets.

A Struggling Multiservice Cooperative: FEDA. —The Federation Para El Desarrollo Agricola de Puerto Rico (FEDA) is a complex federation of some 20 producer associations in Puerto Rico. It operates a tropical fruit juice processing and marketing plant and provides financial and technical assistance to 600 regularly participating and 600 intermittently participating member-farmers who supply the fruit. FEDA has developed all the elements of a fully integrated agribusiness program, including a modern processing plant, new techniques to raise productivity, a revolving loan fund to finance plantings, and a functional organizational and management structure. The average member earns about $4,000 per year farming, and through FEDA can increase the farm's income by at least 50 percent.

The primary product of the federation plant is passionfruit juice, but seven fruits are processed. FEDA also raises rabbits and pigs for sale as food, using the waste from the juice plant for animal feed. FEDA also has spawned a nonprofit institute which conducts botanic research to improve productivity and trains farmers to grow tropical fruits.

FEDA enjoyed considerable success in its early development years, but with an enormous debt load and high overhead costs, it is not yet financially self-sustaining. FEDA's obligation to purchase the product of participating farmers places a tremendous demand on its financial resources. Member farmers who set policy through their elected directors tend to set the price they receive above market price, further taxing FEDA's resources.

To assure financial success and to use the plant fully, new off-island markets for fruit juice must be developed. Major U.S. distributors require enormous quantities of product, more than FEDA can now provide. Ultimate success will depend on the ability to market an estimated 10 million pounds of fruit annually. FEDA is attempting to market to local distributors in South Florida and New York where large Caribbean populations live. It may be, however, that greater returns to the farmers could have been realized by concentrating on locally used foods rather than specialty export products.

Cooperatives That Failed: USVI Fishery Cooperatives. —The Farmer Cooperative Service of USDA, between 1975 and 1978, partially financed fishery cooperatives in St. Thomas (with 44 fishermen) and St. Croix (with 51 fishermen). The cooperatives were formed to provide a more organized and sanitary method of selling catch and to help members purchase supplies such as fuel and ice. Most members were part-time fishermen who had been selling their catch on street corners. Spoilage and fish poisoning were common.

Each proposed cooperative called for the eventual construction of a waterfront supply and receiving facility with a cooler, freezer, fuel pumps, cleaning area, and retail sales area. The co-ops would also sell fish to hotels and restaurants. Both co-ops appear to have been well-planned technically, but both failed. Several factors contributed:

- members were required to sell their catch to the cooperative at a price well below street market price, and the volume available for sale was consistently below projection due to overfishing, theft, and damage to the fishermen's traps;
- both operations were substantially in debt as a result of their financing structures, expensive overheads, soaring fuel prices, and inflation; and
- the fishermen's association never became a strong, cohesive organization and had difficulty setting operating policy, maintaining market discipline, and selecting competent management.

A Potential Cooperative in Koror, Palau.—At least one-half of Palau's population lives in the capital city of Koror, where traditional foods largely have been replaced by canned imports. Although consumers seem to prefer fresh local produce, interest in farming has declined.

Residents of some outlying communities recognize the market potential of island crops, and have steadily increased production of fruits and vegetables since 1977. Primary factors limiting further growth in local food production appears to be related to distribution problems: bad roads, lack of refrigeration during shipment, rats, and handling all take their toll.

All farming is done on individual plots, but some rudimentary cooperative associations have formed. One group of Melekeok farmers shares the cost of shipping produce from their island to Koror. Two small retail outlets have developed to market the produce of certain suppliers on an informal cooperative basis. With some assistance, these associations could develop a formal cooperative similar to the Saipan Farmers' Cooperative Association.

Opportunity: Support Cooperative Organizations.—Few local government agencies or private organizations on the islands actively encourage the development of agriculture or fisheries cooperatives. Although the Government of Puerto Rico has established financing and technical assistance programs to encourage the development of cooperatives, the emphasis has been in housing development and retailing. Despite attempts for at least 3 years, FEDA was unable to obtain local financing, although it secured almost $3 million off island. Only after FEDA obtained considerable mainland attention was it able to obtain local support.

Local governments can encourage development of cooperatives by investing in infrastructure (e.g., roads) and providing tax benefits and technical assistance. Production and marketing specialists may be particularly needed. Guaranteed contracts for the purchase of locally produced items by schools, welfare and social service programs, or tourist facilities could provide market stability. The CNMI government's preparation of a 56-acre plot of land for lease to local farmers has contributed to the success of SFCA; continuation and expansion of such actions could bring the local economy sizable benefits.

A number of mainland-based organizations could become involved in development of cooperatives on U.S.-affiliated islands. The National Cooperative Bank chartered by Congress in 1978 provides financing and development assistance for cooperative business and housing. A nonprofit subsidiary, the Consumer Cooperative Development Corporation (CCDC) has the specific mission of assisting low-income development cooperatives. CCDC will provide "advances" to promising organizations to develop business plans or marketing programs, and could provide term financing for projects like SFCA or FEDA, but probably should not be considered a primary source of startup or development capital. The National Cooperative Business Association provides education and information-sharing services to cooperative businesses through publications, conferences, seminars, and direct technical assistance.

The Agricultural Cooperative Service (USDA) helps farmers maintain successful cooperatives by performing studies on the production, marketing, financial, organizational, legal, social, and economic aspects of cooperative activity. The service also provides technical assistance (based on applied research findings) in running cooperatives, organizing new cooperatives, cooperative merging, and in developing strategies for growth. The service collects and publishes statistics on cooperative activity in U.S. agriculture, and its monthly "Farmer Cooperatives" magazine reports on developments in the field of cooperative development and management.

Verticality Integrated "Contract" Systems

The formation of integrated food production/processing/marketing systems is likely to be a successful method of increasing food production on U.S.-affiliated islands. Contract farming is one method of vertical integration which extends benefits to small farmers as well as to large producers.

Under this system, businesses contract with small farms to raise a specified amount of raw materials at a guaranteed price (and may produce materials themselves]. To coordinate this system, the company determines product quantities required to fulfill identified consumer demands and maintain desired market prices, Commonly, the company provides farming inputs (e.g., fertilizer), some production assistance (technical and financial), and central processing facilities and marketing services. Thus, the farmers own and operate their farms, the central operation unit buys, processes, and sells the product, resulting in an integrated enterprise capable of capturing economies of scale (6).

Integrated contract farming provides significant benefits to both producers and consumers:

- small farmers can capture the benefits of economies of scale in processing and marketing and so obtain greater returns than as independent producers;
- because pricing decisions are made prior to delivery of the product to market, price uncertainties are shifted from farmers to consumers;
- farmers receive greater access to markets, which may be expanded through advertising and promotion underwritten by the central company;
- consumers are assured of more standardized product quality and, perhaps, access to a range of product quality at varying prices; and
- consumers receive relatively stable product availability and price (71).

Numerous examples of successful vertical integration of agricultural enterprises exist in Puerto Rico (71). For example, the Puerto Rico Department of Agriculture provides financial assistance to both the processing and distribution facilities and to "satellite farmers" supplying the broiler and ornamental plant industries (6).

Black pepper production on Pohnpei initially was similarly integrated, although farmers were not under contract and the central processing and marketing unit was a government-run agriculture station. Since high quality is essential to market Ponape pepper successfully, the state government subsidized quality control by supplying staff and processing equipment to the Agriculture Station. Farmers brought mature pepper to the station for weighing and processing by agriculture division staff. The close control of the drying process and prompt packaging by agriculture division staff helped to ensure a uniform, high-quality product (19). After sale of the processing equipment to a nongovernmental organization, pepper quality and exports have declined. The Pohnpei State government plans to repossess the processing equipment (73) and, presumably, return to the integrated production/processing/marketing system originally established.

