OKINAWA'S GREEN TECHNOLOGIES AND SUSTAINABLE DEVELOPMENT (DRAFT)

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ABSTRACT

Okinawa, Japan's only small island prefecture and the birthplace of nissology (the study of islands), shares all the characteristics of small, remote islands. Okinawa hosted the third (2003), fourth (2006) and the sixth (2002) Pacific Leaders Meetings (PALM) with 14 South Pacific island countries. PALM adopted "The Okinawa Initiative on Regional Development Strategies for a More Prosperous and Safer Pacific." (Kakazu, 2012-b, p.12) That initiative highlighted the important role of Okinawa in spearheading and coordinating development and educational relationships among the Pacific islands. Okinawa's situation, experience and issues could be useful in terms of developing appropriate models and technologies for sustainable island development.

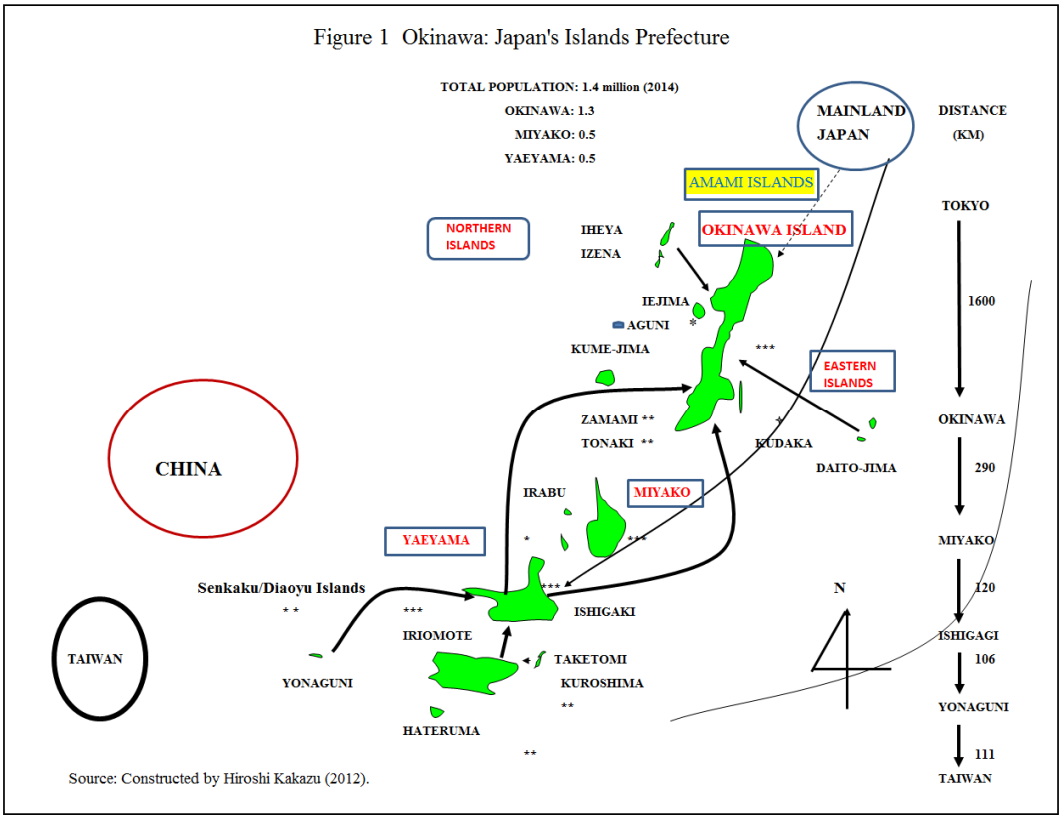
Okinawa has developed various subtropical and island-based green technologies and innovations which support Okinawa's 21st Century Plan. Technologies and innovations such as fruit fly eradication, the re-use and recycling of waste glass bottles, waste cooking oil, renewable energy, underground dams, utilization of deep ocean water, including OTEC, resource-based health foods, eco-tourism, and networking island communities. Any or all of which may be applied to the Pacific island countries with appropriate modifications.

OKINAWA'S GEOGRAPHYAND RECENT ECONOMIC DEVELOPMENT

Geography and Migration

Okinawa Prefecture is the only prefecture in Japan which consists of small islands. "Island" is defined as land area with the total coastal line of 0.01km and over. As of October 2013, there are 160 islands, of which 49 are inhabited including those connected with Okinawa Island by bridges and roads. These islands are scattered a distance of 1,000 km (622 miles) from east to west and 400 km (248 miles) from north to south. These islands consist of the Okinawa Island group, the Miyako Island group, the Yaeyama Island group, the Northern Islands group and the Eastern Islands group (Figure 1). The number of inhabited islands changes slightly every survey year due to emigration, migration and the construction of landbridges or reclaimed land roads which connect two separate islands.

Figure 1 Okinawa: Japan's Islands Prefecture



Okinawa Island, the main island of Okinawa Prefecture, accounted for 91% of Okinawa's total population in 2011, whereas the share was 83% in 1960. All the outlying island groups experienced depopulation from 1960-80, but in recent years, the Yaeyama Islands group recorded positive population growth. It is interesting to note, however, that both the Yaeyama and Miyako Island groups recorded net in-migration

from mainland Japan while simultaneously recording net out-migration to Okinawa Island. This relatively recent phenomenon is serving to slow down the speed of depopulation in these outlying remote islands.

The most frequently used tool to predict the flow of people, goods, or communication between any two places is probably the gravity model which is based on Newton's Law of Gravitation as follow:

(Population of region 1 x Population of region 2)/ (Distance between them)
or (GDP of region 1 x GDP of region 2)/ (Distance between them).

The above model shows that the relative strength of the bond between two regions is determined by multiplying the population (or GDP) of region 1 by the population (or GDP) of region 2 and then dividing the product by the distance between the two regions squared. Since the larger region attracts more people and goods than the smaller region, and with all other things being equal, the closer region has a greater attraction. This model has been particularly useful in explaining flows of trade and migration between two regions where the relatively free movement of goods and services including labor are guaranteed.