Transportation

Good transportation services are essential for marketing produce as well as for agricultural and aquacultural development. In the Pacific islands, sea transportation services are inadequate to provide farmers with access to markets within Micronesia or to Hawaiian or Asian export markets (38). Inter-island transportation problems most often exist in the frequency and expense of transportation services, as well as the absence of any scheduled transportation service to some outlying islands. Intra-island shipping services are few and roads connecting outlying areas to urban centers commonly are unpaved and irregularly maintained. Scattered location of islands, great distances between producers and markets, and small volume of product constrain increased transportation services. Because of inadequate road systems, farmers from remote villages are unable to bring their products to markets in the urban centers (19,38).

The U.S.-affiliated Caribbean islands generally have adequate and regularly scheduled, reliable transportation services. Puerto Rico and the USVI have close contacts with the U.S. mainland and many island residents frequently travel there (101). The Caribbean islands have long been a tourist haven and thus airline and cruise ship transportation is readily available. Additionally they lie within major shipping routes and historically have been transshipment points between South and Central America to Europe. Transportation related difficulties in these islands are more often related to expense rather than availability.

Even where sea transportation services are adequate, e.g., between the U.S. mainland and the U.S. Caribbean islands, the costs are high. This is partially due to U.S. Federal regulations requiring the use of U.S. carriers for interstate commerce and Federal Government negotiation of air routes between the United States (ineluding U.S.-affiliated islands) and foreign countries.

The availability or frequency, quality, and cost of transportation in island economies is generally dictated by: distance and geography, market size or demand, and technology. In the Pacific, the general pattern is one of substantial distance, small markets, and technologies that make transportation an expensive service (25).

Technological advances have increased the transportation options available; however, costs and investments required to use these technological opportunities also have risen substantially. For example, with increases in aircraft size and carrying capacity providing greater passenger/cargo and distance capabilities, operating costs have risen and larger airport facilities are required. Newer aircraft are cheaper to operate than older designs when fully loaded, but can be significantly more expensive if not full. If cargo carrying capacity is to be increased, vessel/aircraft size and/or trip frequency must generally move upward. with this increase, freight costs and attendant business risk would likely also be higher (25).

Economic risks for transportation businesses are compounded in small markets where the potential for local fluctuations are greater. Maintenance and enhancement of international transportation infrastructure is a particularly difficult economic development task. The major capital assets of transportation providers, ships and aircraft, are unlike other corporate capital assets: airplanes and vessels can be rapidly relocated to other markets. Even when a transportation company is financially solvent or is making a modest profit, the level of business success is often measured against standards other than local or corporate gains. Profitability and business risk are measured not only within the local economy, but also are compared with other markets (25).

Many producers will assume transportation costs in order to become or remain competitive in a market: this is frequently the case for outlying producers. It should be noted that these outlying producers begin with a cost disadvantage, attributable partially to transit expenses for inputs. where production cost, including transportation, is a key determinant in the success of a producer, the transport equation is a major factor in economic development. The value of the products needing transportation, and their perishability or sensitivity to transport risks must be carefully assessed prior to investment. In a large transportation market, a canceled flight may mean a delay of several hours, while it could well mean a several day delay or total loss of goods in a small market.

Intra-island and Inter-island Transportation

In many Pacific islands, inter-island and intra-island surface transportation typically is inadequate to provide producers with reliable market access and inputs, such as animal feed and fertilizers, are difficult to obtain. Inter-island shipping services and associated harbor docking/storage facilities need to be upgraded to enable an expansion of renewable resource-based enterprises. For example, the general logistical problems of supplying feed, equipment, and supplies and transporting the products to markets, as well as expense imposed by current transportation systems, hinder aquiculture development (20) and often preclude significant commercial livestock production (38) in many of the U.S.-affiliated islands.

Intra-island Transportation. -Lack of farm and other secondary roads on many Pacific high volcanic islands inhibit accessibility to currently unused agricultural land and hinder market access from existing farms. Fostering of agricultural and aquatic enterprise development will necessitate construction of secondary roads where this deficiency represents a significant constraint, such as in the Federated States of Micronesia (FSM) and Palau (38) and the south side of Pohnpei (19). Although infrastructure development generally is given high priority in development plans, the amounts allocated to road construction may not be adequate to address farm needs.

The dirt and coral roads of Micronesia are notoriously poor and heavy rains result in impassable mud, ruts, potholes, and sometimes washouts. In addition, poor roads result in high vehicle repair costs and can reduce the productive lifetime of vehicles already shortened due to salt-air corrosion. The expense and expertise required to maintain roads in good condition may be beyond some local government capabilities (19). In addition, while roads bring access to markets, they also expose formerly traditional communities to outside influences and accelerate the departure from the traditional lifestyles to which some people prefer to adhere (27).

In some cases alternative transportation might be considered. For example, for several years, a locally built shallow-draft barge has transported lumber successfully from Pohnpei's southern mangrove forests into Kolonia. while the use of draft animals for transportation is not a viable alternative for most islanders, the practice exists in some rural areas. Carabao (a Southeast Asian water buffalo) are used by some rural families for transport of such items as building materials. The number of carabao—130 in the FSM islands in 1983, and 16 on Palau in 1982—is so small that use trends cannot be determined (85).

Inter-island Transportation: Remote Islands to Population Centers.—The remote or small coral islands and atolls provide a special set of management problems. The infrequency and often unpredictable transportation service sometimes result in occasional food and supply shortages in the outer Marshall Islands (67). Many outer islands, and particularly atolls, lack basic infrastructure and transportation facilities necessary to future economic development activity such as medium-draft docks or harbors for export and import trade, to support fishing fleets, or airstrips to facilitate emergency evacuation in case of storms, injuries, or epidemics. A dilemma in interisland transportation is the cargo capacity limitation imposed by airstrip size. The length of most outer island runways precludes economically efficient cargo airplanes; conversely, the short-takeoff and landing (STOL) craft used have minimal cargo capacity and, thus, the cargo space tends to be relatively costly (25).

Many development activities on outlying islands currently are determined by the availability and frequency of sea-going transportation services. On many small atolls and remote islands, boat visits are infrequent and often unpredictable. Part of the frequency problems are attributable to the lack of appropriate ocean infrastructure compounded by the natural roughness of the Pacific Ocean's high seas. Relatively loose scheduling of calls is commonly required because narrow, dangerous channel passage or anchorage/cargo handling often is achievable only at certain tides (25).

Some islands within this category rely on copra production, which requires little support infrastructure. Copra transportation within the Marshall Islands is well organized, though logistically it is not a simple task. Sailing canoes or small boats (20 to 30 feet) with small outboard motors or inboard diesel engines transport the copra to a common collection point within each atoll (67).

Copra from the outer islands is transported to Majuro for processing by small transport vessels which carry trade goods, cargo, and passengers throughout the Marshalls. Four "field trip ships" currently are operated by the Republic of the Marshall Islands Government and privately owned ships have occasionally provided similar services in recent years. A typical round-trip voyage from Majuro lasts 2 to 3 weeks and includes stops at four to six atolls. The length of each stop and duration of the entire trip is unpredictable because departure and arrival times and transit of reef passes must be adjusted daily to tides and weather conditions. This unpredictability can compromise the quality of the copra, since it deteriorates if it is stored too long, and may prevent the product from reaching buyers in a timely manner (67).

Opportunity: Upgrade inter-island Air Links

Each of the FAS governments has devoted considerable efforts to upgrading inter-island air links. For example, 19 runways have been constructed on the outer Marshall Islands since 1980. These can accommodate small 14- to 16-

Photo credit: Office of Technology Assessment

This Airline of the Marshall Islands (AMI) aircraft and airfield on Ailinglaplap (Marshall Islands) are typical for those remote atolls having airfield facilities.

passenger planes operated by the Airline of the Marshall Islands (67). Recently, a missionary organization, Pacific Missionary Aviation, organized villagers in the outer atolls of the FSM to construct short airfields for emergency air evacuation, improved communication, and mail service. Today, airfields have been completed on Pingelap and are being constructed on Mokil and Ngatik in Pohnpei (39). The construction of small airstrips on other outer islands (that can afford the loss of productive copra land) could help to stimulate economic activity, tourism, and communication, and facilitate government administration (39).

Intraregional and International Transportation

potential for intraregional and international commodity exports in the Pacific islands are hindered by inadequate transportation services, particularly in the FAS and American Samoa. Little or no regularly scheduled surface shipping exists between the FAS or American Samoa and Asian-Pacific markets (38). Even where transportation services are available, the expense often hinders tourism and export potential of certain commodities. Rates for air cargo from U.S.-affiliated islands are based on international schedules rather than domestic rates, making shipping expenses extremely high (80).

An additional factor is the nature of most Pacific markets. Generally, the markets are import-heavy, with very limited out-bound cargo. The one-way traffic is a contributing factor to high cargo carrying costs; in Pacific markets, these rates must amortize the costs of virtually empty cargo holds on the out-bound voyage (25).

Opportunity: Coordinated Regional Transportation Development

Strategies to increase resource industry development would necessarily involve developing adequate land and water transportation and, in some instances, air shipment (30). The potential for intraregional trade depends on strengthening surface and air transportation services among the territories and on coordinated development planning (38). Quarantine and inspection services must be upgraded concurrently with transportation to reduce the risks of accidental introduction of harmful pests into the islands (88).

Coordinated regional development of the transport network is one means to address the problem of virtually empty back-haul. Experience in the deregulated air industry has shown that focus of commercial carriers on the more lucrative parts of the Pacific regional market has generally left the smaller Pacific points with reduced service (25).

Another strategy for increasing cargo capacity and reducing freight costs is a passenger/freight mixed load approach. Dedicated air cargo services have had little success in the pacific due to the economic context. The mixed use approach probably would increase revenue/load potential while reducing business risk. This strategy, however, does not overcome the problems of converging seasonal peaks of passengers and cargo.

Opportunity: Subsidization of Air Transport

General transportation problems in the Pacific islands may restrain development of certain enterprises which require imported inputs or export capacity. For example, the high costs of air freight within the region, together with the general lack of airline services, make it difficult to obtain needed equipment and supplies. The high cost of transportation also reduces or eliminates the profit margin on products destined for export. Some form of government subsidy for the shipment of supplies and products (56), or government-sponsored identification and/or research into more cost-effective forms of transportation for the U.S.-affiliated islands, could be considered to help remedy this situation.

Another approach would be to amend the Essential Air Services program, which guarantees a minimum level of service to small communities, to include cargo movement needs in the service level determination process. Although this would increase Federal liabilities by raising minimum guarantees, carriers may fulfill minimum requirements without subsidy as island economies develop.

INTERSECTORAL INTEGRATION

Some basic human services required by island people as by those elsewhere are clean water, energy, and safe disposal of wastes. In addition, development trends of U.S.-affiliated islands require that the services required by tourists and increasingly urban populations be provided. These services commonly require large government investments in infrastructure and dedication of land and other resources to their operation. However, these forms of economic development are not necessarily competing with resource management and development. In many cases, they can be designed and developed to provide long-term secondary benefits to agriculture, aquiculture and fisheries. For example, the airstrip on Majuro (RMI) also serves as a passive water catchment, collecting the rainwater that falls on the cement surface and directing it into a holding pond that can be tapped for use. Roads can be similarly designed.

Although analyses of the potentials for combining such developments with renewable resource development must be performed on an island-by-island, and probably case-by-case basis, which is beyond the scope of this report, a number of means to derive benefits for resource development from infrastructure development can be suggested, including:

- integrating agriculture and aquiculture with energy development,
- integrating tourism and resource development, and
- integrating urban development with resource management.

Integrating Agriculture and Aquaculture With Energy Development

Energy is a major limiting factor to economic development, particularly in the U.S.-affiliated Pacific islands. Fossil fuels must be imported and the operating and maintenance costs for oil and gas energy production systems are high. Thus technologies conserving imported fossil fuels or using renewable energy sources are preferred.

The energy demands in Micronesia are small but increasing; in aggregate 5.8 million barrels of petroleum fuels (excluding jet fuel) are imported annually. The cost to local governments is high. Metered rates, where they exist, usually have little correlation to the cost of production. Local governments often subsidize use by at least 50 percent (91). Given policies of not actively collecting bills, this can rise to 100 percent (24).

Puerto Rico and the USVI have well-developed networks for electricity production and distribution. It is unlikely that development of renewable resources (e.g., for processing plants) may be hindered by the lack of electricity. The cost of electric power, however, is high (77). In the past, the rural poor in Puerto Rico depended on cheap, accessible wood for cooking, but today that demand has diminished considerably and firewood is only used occasionally (68). However, charcoal commonly is used for backyard barbecues and roadside food stands,

Energy availability and cost will continue to be a major economic development problem in the Caribbean and the Pacific. In the short run, energy conservative activities and technologies not dependent on expensive fuels are needed. In the long run, renewable sources of energy, based primarily on the sun and the oceans, must be developed. Although this energy has been considered "free," establishment and maintenance of the infrastructure required to tap it are costly and can require long payback periods. Alternative energy sources are being explored in all of the island areas. These sources include energy from biological processes, thermochemical processes, ocean-related energy generation, and hydropower.[2] Each of these can be developed to include components mutually beneficial to agriculture, aquiculture, and energy.

Agriculture and Energy Development

Agriculture can be integrated with several other technologies to conserve and recycle resources and energy, increase production efficiency, and improve island environments. Opportunities exist for generation and use of biomass for energy generation and biogas energy from animal and crop waste and residue.

Energy from the conversion of wood and other plant matter represents an important, potentially underexploited resource for the islands. As renewable domestic energy resources, these can help the islands reduce their dependence on imported oil. Energy could be derived from numerous types of biomass, including wood, grass and legume herbage, crop residues, animal manure, food-processing wastes, oil-bearing plants, seaweed, and many other materials (50,95).

Wood Fuels.—Fuelwood, including coconut husks and shells, is the most plentiful and least expensive source of energy in Micronesia, and on most atolls the only source. Most of this fuel is used for cooking and sometimes for creating smoke to repel insects from homes and gardens. Fuels used in cooking largely are byproducts of the food production system: dried husks of mature coconuts, husks of *Inocarpus* nuts, and wood from secondary vegetation generally from fallowing garden sites (15). Charcoal is not widely used, though species that make high-quality charcoal (*Leucaena* spp., *casuarina,* and mangroves) occur commonly on the high islands (24).

Conversion to wood-fired electric plants in Micronesia is not foreseeable in the near future. Labor and capital investments are generally higher for fuelwood plantations than for conventional stands due to higher stocking densities (often 20 to 40 times as high) which in turn affect the cost of seedling production. More mechanized harvesting and processing methods are also required. Converting electric plant facilities and adjusting existing grid sizes also would be costly.

Coconut-Derived **Energy Products.—A** number of coconut palm products traditionally have served as primary fuel sources in the U.S.-affiliated Pacific islands. Coconut husks and shells have been the major Marshallese cooking fuel for centuries. Husks and shells also fuel copra dryers; distillation of salt from seawater; melting of lead for fishing weights; and bleaching of the *Pandanus* leaves used in woven sleeping mats and fine handicraft items (67).

Coconut shell charcoal has been considered as a possible byproduct of copra making in the Marshall Islands. High shipping costs, relatively high labor costs, and small potential output would make centralized processing prohibitively expensive, although decentralized processing on the outer islands (where there is excess labor) might be possible (67).

The use of coconut palm biomass to fuel larger scale activities such as steam generation

[2] A complete analysis of these technologies is beyond the scope of this assessment. For further information see (50,51,52,53, 55,94,96).

is technically possible (16). Difficulties lie in in collecting, storing, and handling the quantities needed for such uses. In the Marshall Islands, husks could be gathered in large quantities on Majuro Atoll. However, husk shipments to Majuro from the outer islands are not possible given current shipping capacity; the sheer volume of whole nuts or husks would be 10 times greater than the volume of copra from an equivalent number of nuts. The costs of expanding service and of acquiring new ships probably would be prohibitive. If husks were gathered in large quantities for fuel, moreover, they would not be available for decay and return to the soil. Atoll soils are very sandy and organically poor, and loss of this nutrient input overall could have a negative impact (67).