Actual estimations of migration flows between the regions (or islands) of Okinawa are made based on a logarithmic form as follow:

$$LogM_{ij} = \alpha_1 + \alpha_2 LogY_i Y_j + \alpha_3 LogD_{ij} + E_{ij},$$

where $M_{ij,}$ denotes migration from i region (or island) to j region (or island), is positively related to the size of GDP of the both regions denoted by $Y_i Y_j$, but negatively related to the distance between the two regions (D_{ij}). E_{ij} is an error term. Therefore, the expected signs of the parameters (α_1,α_2 and $\alpha_{3)}$ are:

$$\alpha_1,\alpha_2>0,\ \alpha_3<0.$$

The estimated results for the period of 1995-2000 based on a cross section of data are shown in Table 1. The parameters on migration from Okinawa to mainland Japan satisfy our assumptions and are significant at a 5% cut off value. It is noteworthy, however, that distance (D_{ij}) plays positive when it comes to migration from Yaeyama to Okinawa Island. That is to say, people from the distant islands of the Yaeyama region tend to migrate more to Okinawa Island. This can be explained by the ‘push’ and ‘pull’ factors between the two regions.

Persons from smaller, distant islands tend to migrate to more prosperous, larger

islands where social and economic opportunities are greater than in neighboring small islands. Of course, ease of transportation between these islands is also an important factor. The model confirms a frequently observed theory of “circular migration” among islands societies, though we certainly need to base it on more reliable data (Hugo, 2005; Kakazu, 1994).

Table 1: Net Migration among Major Island Groups in Okinawa: 1995-2000

	Mainland Japan	Overseas	Total
Okinawa			
in-migration	52,738	3,694	56,432
out-migration	58,657	0	58,627
net change	-5,919	3,694	-2,195

	Okinawa Island	Mainland Japan	Overseas	Total
Miyako				
in-migration	2,844	1,650	73	4,567
out-migration	3,204	1,537	0	4,741
net change	-360	113	73	-174
Yaeyama				
in-migration	2,647	2,758	111	5,516
out-migration	3,301	2,115	0	5,416
net change	-654	643	111	100

Source: Constructed from the Population Census, 2000.

Gravity Model (see Text)

$LogMij = \alpha 1 + \alpha 2 LogYiYj + \alpha 3 LogDij + Eij$

Migration from Okinawa to Mainland Japan

$LogMij = 0.23 + 0.76 LogYiYj - 0.39 LogDij$

(0.046) (2.61) (-0.690)

Migration from Yaeyama Islands to Okinawa Island

$LogMij = 0.12 + 0.56 LogYiYj + 0.46 LogDij$

(0.023) (0.52) (0.223)

Migration from Okinawa Island to Yaeyama Islands

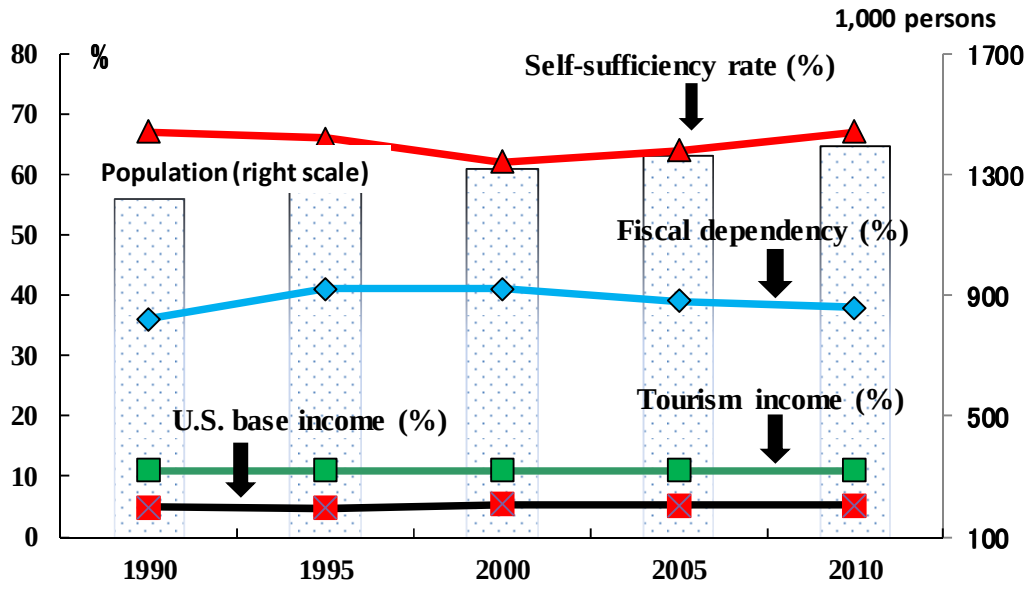
$LogMij = 0.54 + 0.89 LogYiYj - 0.41 LogDij$

(0.045) (2.86) (-0.78)

Main Development Indicators

One important indicator of economic performance is population growth which signifies economic dynamism, particularly in the Japanese regional context where almost all rural prefectures have experienced depopulation. Okinawa's population increased from 970,000 in 1972, the year Okinawa was returned to Japan, to 1.4 million in 2010 (Figure 2). Okinawa is the only prefecture, which has more than doubled its population in the period since WW ll. Okinawa has experienced very unique patterns of population growth in recent years. The social change (net migration) turned from negative to positive since 2009. This means that Okinawa has attracted more in-migration, mostly mainlanders than its out-migration. This is particularly true after the 3.11 Great East Japan Earthquake.