The use of coconut oil as a substitute for diesel fuel is being examined in a number of countries. Tests conducted in Western Samoa have shown that coconut oil can be used alone or in a blend with diesel fuel without affecting engine power. Particulate matter in the coconut oil, however, clogged fuel filters after a few hours of operation. Injector coking and residue accumulation on other internal parts were expected to be serious problems (63). Further research may reveal a way of avoiding these by pretreatment of the coconut oil, modification of engine design, fuel blending with petroleum products or ethanol, or a combination of approaches (67).

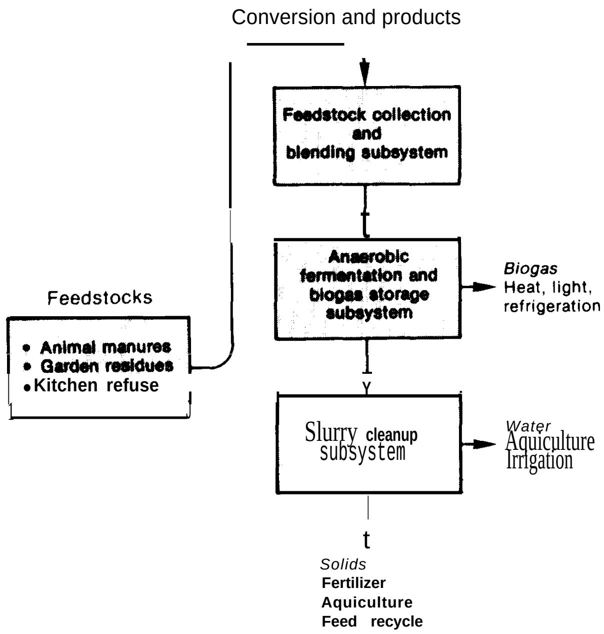
Successful coconut oil-fueled engines also could be used for power generation, thus eliminating the supply problems inherent in basing petroleum-fueled generating systems on remote islands. A 1983 cost comparison in the Marshall Islands showed that a 10-kW coconut oil-fueled, generator-expeller combination would be cheaper than a photovoltaic system of the same size (28). Neither system, however, is affordable by outer island standards, and they were not compared to standard diesel-powered systems. Moreover, the comparison did not account for fluctuations of coconut oil prices or declining costs for photovoltaic systems as the efficiency of that technology improves. These factors could drastically affect the comparison (67).

Biogas.—Considerable interest exists in enhancing agriculture production through new and sometimes innovative integration of diverse technologies into one production system. These include waste recycling by anaerobic digestion to derive energy and nutrients—energy-integrated farming. By adding simple components, this system also can be integrated with aquiculture or residential waste disposal. This innovative system has not been used widely for commercial application, perhaps due to lack of support by local practitioners, continuity in technical assistance, or social or economic analysis.

The major objective of energy-integrated farming systems is to transform animal or crop wastes cheaply into useful products and, thus, effectively recycle a wasted resource. The core of the system is a digester: an oxygen-free container in which organic matter is fermented by micro-organisms producing "biogas" and a thick slurry (l). Biogas is comprised of about 60 percent methane and 40 percent other gases principally carbon dioxide. The same fermentation process occurs in nature whenever organic matters decompose in the absence of oxygen, e.g., in animal digestive tracts or in swamp muds. The organic matter for recycling need not be animal wastes. Crop residues, leaves, grasses, straw—virtually any organic material suitably prepared—can be used independently or in conjunction with manures to produce biogas. Induced fermentation processes in digesters can be made more efficient by controlling the variables such as quantity and quality of organic materials and temperature (l). The quantity of biogas and residue produced in the digester depends on the amount and types of organic matter, the capacity of digester, and ambient temperature.

Completely fermented slurry has reduced harmful organisms, is virtually odorless, and retains the fertilizer value of the original material. Solids can be manually or mechanically separated from the liquid. The resulting sludge can be processed and used for various purposes, such as potting soil or as an animal feed additive (1,11). Slurry and sludge also can be used for fertilizing agricultural lands or to fertilize

Figure 8-4.—Components of On-Farm Biogas Systems



SOURCE A.G. Alexander, "Assessment of Energy-Related Farming Technologies for U S Insular Areas," OTA commissioned paper, 1986

aquiculture ponds. Biogas can be used to fuel a variety of gas burning appliances such as lights, stoves, refrigerators, or even to run modified gas-fueled engines (1,32).

Although each system is different, the basic components of an energy-integrated farming system are the same, with three basic units (figure 8-4) (l): 1) a collection and blending system in which organic matter (manure and wastes) is collected and mixed with water before fermentation, 2) a biogas digester wherein anaerobic fermentation of organic matter takes place and biogas is produced and stored, and 3) slurry and wastewater storage or separation. Effluent can be used directly or the solids can be separated from the liquid and used separately.

Social, economic, and environmental benefits derived from the digester system include:

- reduced fuel, fertilizer, and/or animal feed use;
- avoided costs of waste disposal to achieve compliance with Environmental Protection Agency regulations;
- sales of farm products which are otherwise wasted;
- increased yield and quality of traditional farm commodities;
- reduced production costs;
- decreased purchased fuel or fuelwood use through substitution of biogas; and
- reduced health hazard and environmental pollution caused by improper treatment of wastes (l).

In addition, water is needed to wash wastes into the system on a daily basis. Thus, a program to build biogas systems could result in improved water systems for families as well as improved sewer systems which could help alleviate health problems (15).

Biogas production lends itself to a broad scope of applications ranging from single-household, manually operated digesters with little need for high efficiency, to huge, costly, corporation-sustaining complexes totally reliant on high technology and having closely calculated "payback" scenarios that dictate their ultimate success or failure (1). Currently, a viable biogas plant requires a minimum of four to five confined pigs or cattle (53). Development of energy-integrated farm technologies in the near term (6 to 7 years), probably will affect comparatively few farmers having existing large manure supplies and pressing need for its disposal. In the longer term (8 to 20 years), small-farm and household-level biogas units could be implemented that could contribute to the general welfare of insular communities.

Small-Scale Operation. —In small farm operations or rural family farming, biogas can be used for lighting or cooking. The solids can be separated from the residual liquids by coarse sieving or merely by gravity separation in a small settling pond designed for periodic draining and cleaning (l). Wastewater can be used for garden irrigation, or can be cleaned by an inexpensive aquiculture of organisms such as tilapia and water hyacinths that thrive on the rich suspended organic matter still contained in the digester effluent. The major constraint for increased application of small-scale operations is the strong cultural resistance of many

This plastic lined settling pond is part of the small-scale biogas system in the Northern Mariana Islands. The effluent from the pond is discharged through an irrigation system.

islanders to handling animal wastes. Furthermore, the initial capital cost is outside the capacity of most small farmers.

Large-Scale Operation.—Although opportunities for large-scale integrated farming systems exist, implementation and widespread application are seriously constrained by: 1) lack of large livestock operations that can produce enough recoverable wastes, 2) lack of expertise in design, installation, and operation, and 3) lack of capital support *(1)*. The largest commercial application of energy recovery of wastes using fermentation principles was recently installed by the Bacardi Corp. in Puerto Rico (84). Benefits derived from large-scale operation include potential direct substitution of purchased utility power and periodic sales of excess power to local utilities. Indirect substitutions include the recycled mineral nutrients contained in the digester solids and wastewater, in protein recycled to farm animal feed, in imported dry-feeds and feed concentrates substitution with greenfeed, and on-farm production of plants and aquatic organisms produced in the aquiculture subsystems (l).

Aquaculture and Energy Development

Aquiculture can be integrated with irrigation and other agricultural support systems, as well as with wastewater treatment and energy development, to the mutual benefit of each development component. Because power is a basic commodity in developed and developing economies, and most power-producing plants are constructed in coastal zones, powerplants

Photo credit: Office of Technology Assessment

Slurry derived from this large-scale biogas system is directed through aquiculture tanks containing tilapia and water hyacinth before being discharged through an irrigation system, thus, providing several benefits in addition to energy generation.

and mariculture systems could be designed to be mutually beneficial.