Figure 2 Okinawa's Main Development Indicators, 1990～2010



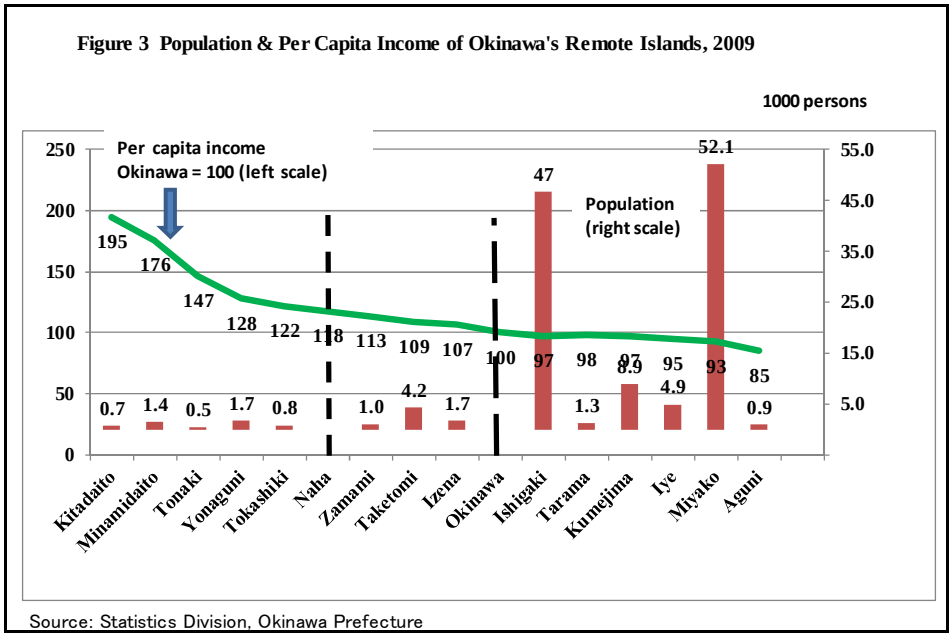
Notes: Self-sufficiency rate = 1 - (Exports/Total demand, %)
Dependency rate and incomes are % of GDP.
Sources: Constructed from the *Okinawa Statistical Yearbook* , various issues.

A rapid population increase, accompanied by a proportionally larger labor force, has generated a continuous labor surplus in Okinawa's job market. Over the post-reversion period, the labor force has increased by 2.3% annually. Although local employment has also increased by 2% annually during the period, it has not been enough to absorb the increased labor force. Consequently, the jobless rate jumped from 3% in 1972 to about 7%-8% in recent years, which is twice as high as Japan proper. The creation of jobs has been the most important economic and political agenda in Okinawa since reversion.

During the post-reversion period (1972-2010), Okinawa's real GPP has grown on average by 4.8% annually. This has been supported mainly by public expenditures, accounting for about 30% of GPP, followed by income generated from tourism (10%), and the U.S. military base expenditures (5%) (Figure.2). With a higher growth rate than Japan proper, Okinawa's per capita income (PCI) increased from $1,877 or 58% of the national Japanese average to $24,955 or76% of the national average in 2010. Clearly, a pronounced disparity between Okinawa and Japan proper exists in the area of PCI, yet in terms of nominal U.S. dollar, Okinawa’s PCI is comparable to the average PCI of the OECD member countries which consist of world’s 34 advanced industrial countries. One important indicator of Okinawa's high quality life style is demonstrated by the well-publicized longevity of Okinawans. The average life expectancy of women in Okinawa is 86 years, the highest in the world.

As we have seen already, almost all Okinawa's small, remote islands have experienced depopulation in the past decades. It should be noted, however, that the size of population or economic scale (GDP) is not directly related to the level of per capita income. Kitadaito and Minamidaito (The Eastern islands group) with population less than 2,000 proud of the highest per capita income in all Okinawa's municipal governments followed by Tonaki, Yonaguni, Tokashiki, Zamami, Taketomi and Izena (Figure 3).

The Eastern islands group has recorded top per capita incomes for many years because of their large-scale sugarcane production. It is interesting to note that per capita incomes of these eight "micro" and remote islands are higher than the average per capita income of Okinawa Prefecture and Naha City, the largest municipality in Okinawa by any measures. High per capita incomes of Tonaki, Yonaguni, Tokashiki, Taketomi and Zamami are due largely to the expansion of tourism and tourism-related industries which promoted the islands' industrial structure from a low income primary industry to a high income tertiary industry centered on tourism (Kakazu, 2011). This suggests that the tourism industry is the main engine to sustain both population and standards of living on small, remote islands.



It should be noted, however, that the increasing number of tourists beyond islands' carrying capacity has adversely impacted on islands' fragile environments and daily life. Zamami Island, for example, has been suffering from extreme shortage of drinking water due to a surge of tourist scuba-divers in recent years (Kakazu, 2012-a). The island

accommodated about 90,000 tourists which are nearly 100 times of the island's total population. In addition to water shortage, the Zamami local government has been facing a financial crisis to deal with the increasing demand for public services including waste disposals and preserving public facilities. The islands' most important tourism resource, namely world-renowned coral reefs haves been on the verge of extinction due largely to global warming and various construction and tourism activities. Although the Zamami and other islands' authorities are considering a visitors tax in order to support the basic resources to sustain its tourism, it is an urgent task for tourism dependent island economies to determine the "carrying capacity" of tourists' absorption for sustainable development.

The structure of the Okinawan economy is very similar to that of Hawaii. In both cases, the service industry dominates economic activities. Agriculture, which was the dominant industry during the 1950s, now accounts for only 5.2% in terms of labor force and 1.8% in terms of income (Table 2). Empirical law discovered by Kuzunets (1965) and Oshisma (1965) suggeststhat the agricultural sector tends to generate low incomes in part because of the low income elasticity of its products as a whole compared to those of other sectors; as the cost of producing farm products falls with technological progress, prices tend to fall as well. Moreover, the skills required for traditional agricultural production are fewer and do not demand extensive higher education. Okinawa has followed this pattern more than any of Japan's other prefectures.