The oceans of the world, and the Pacific in particular, are a reservoir of potential energy. There currently is no available low cost and simple means of exploiting this potential in substantial quantity. Numerous technologies being researched may one day change this situation although, with the exception of wind-powered shipping, this does not seem likely to occur for several decades. Major ocean energy systems potentially suitable for the tropics are ocean thermal energy conversion (OTEC), passive seawave energy systems, and biomass and solar pond systems. Integration of aquiculture with these technologies may improve their economic feasibility and make productive use of ocean energy "wastes."

OTEC systems use large quantities of cold water pumped from deep ocean areas to the surface, similar to natural upwellings of cold waters along some continental coasts (94,96). OTEC uses the surface water as a heat source and the cold deep water as a heat absorber. The "fuel" is free, but low efficiency means that very large volumes of warm and cold water must be circulated through the system. The energy and material cost of pumping large volumes of cold water from considerable depths effectively precludes the development of small-scale OTEC systems.

A byproduct of OTEC schemes is artificial upwelling of deep, cold waters. Tropical surface waters are nutrient poor, but the deep water is nutrient-rich. Such water, after its temperature change has been used to generate energy, can be used for mariculture. The culture systems use the upwelled, nutrient-rich water and abundant sunlight for primary productivity (mainly phytoplankton) on which other organisms are cultured in sequence. Such technology may be applied wherever the land borders deep seas (e.g., atolls and volcanic islands) primarily along the equatorial belt, where solar radiation is plentiful.

Artificial upwelling mariculture systems have been demonstrated on St. Croix and in Hawaii. The USVI project has since closed and is considered a failure due to a need to supplement upwelled water with additional nutrients and rapid spread of infections and disease within the monoculture organisms (59).

Since 1981, a number of mariculture experiments have been conducted at the Natural Energy Laboratory of Hawaii (NELH), an alternate energy research, development, and demonstration center. Some species demonstrated higher growth rates in comparison to natural rates or those in other aquiculture systems. Currently kelp and abalone are being commercially cultured using NELH's "artificial upwelling," and plans are underway to grow algaes to produce a nutritional additive, pharmaceutical-grade biochemical, pigments, vitamins, and fertilizers. Indications are that development of artificial upwellings do not need to be involved in power generation to be financially attractive (9).

Wave energy systems are a more steady and predictable energy source than the winds from which they draw their energy, yet variations in wave size and energy are substantial. Wave energy is concentrated at the sea surface, consequently a wave energy collection device needs to be of substantial extent, hindering its applicability to small islands (14). However, sedentary species can be cultured in much of the area otherwise reserved for energy generation.

Biomass energy generation systems have primarily focused on using kelp, a large, coldwater seaweed. Submerged reef areas and lagoons are probably available near the U.S.-affiliated islands where other macroalgae could be grown, but the nutrient-rich water required is largely lacking in tropical areas.

In several places in the Caribbean, including St. Croix, pilot programs have studied the feasibility of converting raw algal biomass into methane gas and other sources of cheap, nonpolluting energy (17). Algae are grown on enclosed (often floating) artificial substrates, harvested periodically, and converted chemically to gas. Two major problems influence the success of this process: 1) the relative scarcity of large, fleshy algae in island waters, particularly in light of intense fish grazing; and 2) the cost of nutrients and processing chemicals (103). This technology probably is more suitable for open ocean culture rather than nearshore systems (14).

Solar ponds use a strong salinity gradient to suppress convective mixing of a body of water heated by the sun (55). A substantial supply of salt is needed to maintain the required highly saline bottom layer. Hypersaline ponds in Puerto Rico and the USVI and Pacific atoll lagoons may lend themselves to solar pond energy generation. The cleanliness of the air on small islands and the clarity of the sea water would greatly reduce one of the problems with land-based ponds: heat-absorbing leaves, dirt, etc., accumulate in the surface layer reducing the heat collected by the highly saline lower layers. Certain salt-tolerant species, such as brine shrimp (used in livestock and fish feeds) probably can be cultured in these ponds with little detriment to energy generation.

Integrating Tourism and Resource Development

Tropical island environments not only encompass a variety of economically important renewable resource systems, they also attract tourists. The integrated development of renewable resource uses and of tourism will require careful planning, but is preferable to isolated and possibly conflicting approaches to these two opportunities for economic development on the islands.

Economic benefits and negative environmental and social impacts as well have been attributed to tourism in developing countries (33). Whether the former outweigh the latter has been a matter of some debate among economists and social scientists. While small tropical islands may be particularly vulnerable to tourism's negative impacts, with proper planning and management, tourism development may be paced and integrated with resource management in ways that maximize the economic and environmental benefits of a tourist industry and mitigate its adverse impacts (3). For example, tourism can provide both the need and the capital means (as well as one rationale) for protecting natural areas, as well as the impetus for repairing environmentally degraded areas. Tourists represent potential consumers of island products, and their presence creates jobs in a variety of production and service sectors.

Local governments can set objectives for integrating tourism into island economies and decide what environmental and social changes can be tolerated and what resources can be committed. If the scale of development exceeds the limits of change acceptable to the environment or community, a tourist destination could quickly "peak out" and stagnate or decline in popularity.

Impacts of Tourism

Tourism research to date has primarily focused on economic and social impacts (3). The potential benefits of a tourist industry include increased job opportunities, improvements in infrastructural services, and increased tax revenues and foreign exchange earnings. Income from tourism can help offset deficits created by imports of raw materials and manufactured goods.

The quality of the environment, which is what attracts tourists to the islands, however, can be compromised by tourists themselves. Demands for land, water, and waste disposal generated by tourism may stress the limited resource base of small islands. Waste disposal, especially from large development, can be a particular problem if effluents are discharged into lagoons or other nearshore areas with limited circulation. Other potential contributors to environmental stress are construction and recreational activities (66). Tourists may disturb wildlife, trample coral, and collect live shells and corals. It has been estimated that 1 live coral head was collected for each 230 visitors to Hawaii—equivalent to about 19,000 to 24,000 specimens in 1 year (3). All of these environmental impacts will vary with the character and intensity of tourist site-use and development, and resiliency of the ecosystem (7).

Some of Caribbean tourism's most visible impacts are on the environment. In the space of one generation, natural coastal and beach areas have been displaced by hotel and marina expansion. Mountain faces and pristine landscapes have been etched with condominiums and roads. Large developments have alienated vast land areas from traditional uses and even modified climatic features (41). Sensitive ecosystems like swamps and mangroves have been irreversibly disturbed and lobster and fish beds have deteriorated (43).

Tourism may also have negative socio-cultural impacts, including changes in demography, lifestyles, consumption patterns, work and leisure habits, and loss of traditional values and customs, These effects vary with the numbers of tourists (relative to native population), and with the extent of the cultural and sociological differences between the tourist and indigenous populations (89), Their impact can be large on island territories with small populations.

Finally, some of the positive economic benefits of tourism may have been overstated. Tourism can function as a seed industry if profits are reinvested in other sectors of the economy. This does not happen as often as expected; much of the income from tourism goes off island to purchase imports, many for the tourist industry (3).

The failure of tourism to benefit the local economy on a greater scale, and the imposition of burdens on the local population to the benefit of the industry (e.g., loss of public beaches to resorts) has, in some cases, contributed to a sense of resentment by the resident population. Tax incentives encouraging to tourism development means loss of revenue for local governments. Local people become frustrated because, while they are employed in a range of jobs from low service positions to middle management, top managers and owners are usually foreign (10). It has been argued that potentially negative impacts of tourism on a host country are primarily a concern and responsibility of government (26), since private sector involvement is likely restricted to financial and economic considerations.

Pacific Tourism.—Tourism has developed only on certain Pacific islands; vast stretches of ocean separate destinations. Statistics on tourism in the Pacific are scattered among myriad sources and are not presented in a consistent or standardized format. The Pacific Area Travel Association annually compiles one of the more complete and detailed compendiums of statistical information on tourism, but does not cover Palau or the Marshalls.

Tourism development is a stated goal of each of the U.S.-affiliated island governments. Guam

Photo credit: Office of Technology Assessment

The natural beauty, unique cultural settings, and historic sites of the U.S.-Affiliated tropical islands attract growing numbers of tourists.

and Saipan have reached the intermediate stages of the tourist development model proposed by Butler (4), as defined by: 1) increasing external influence on tourist infrastructure, 2) large numbers of tourists who use the services of travel agents and other organized infrastructure, 3) declining rates of increase in tourist numbers, 4) heavy advertising and marketing to attract visitors and extend the tourist season, 5) the presence of major franchises and chains, and 6) some local opposition to tourism. The more remote islands of Micronesia attract considerably fewer visitors than do those of the Marianas chain. In 1981, only 20,981 visitors were recorded for Palau and the FSM combined, most from the United States (44,61,62). American Samoa also receives few tourists.

Many of the same factors that constrain renewable resource development also constrain the development of the tourist industry in the Pacific region. These include lack of reliable, inexpensive, frequent air service; lack of developable land for transportation and facilities; insufficient infrastructure; a reliance on imported foods, materials, and energy; and lack of trained personnel. Availability of transportation is often cited as the primary limiting factor in the development of an island's tourist industry (64). The distance between service points necessitates large aircraft, but lack of market populations prohibits reasonable operating cost structure (62). Carriers, routes, and timetables change frequently. Water supplies critical to tourism also are small on many islands. Depending on the nature of development, potable water requirements could vary from 100 to 500 gallons per person per day (22,99).

Finally, in some areas, cultural traditions inhibit acceptance of tourism as a viable option for earning a living (29,31,90). Even where tourism employment is acceptable, avoidance of hostility among local people is linked to the provision of good jobs, not menial employment only, and to local ownership (66). Management jobs, however, are primarily filled by expatriate personnel rather than local people, possibly leading to frustration.

Caribbean Tourism.—Many attractive beaches, an ideal climate, and proximity to major markets have given the Caribbean an advantage in competing for international tourists. However, only with the advent of mass tourism of the 1950s and early 1960s did tourism become a major economic activity in the region (81). The Caribbean region captures almost 3 percent of world tourism. As a result, the importance of tourism has become pervasive, and it has become the leading sector for the majority of Caribbean microstates (42).

Puerto Rico and the USVI depend largely on visitors from the urban populations of the United States and Europe. In the USVI, tourism is the base of the private economy and the major economic activity contributing to the gross domestic product (GDP) and employment generation (43). Tourism is economically, socially, and physically pervasive. The territory has received over a million tourists annually since 1972 and, in 1979, total visitors outnumbered local residents by a factor of 13. Their gross expenditures were double the entire operating budget of the Virgin Islands local government. Because it is so labor-intensive, the tourist industry has a considerable impact on employment, generating nearly one-third of all island jobs. Tourist infrastructure dominates the insular landscape. The islands' tourist economy makes the territory a major growth center within the eastern Caribbean; however there is no consistent, reliable, quantitative base from which to assess the economic contributions and performance of the tourism industry (81).

In Puerto Rico, which is economically more diversified, tourism accounts for a smaller portion of the GDP and total employment (81). Although tourism accounts for only about 5 percent of GDP, it creates linkages throughout the economy which result in increased total output by nearly all other economic sectors. Thus, for every tourist dollar spent between 1970 and 1980, GDP increased by an estimated average of $1.25 and total gross output by an average of $2.08. In all, 142 jobs were created in Puerto Rico in fiscal year 1980 for every $1.0 million spent by tourists, including an estimated total of 1,442 jobs in agriculture (75).

Caribbean tourism appears to face a challenging period ahead. A new recognition exists within Caribbean governments of the costs and benefits of tourism, and of the need for long-term planning with accurate market information (81). Long-term tourism viability will probably require a more focused marketing strategy, and it may depend on the industry's linkage potential with domestic sectors, such as agriculture and fisheries (43).

Local governments may need to insist on substantial local shareholding and participation in tourism-related companies. Residents could be trained as tour leaders in a program similar to the intensive summer training at the University of Hawaii School of Travel Industry Management.

Opportunity: Create Linkages Between Tourism and Island Producers

Systematic management to promote increased use of local agricultural produce in hotels and restaurants could help encourage regularity of supply and quality (18). Similarly, increased use of island handicrafts for decor in tourist facilities, and sales of handicrafts to tourists can foster this resource-based productive sector.

Whereas large, "industrial tourism, " characterized by hotels and infrastructure meeting international standards, require substantial investments in support facilities, and largely depend on imported foods, smaller scale, economy-class tourism, and "craft tourism" with "homestays" can make more use of island products. The islands could strive to attract more tourists of the second type, including "explorers" and "adventurers" (3). Educational tourism also is becoming popular as upscale travelers seek opportunities to learn about the culture and environment of remote areas. Promotion could be approached from the islander's perspective. What is special and important to the person who lives there? What would they like the tourist to see to get a true sense of the place?

Handicrafts Industry Development[3]

Island peoples have traditionally used fibers, shells, wood, and other local materials to make a wide variety of implements and decorative objects (table 8-2). Although some loss of skills has become evident on some islands in recent years, considerable interest in and demand for island handicrafts exists, mainly on the part of expatriate and tourist populations. Handicraft industries, if developed with attention to efficient production, marketing and quality control, could contribute significantly to island economies; attract more tourists; foster preservation of traditional art forms and pride in indigenous skills; and make productive use of some natural resources that might otherwise be left unused.

Many contemporary handicrafts in the islands are derivatives of traditional forms, in some cases miniaturized and standardized for sale to tourists. Other are innovations, fashioned with newly imported tools and materials, and geared to the tastes of tourists and other nonnative buyers, Few handicrafts today are integral to life and culture on the islands.

Pacific.—The rich variety of traditional handicrafts in Micronesia reflects the cultural diversity of the islands. Basketry and hand-weaving of natural fibers was the most widely spread skill, developed to a fine art in eastern Micronesia where wood was scarce. Containers with elaborate shell inlays were characteristic of Palau, and pottery was made where clay was available in Palau, Yap, and Saipan. Loom weaving was practiced in the central Carolines and tapa cloth (made from tree bark) was made in Samoa. The Trukese were skilled in both woodwork and fiber arts.

[3]This section is summarized from M. Vitarelli, "Handicrafts Industry Development and Renewable Resource Management for U.S.-Affiliated Pacific Islands, " OTA commissioned paper, 1986; and from D. Sheehy, "Traditional Crafts in the U.S.-Affiliated Caribbean Islands: An Addendum to Handicrafts Industry Development and Renewable Resource Management for U. S.-Affiliated Pacific Islands," OTA commissioned paper, 1986.

Table 8-2.-Primary Resources Used in Craft Production in U.S.-Affiliated Pacific Islands

Name of raw material	Where used	Type of material (and part used)	Crafts made from materials
Coconut (tree)	all islands	fiber (leaves)	baskets, purses, mats
		wood (trunk)	spears, bowls
		husk, shell of nut	twine, ladles, jewelry, belts
Pandanus (tree)	all islands	fiber (leaves)	mats, fans, purses, baskets, pillows, hats, wall decorations, cigarette cases, woven sails for model canoes, etc.
		wood	
Banana (tree)	most islands	fiber (leaf sheaths)	lava-lava skirts, cordage, wrapping used in other crafts
Mangrove (tree)	high islands	wood	wood carvings, statues
Breadfruit (tree)	low islands	wood	carvings, model canoes
Ivory nut palm (tree)	Pohnpei	nut	carvings, jewelry
Mahogany (tree)	high islands	wood	carvings
Ironwood (tree)	most high islands some low islands	wood	carvings
Dort (tree)	Palau	wood	carvings
Ifil (tree)	many islands	wood	carvings
Paper mulberry (tree)	American Samoa	fiber (inner bark)	tapa cloth
Hibiscus (bush)	all islands	fiber (inner bark)	fiber leis, mwarmwar, ropes, nets, "grass" skirts,
		wood	carvings
Bo-jo-bo (vine)	Saipan	nut	bo-jo-bo dolls
Tumeric (herb)	most islands	root	yellow dye for fibers
Bamboo	high islands	woody fiber	fish traps, hair combs, navigation charts
Trochus Shell	most islands	shell	jewelry (exported for use as buttons)
Pearl oyster	most islands	nacreous shell	jewelry, inlay for wooden bowls, carvings
Turtle shell	most islands	tortoise shell	jewelry, combs, women's "money plates"
Cowrie & other shells	most islands	entire shell	jewelry, purses, ornaments, parts of decorative wall hangings
Coral (red & black)	W. Carolines	coral	jewelry

SOURCE: M. Vitarelli, "Handicrafts Industry Development and Renewable Resource Management for U.S.-Affiliated Pacific Islands," OTA commissioned paper, 1986

While the range, diversity, and variety of form; quantity; and quality of handicrafts have all decreased, only certain traditional skills have disappeared. Many interesting new forms of handicrafts have emerged in part because tourists, foreign museums, and shops all express an interest in purchasing island crafts. Market surveys have shown that Pacific island handicraft products are readily salable within and outside the territory, for example, to major outlets in Hawaii, the U.S. mainland, and Canada (78). However, production at reasonable prices must be stimulated and the success of the industry currently depends on tourism, not export.