Table 2: Okinawa's Changes in Industrial Structure, 1972-2011
(% of Total Employment)

	OKINAWA					JAPAN	
	1972	1982	1992	2011	(2009)	2010	(2009)
Primary industry	18.1	13.2	9.6	5.2	(1.8)	4	(1.2)
Secondary industry	20.9	20.2	20.2	15.5	(12.9)	24.8	(23.7)
Manufacturing	9.1	6.7	6.7	5.0	(4.1)	16.8	(17.8)
Construction	11.8	13.2	13.5	10.5	(8.6)	8	(5.8)
Tertiary industry	61.0	66.6	69.8	79.0	(88.8)	70.2	(75.2)
Trade	25.0	28.7	28.2	20.8	(28.6)	21.3	(31.0)
Services	24.5	23.1	28.8	36.2	(46.2)	30	(31.3)
Others	11.5	14.8	12.8	18.3	(17.6)	18.9	(12.9)

Notes: "Trade" includes wholesale and retail trade, finance, insurance and real estate. Data in parentheses are GPP shares. "Services" includes private and public services.

Source: Statistics Bureau, Management and Coordination Agency

Although Okinawa's agriculture has been diversifying away from traditional sugarcane and pineapple cultivation to flowers and vegetables, such as chrysanthemums, orchids and *goya* (bitter melon), and tropical fruits such as mangoes, citrus and dragon fruit,the relative contribution to Okinawa's GPP may continue to decline in the future as a result of increasing international competition, stagnated productivity gains, and aging farm workers.

The share of manufacturing income declined sharply from 9.1% of GPP in 1972 to 4.1% in 2009. There is a consensus amongst policy makers and researchers that the development of a large-scale manufacturing industry in Okinawa is simply not viable, either now or in the future. Okinawa’s local markets are small, fragmented and far away from major markets; wage and rental rates are far higher than those in neighboring Asian countries; and the level of human resources and technology development are low. Although Okinawa's standards of living, in terms of per capita income and the level of infrastructure, have improved remarkably during the post-reversion periods, the economy's capacity and capabilities to transform itself from a dependency structure towards greater self-reliance, that is to say, financing its mounting trade deficits through internally generated incomes, have not been achieved successfully.

Key amongst the still unresolved problems of the Okinawan economy are: rising under-and unemployment, heavy reliance on government and U.S. base expenditures as major sources of income and employment, reliance on a limited number of primary products and tourism for export earnings, chronic external trade deficits, diseconomies of scale and high transportation costs, environmental degradation, notably air and water pollution and the widening income gap among households and regions.

Major Development Constraints

In Okinawa, There are also possible supply constraints with public utilities such as water and electricity which have increased more than Okinawa's economic growth rate since reversion. Although a severe water shortage has not occurred in recent years, the water supply is precariously dependent on rainwater. Recent severe water shortages in the Zamami Islands, one of the most popular tourist destinations in Okinawa, indicates that there is a potential risk to island tourism arising from water supply which is the most important lifeline for isolated, small islands (Kakazu, 2011).

The major problem with electricity supply is the relatively high cost of power generation because of the existence of only small-scale, isolated operations compared to mainland Japanese companies where electricity can be mutually traded during peak demand seasons. Okinawa is not only far removed from the mainland market, but there are also about thirty very small, remote islands within the archipelago of Okinawa which make power generation a costly and risky operation.

In addition to the increasing demand for water and energy resources as the population and the number of tourists increase, the economy's carrying capacity and environmental disruptions will become serious constraints on future development. It is particularly serious for Okinawa where tourism, which depends on clean, sandy beaches, is the most important engine of the economy. There is already good evidence that Okinawa's world-renowned coral reefs are on the verge of extinction due largely to global warming, overfishing, redsoil errosion and various construction activities. It is particularly important to assess whether or not Okinawa's small, environmentally fragile islands can sustain their ever-increasing de facto population given their extremely limited capacity of renewable as well as non-renewable resources. Therefore, capacity as well as capability building towards sustainable island development are crucial for Okinawa's 21st century plan which covers from 2012 to 2021.

OKINAWA'S GREEN TECHNOLOGIES AND INNOVATIONS

What is Green Technology?

According to the Oxford Dictionary of English, green technology is defined as "technology whose use is intended to mitigate or reverse the effects of human activity on the environment." Green technology is also called "sustainable technology", "alternative technology", "clean technology", and "zero-emission technology". The concept of green technology has rapidly spread after the concept of "sustainable development" which was defined in the Brundtland Report (1987, p.5) as follows:

"A process of change in which the exploitation of resources, the direction of investment, the orientation of technological development, and institutional change are all in harmony and enhance both current and future potential to meet human needs and aspiration."

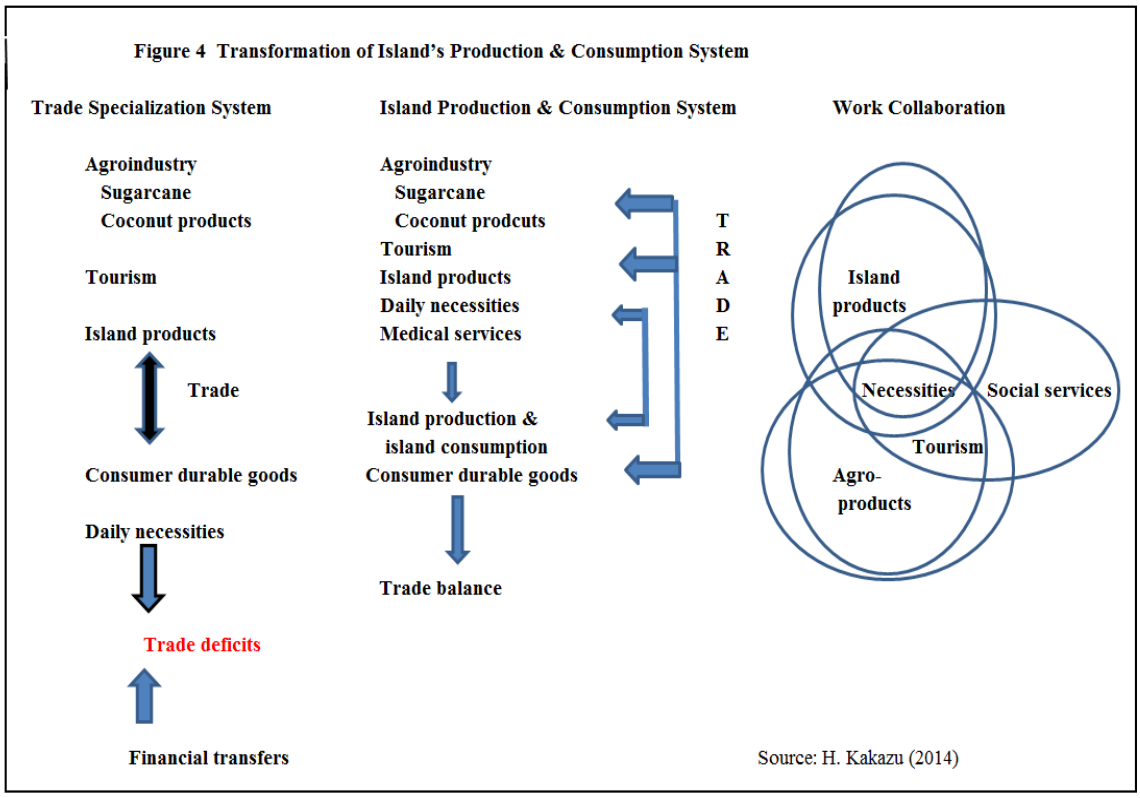
Green technology aims to find ways to create new technologies in such a way that they do not damage or deplete the planets natural resources. It also has to be environmentally friendly to all living creatures as well as the planet. Green technology includes both production, or process technologies and the use or management of such technologies.

Island's green technology and innovation needs to be differentiated from large-scale technology as is illustrated in Figure 4. Technologies and innovations appropriate to small, isolated islands should meet the following three principles for their sustainable development:

(1) They should be small scale as to make full use of island resources.

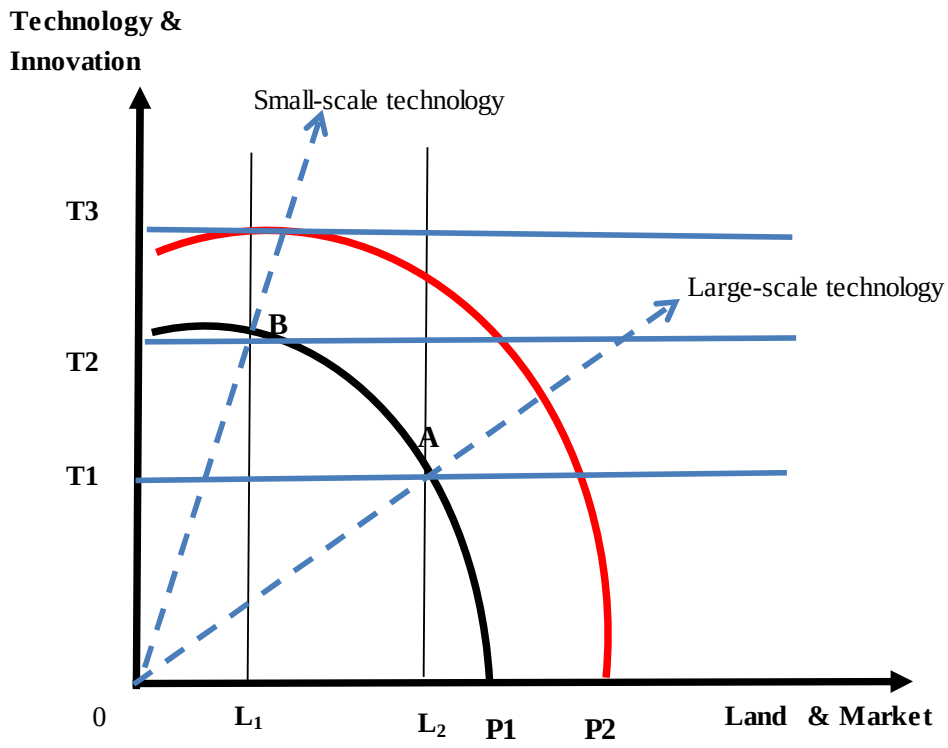
(2) They should be effective to “displace or replace imports”, namely substituting island products for what they are now importing such as vegetables, egg, rice, canned fish, soft drinks and various products which can be produced by modifying island traditional technologies.
(3) They should meet the island’s “safe-minimum self-sufficiency” rate for food security. Such a rate might be derived from a minimum caloric requirement for survival of the population on the island (Kakazu, 1994).
(4) They should be “green technologies” as defined above.

In order to meet the above principles, island’s production and consumption system must be transformed from a current trade specialization system, or import dependency regime or to a system of island production and consumption, as is illustrated in Figure 7. Under the current production and consumption systems, islands tend to specialize in a few products or services such as tourism, remittances and offshore business to finance an increasing demand for imports. The new system is to meet basic human needs through production and consumption using full use of island resources. Of course, each island has to develop export products or services to import capital or consumer durable goods such as heavy machinery, automobiles and electric appliances which cannot be produced in the island. This island model is being experimented in Okinawa’s Kumejima.



In order to facilitate Island's production and consumption transformation depicted in Figure 7, technologies and innovations should be based on the three Rs (reduce, recycling and reuse) principle with a collaborative community system. In Figure 8, P1 designates usual production possibility curves. Increase in productivity induced by technological innovations will push the production frontier to P2 beyond the constraints of land and market. In order to achieve the same level of production, a small island economy has to find a technology which is appropriate to its market and available resources both human and nonhuman. As a result, an island economy adopts a small-scale technology, which is more technology and land incentive compared to a large-scale economy (Kakazu, 2014).

Figure 5 A Concept of Island Technology & Innovation



Source: H. Kakazu (2014)

Okinawa's Island-based Technologies and Innovations

Okinawa has developed various subtropical and island-based niche technologies and innovations which support Okinawa's 21st Century Vision Plan. Some important ones are listed in Table 3.