Development of handicrafts as a small industry has not yet occurred within the Pacific islands for a number of reasons. Local products often lose out in competition with cheaper imports. In some areas, tourist demand for handicrafts outstrips local supplies of quality products offered at consistent prices. Guam, for example, attracts many tourists and has numerous outlets for sale of handicrafts, yet few are locally produced. The lure of a steady income through government employment may be largely to blame. Handicrafts are normally home-produced and marketed on an individual basis, and in one's spare time. Production is rarely an organized group effort, although exceptions occur (e.g., museum-employed draftspersons on American Samoa; a National Endowment for the Arts project on Palau; the Small Industries Workshop on Truk; Ponape Coconut Products packaging; crafts groups at Kolonia, Pohnpei; and a few government-sponsored projects).

Few producers have marketing skills and no cooperatives or intermediary marketing agencies exist to supply these and help assure regular quality production. Also lacking are mechanisms for the preservation and transfer of handicraft skills; a guaranteed market in some areas; and an assured, constant supply of raw materials, some of which must be prepared for

Photo credit" M. Vitarelli

Traditional crafts, although gaining importance as commercial items, retain their practical application in everyday island life. Shown here, coconut leaves are being woven into a utility basket by an island draftsperson.

use. Even today, periodic depletion of resources, and delays in getting materials to draftspersons sometimes hampers production.

Caribbean.— As in the Pacific, traditional crafts until recent decades played a vital role in the daily lives of most Puerto Ricans and Virgin Islanders. Historically, most were dependent on traditional craft skills for many of their everyday necessities.

The traditional handicrafts currently found in Puerto Rico clearly reflect three major strains in the island's cultural history. Woven hemp hammocks were common to the local Arawak Indians and are still fabricated locally. The bomba drums and painted coconut husk masks and *maracas* are clearly of African derivation. Certain musical instruments, carved wooden animals, and *santos* (religious icons) are uniquely Puerto Rican but draw from Spanish prototypes. Other prominent Puerto Rican craft forms are pacemaking; jewelry made from local seeds, shells, and coconut shell; basketry; machetes; wooden furniture and caning; tinwork; and pottery and papier mache masks.

As the modern technology and factory-made goods of the United States were increasingly imported by the islands from the 1920s to the present, three general trends of change were observable. First, many handicraft skills were eclipsed or were forgotten through disuse, as foreign-made or factory-made items were imported. Skills at roof thatching, for example, were all but lost as corrugated tin and other ready-made materials were used to cover people's homes; brooms, vine baskets, palm hats, hand-hewn wood furniture, fish traps, and other common necessities were increasingly of foreign origin.

Second, as society became more commodity-oriented and the dictates of the marketplace played an ever-increasing role in the production of handicrafts, crafts that were not competitive as commodities fell into desuetude. As the set of esthetic criteria that determined quality shifted from those of the local, primarily rural and agricultural community members to those of the city-dwelling consumers of urban San Juan and foreign lands, traditional crafts that could find a niche in the marketplace commonly suffered an esthetic disjuncture. In some cases, the change in the process of crafts production from the craftsman devoting great attention to each individual piece to the craftsman having to maximize the number of pieces produced in order to meet the demand resulted in greater standardization, reduced artistic diversity, and miniaturization.

Finally, the burgeoning tourist industry, hand-in-hand with underemployment, created an economically appealing situation for those interested in producing and selling handicrafts for foreign tourists. Many (if not most) of these craft items were made and marketed as souvenirs or "hand-made" crafts and did not draw on local traditional craft skills or esthetic ideals.

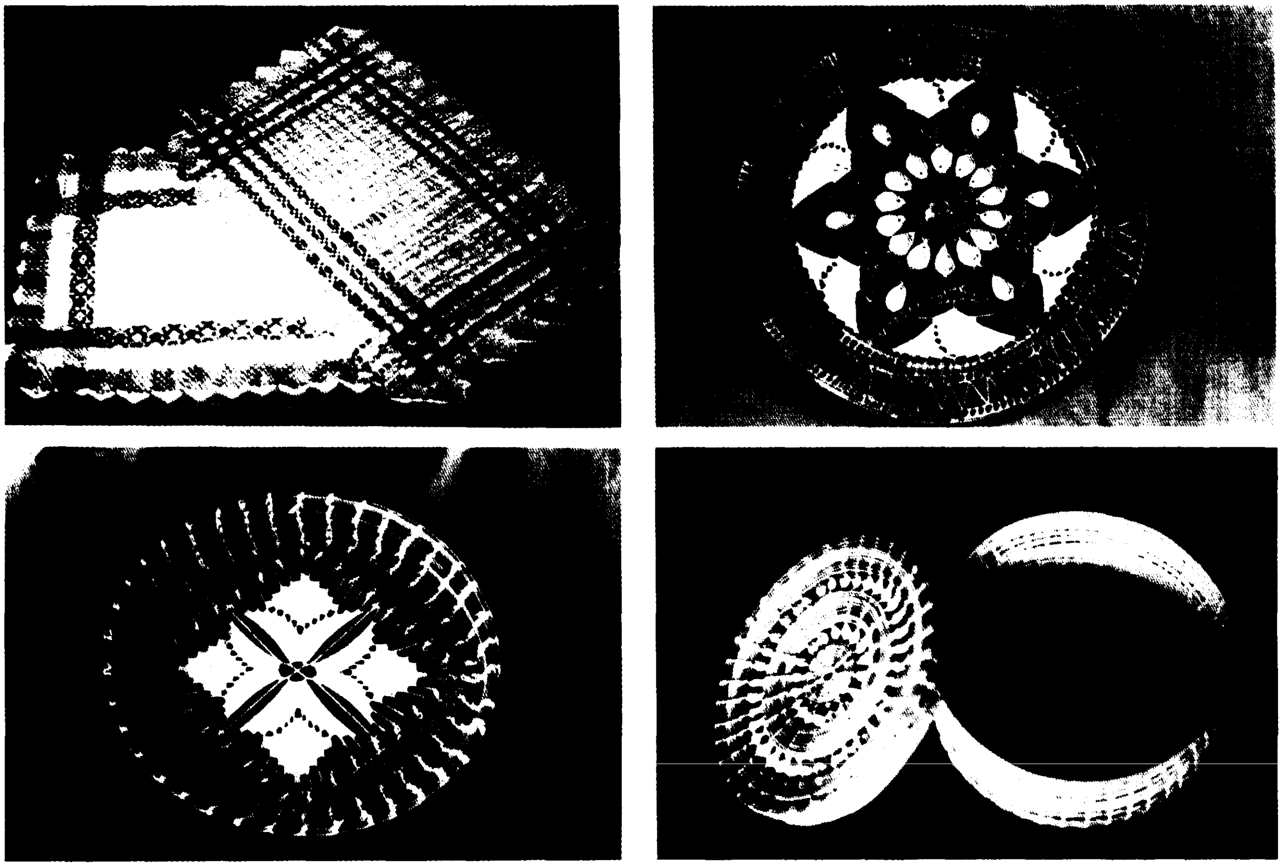


Photo cradit: M. Vitarelli

Traditionally used raw materials such as pandanus and coconut leaf fibers and shells still are used today in many fine island handicrafts. Clockwise from top left 1) Marshall Islands' place mats, 2) Trukese wall decoration with cowrie shell accents, 3) Marshall Islands' sewing basket with cowrie shell accents, and 4) Trukese decorative tray.