Some important green technologies listed in Table 3 are highlighted.

Table 3 Green Technologies & Know-how Developed & Applied in Okinawa

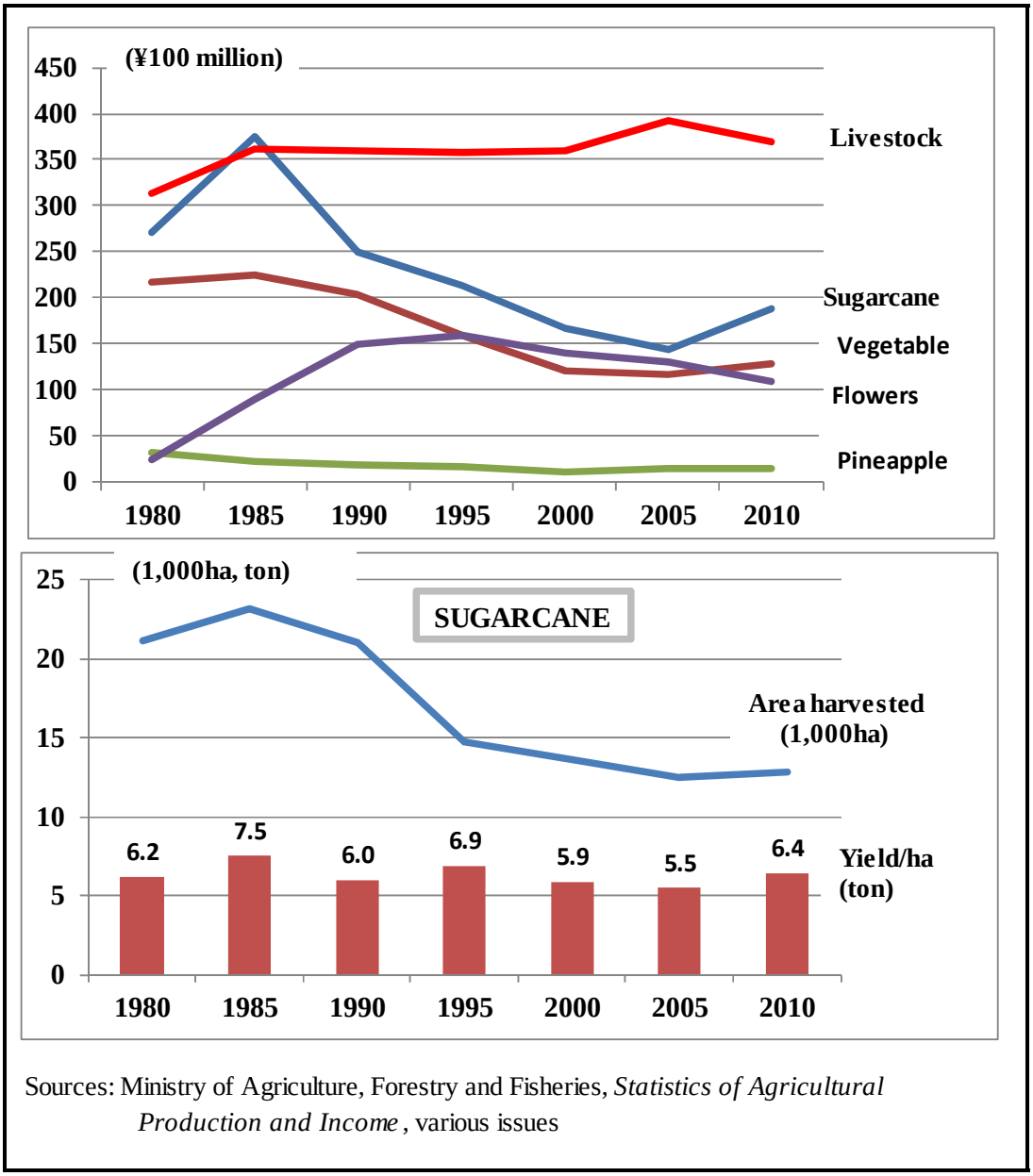
Subtropical Base	Island Base
Fruit fly and sweetpotato weevil eradication	Health & longevity (heath foods, reflexology, kariyushi-wear
Tropical fruits & vegetables mango, orange, papaya, goya, mozuku seaweed	Transportation, communication & waste disposal systems (monorail)
Tropical flowers (chrysanthemum, orchid)	Water resources management underground dam multi-purpose dam desalination plants water tanks
Sugarcane cultivation	Energies wind power solar ethanol biodiesel
Aquaculture and payao (artificial fishing nests)	Coastal Sea Conservation soil erosion prevention & monitoring, GIS
Deep-sea water utilization aquaculture, industrial use, OTEC, etc.	ITC technology call centers back office data center banking distance learning
Environmental conservations coral reef conservation mangrove disaster management (typhoon)	Community development uimaru (mutual help), moai
Grassroots public health and hygiene medical support info. system for remote islands	
Subtropical & eco-tourism medical tourism, destination-based tourism	
3R (waste bottle recycling, biodiesel, waste morasses)	
Studies on tropical biodiversity & longevity	
Amicable environments for education & training (i.e., JICA International Center, LEAD Program)	

Source: Kakazu (2012)

Ago-industry

Local resource-oriented agro-industry or "the sixth industry," which is a concept of a consolidated package of agriculture, processing agricultural products and sales, is one promising area for further development. Of Okinawa's agro-resources, sugarcane has been the most important cash crop, accounting for about 20% of all farm incomes and 50% of cultivated land. Incomes from sugarcane production, however, have declined significantly in recent years as a result of stagnant prices and productivity as well as increased international competition (Figure 6).

Figure 6 Okinawa's Agricultural Production, 1980-2010



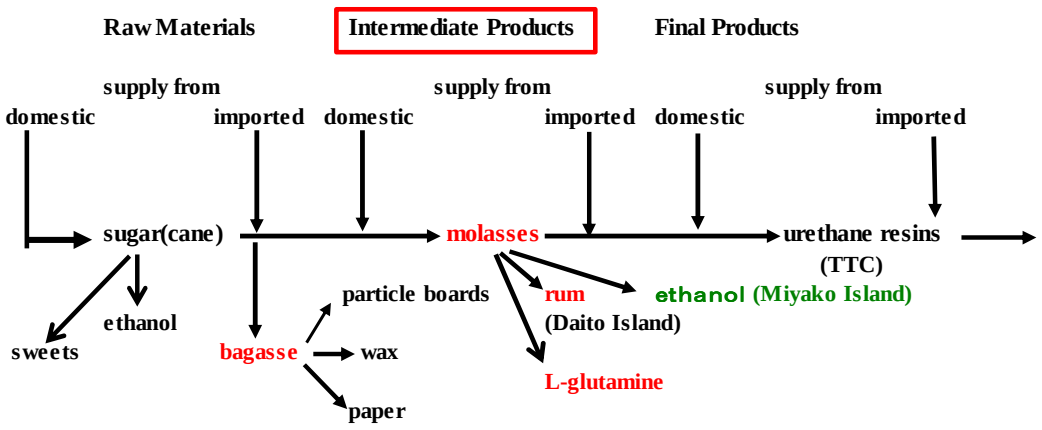
Sources: Ministry of Agriculture, Forestry and Fisheries, *Statistics of Agricultural Production and Income*, various issues

The farm gate price of sugarcane, on average, was 21,661 yen ($250) per ton for the 2011 crop year, which was about four times higher than the price per ton in Thailand. Moreover, the per-hectare planted land productivityof sugarcane has remained unchanged for decades. Okinawa's sugar industry is only surviving through the government's price support programs. These indicators demonstrate that Okinawa's sugarcane cultivation will be diminished in the future, even under heavy government subsidy. Because of the declining trend of sugarcane cultivation, Okinawa's uncultivated farm land has been expanding, particularly on Okinawa Island. Sugarcane, however, is the only cash product in many small, remote islands. Therefore, some kind

of compensation scheme, such as direct income provision, may be needed to obtain a consensus for pursuing Japan's possible entry into theTPP.

We should note here that Okinawa's traditional, declining sugarcane has been revalued in recent years because of its high-valued alternative use (Figure 7). Sugar-related inputs such as molasses and bagasse, which in turn can be transformed into urethane resins, particle boards, rum, wax, paper products, sweets and recently ethanol, have been pursued at many remote islands and local research institutes (Kakazu, 2011-b).

Figure 7 Diversification of Sugarcane Products in Okinawa



Note: TTC = Tropical Technology Center originally developed urethane resins from molasses.
Source: Kakazu, H. (2009)

The urethane products, which were developed by the Tropical Technology Center (TTC) in Okinawa, have an enormous potential for a wide-range of products from pet bottles to home and industrial appliances. These products are decomposable (biodegradable) and therefore can be substituted for environmentally hazardous plastic products if quality and prices are reasonably acceptable to users and consumers.

Miyako Island, which is a major producer of sugarcane, has been designated by the national government to produce ethanol for fuel. Islanders are hoping to substitute this renewable and environmentally friendly fuel for gasoline in the future (Uehara, 2014). L-glutamine can also be produced from sugar molasses. Dr. Yutaka Niihara, a hematologist and a former professor at the UCLA Medical School, patented L-glutamine therapy for the treatment of sickle cell disease. It is also used in dietary supplements and is claimed to be useful for a variety of different conditions such as

depression, anxiety and insomnia.

Pineapple production, another important traditional cash crop in Okinawa, has declined more rapidly than sugarcane for similar reasons. Only fresh pineapple and pineapple wine are holding their own, and this as a result of tourists' consumption. It is an urgent task for the local government to diversify from sugarcane-centered monocultural agriculture into high value-added agro-industry and other diversified cash crops such as flowers, health foods, tropical fruits, vegetables and livestock.

For the successful development of these resource-based products, several problems must be resolved. One important factor is the size of the market, which in turn, determines the cost of production. As can be typically seen in the case of integrated circuits, the initial unit cost of production is very high. But as the market expands, the cost is reduced approximately to one-half within a decade. Products such as urethane resins require a large segment of the market in order to compete with plastic products.

The second important consideration is “cost escalation,” which will quite often accompany when local resources are used as raw materials or intermediate inputs. The price of Okinawan sugar, for example, is about four times higher than the international price because of government protection. High sugar cost means high costs for molasses and consequently for the production of urethane resins. Here the producers of urethane resins face a dilemma because they are obliged to import molasses in order to compete in the international market.

The third important consideration is a stable supply of raw and intermediate materials with competitive price and quality standards. It's easier said than done. Despite growing uncultivated agricultural lands, Okinawa has supplied only a 40% of its vegetable demand, the rest has been imported due partly to occasional typhoon visits.

It is important to realize that in order to diversify local products toward more value-added products, domestically produced raw materials must be available at international prices. Unless there are incentives such as subsidies and taxes, which will compensate for the cost disadvantage during the initial stages of production, an Okinawan producer of urethane resins would always choose imported molasses over the costly local alternative. Okinawa’s molasses have price competitiveness at the moment simply because there is not much demand for them.

Health Foods and Longevity

Okinawa is fast becoming a brand name connoting "health and longevity." Okinawa's longevity is the product of a complex combination of climate, culture, closely-knit social organizations, foods, and lifestyles. Greek physician Hippocrates said “let food be your medicine,” so food is considered to be the most important factor influencing

longevity. “There is certainly strong evidence that some of the compounds in the herbs and medicinal plants regularly consumed by Okinawans have powerful antioxidant and positive hormonal effects, and few ill effects have been associated with using them as foods, condiments, spices, teas, or home remedies“ (Willcox, Willcox and Suzuki2001).