Although Puerto Rico's crafts have clearly suffered a decline in this century, in many cases there has been a renewed vitality since the 1950s. The Institute of Puerto Rican Culture, created in the 1950s, began a policy of stimulating the practice of indigenous traditional arts through contest, local and islandwide crafts fairs, exhibits, and education programs. More recently, the Office of Crafts Development of the Administration de Fomento Economico provides technical assistance and some tools to traditional craftsmen. It also has instituted an annual recognition program of Master Craftsman of the Year and Young Craftsman of the Year, bringing prestige, recognition, and greater visibility to Puerto Rico's craftsmen. In addition, several crafts items have been consciously promoted as symbols of insular identity, such as the omnipresent carved wooden coqui (a small frog).

Traditional crafts of the U.S. Virgin Islands suffered a similar decline as did the crafts of Puerto Rico, but have not enjoyed a similar renewal of vitality. Few traditional craft items have been converted successfully to commodities for the tourist or local market. Some crafts traditions continue, such as fishnets, fish traps, and the woven grass hats of Frenchtown, but they are to be found at the margins of daily life.

Traditional crafts have not received the governmental recognition and support in the USVI as they have in Puerto Rico. The Virgin Islands Council on the Arts and the multicultural education divisions of the local public schools have given some attention to local traditional culture, but to date there has been no comprehensive survey to inventory local crafts and assess the needs of local traditional craftsworkers, nor has there been any focused government effort at conserving local handicrafts.

Opportunities to Encourage Handicraft Industry Development.–Several measures can be taken to mitigate these constraints and to encourage the growth of a handicrafts industry in the U.S.-affiliated islands. Producers, for example, can cooperate for specific purposes (advertising, participation in fairs) and standardize prices for handicrafts. Island hotels, restaurants, and offices can make more use of handcrafted items in place of imported glass and plastic decorative items. Perhaps with Federal Government support, island governments could:

- aid in the provision of tools, materials, and workplaces;
- help establish vocational training in schools and master-apprentice programs for transfer of skills from elders;
- provide publicity, sales promotion, and sales agents;
- establish museums and cultural centers (with handicraft sales shops) on major islands;
- provide funding for filming or other documentation of crafts being made to aid skill transfer and educate visitors;
- where export is feasible, compile a trade index or list of overseas products, producers, and retailers for distribution overseas;
- create tax incentives for organizations and businesses who support local handicrafts, or culture and the arts; and
- prepare handicraft development plans.

In the latter, planners must choose between emphasis on limited production or mass-production; indigenous handicrafts or innovative derived forms; local consumption or export. Except in unusual cases, in the near-term handicrafts are likely to remain a source of supplemental income to small-scale artisans, thus programs to increase the earnings potential of handicrafts must be long-term (56). A wise approach to development might be cautious step-by-step expansion, building on existing skills and focusing on quality and organization before mass-production is attempted.

If a systematic effort is made to improve and expand the handicraft industry, methods of conserving and/or replenishing supplies of raw materials must be researched and implemented to avoid depletion. As limited rural lands continue to be developed in the U.S. Caribbean, and as certain crafts grow in popularity, resource depletion may hinder development of some crafts. Reforestation programs could be initiated to ensure a continuous supply of wood, laws enacted and enforced regulating the collecting of shells and coral, and neutral lands set aside for cultivation of fibers (40).

Integrating Urban Development With Resource Management

Renewable resource management can be integrated into urban development in a number of ways, including: wastewater treatment and reuse to protect nearshore ecosystems and for land fertilization, and development of urban forestry to provide noise reduction and other environmental services and a source of high-value wood for small-scale artisans.

Wastewater Treatment and Reuse

Providing safe drinking water and protection of groundwater supplies are important goals in the U.S.-affiliated islands. Solid waste management, including controls over littering and centralized refuge collection and disposal, is also needed. Sewerage linkups to appropriately designed treatment plants and outfalls are needed by many urban subdistricts and villages (39).

Most U.S.-affiliated islands are facing problems in ensuring safe water supplies and adequate sewage disposal. For example, reports from diving groups suggest that Truk lagoon is becoming so polluted that, unless waste disposal in the lagoon is minimized, divers may venture elsewhere in the future, reducing tourist income (39). In July 1982, sewage pollution in Truk lagoon activated a cholera outbreak leading to loss of life (8).

Although EPA is constructing outfalls and treatment facilities for domestic sewage on the islands, funds are inadequate for hookups to individual houses and businesses. Thus, sewage pollution remains a serious problem. Construction of sewage outfalls and treatment plants has been accomplished or is planned for Pohnpei, Kosrae, Yap island, and Falalop on Ulithi (Yap). Solid waste disposal and landfill management continue to be challenges (39). The need to manage wastewater discharges and solid waste disposal will continue to grow with the populations unless remedial actions and novel approaches which reduce construction and maintenance costs are identified and initiated.

Integrated Aquiculture/Wastewater Treatment Systems.—Seaweed or aquatic plant cultivation might also be used for water treatment (57,58). Aquatic plants effectively strip much of the nutrients from wastewater, thereby reducing eutrophication effects in the receiving water body (46). The use of aquatic plants for wastewater treatment has considerable potential for use in the tropics because of the stable environmental temperatures. Aquaculture systems for water treatment have been instituted in several areas of the continental United States (23,76) and this concept deserves more attention for application on the islands (56).

Land-Application of Sewage Sludge and Wastewater.—Treated wastewater is not now used for irrigation on the U.S.-affiliated islands. On St. Croix, use of a saltwater flush system in some areas makes wastewater too saline (47). However, wastewater blended with impounded runoff can be used for irrigation.

Some wastewater facilities plans in Puerto Rico call for the land disposal of some effluents via irrigation (34). However, there is declining interest in this since irrigation demand has diminished (47).

Adequately digested and disinfected sewage sludge could be valuable as a soil conditioner and fertilizer in many areas. On Guam, treated sludge is used to a very limited extent by local farmers. In other areas, cultural beliefs would have to be overcome and facilities constructed to yield safely treated sludge. An increasing concern is the extent to which heavy metals and toxic substances enter sewer systems and concentrate in sewage sludge (37). Only the Umatic/Merizo waste treatment facility on Guam employs land treatment on a relatively large-scale, but the success of this operation has been hampered by operating and maintenance difficulties. These, plus land availability and public acceptance constraints are major obstacles to land treatment of wastes.

Urban Forestry

Urban forests have a number of influences on the quality of the residential and urban environment in addition to contributing to an esthetically pleasing environment. Although little information exists on the effects of open-grown trees and 30 to 50 percent tree canopy cover applicable to urban forest situations (74), urban trees can reduce the kinetic energy of raindrops thus protecting parks, lawns, and unpaved roads and may help regulate water runoff. Trees shade buildings, thus reducing ambient air temperatures and, perhaps, reducing energy consumption by air-conditioners. On the other hand, trees can restrict air flow around buildings and reduce the cooling effect of wind on the buildings. Urban noise can be ameliorated by woody vegetation, which serves as a barrier to sound waves, and dense litter layers, which absorb sound (74).

Forests and forest soils in and around urban areas can serve as “sinks” for air pollutants such as carbon monoxide although, of course, they also can be a source of allergens. Urban forests also commonly are inhabited by birds, some of which are insectivorous and reduce insect populations perhaps reducing the need for pesticides. Finally, urban forests can serve

as a source of valuable woods. Urban and roadside trees that must be removed for other reasons supply much of the raw material for a small wood crafts and specialty furniture industry on St. Croix (USVI). This use of available wood could be a model for economic use of wood where large-scale commercial forestry is not feasible (92).

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