Okinawans are accustomed to consuming less salty, mineral-rich foods than mainland Japanese. Okinawa has developed and marketed various health foods such as turmeric *(ukon*), bitter melon (*goya* or *nigauri*) products, naturally processed salt, sea vegetable products (*mozuku*, *umibudo*), ostrich meat, and various deep-sea water products to name a few well-known examples. Sales of these health foods have jumped from ¥2 billion in 1995 to over ¥20 billion in 2004, but declined thereafter due largely to intense keen competition. The sales of health foods exceeded the sales of sugar, the most important agricultural cash crop in Okinawa for many years (Table 3). Sales of health foods have been buoyed by increased attention to Okinawa’s world-renowned longevity, but also by enhanced health-consciousness among Japan’s aging population.
Health foods possess comparative advantages in the uniqueness of resource use and technology which can be developed on a small scale basis. Furthermore, these products usually require more local inputs, including raw materials and labor, than conventional trading products. The OPG has been promoting “one island, one health food” because each island has its unique medicinal plants and herbs. Of course, there has been keen competition in recent years among health food producers.

Table 4 Okinawa's Main Health-realted Products

Salt

Okinawa islands are blessed with unlimited marine resoureces Seawater is one of them. Using this resource, many islands produce fine, rich, expensive salt products for exports. A unique crystallizaton process was developed in Miyagi Island.

Mozuku

Mozuku, a alga-like seawood, has been consumed extensively in Japan a delicacy served in a venegary sause as well as a helth food. Okinawa is a major suppier of mozuku from which "fucoidan, " cancer fighting mecicine is extracted.

Goya

"Goya" (bitter melon) is the best known Okinawan vegitable which has been used for a favorate Okinawan dish as well as juice, tea and the treatment of fever, infections and various other deseases. Fresh goya is Okinawa's major agri-export product.

Ukon

"Ukon," (turmeric) is the ginger family. It has been one of the Okinawa's favorate herbs for many years. The most popular use of turmeric is as a a curry spice. Turmeric has been used for medicinal purposes, particularly for treatment of hepatits and icancer.

Flat Lemon

Flat lemon (shekwasha) is a green citrus fruit, rich in flvonoids and native to Okinawa and Taiwan. The fruit is very sour, and it is often used like lemon but is also used to make jam, or a yellow juice. The fruits became very popular in Japan as a helth food because of its tumor sppression effect.

Acerola

Acerola (Barbados cherry) ia a tropical fruit-bearing shrub native to tropical America. The fruit It is known for its extremely rich in vitamin C, almost as much as camu camu. It is used to make juice and cosmetics. Motobu in Okinawa is a major producer in Japan.

Peucedanum

Peucedanum（choumeiso or botanboufuu) is a plant of perennial parsley family. The plant is self-fertile, and it grows thickly in the costal area. Yonaguni Island is the most popular place for its various health and cosmetic products.

Purple yam

Purple yam (beni-imo) is a family of yam with deep red color. Okinawa's confectionery shop called "Porsche" created mouth-puckering sweet tarts, cakes, ice cream and cookies made from the yam. These products became Okinawa's best selling souvenir.

Mango

Mango is a sumac family tree, native to Asia. Mango fruit is called "The king of the fruits" with nutritionally rich unique flavor and heath promoting qualities. Particularly mangos from Miyako Island are popular with high prices.

Shell ginger

Shell ginger (sannin in Okinawa) is a perennial species of ginger, native to East Asia. Its leaves are used as herbal tea, flavor noodles and wrap rice cakes and traditional medicine. Because of its antiulcerogenic and antioxidant properties, cosmetics and medicinal products are made.

Aloe Vera

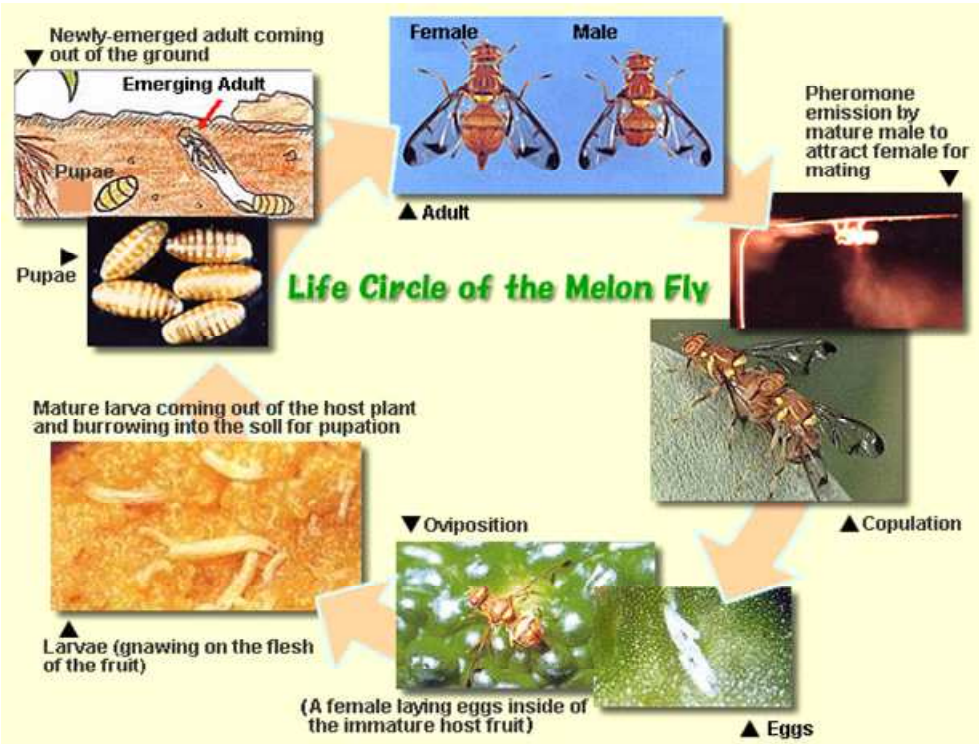
Aloe Vera is the lily family (Liliaceae) which also includes garlic and onions, native to Africa. Aloe produces two substances, gel and latex, which are used for medicines for fever, itching, inflammation, stomach ulcers and other treatments. Miyako Island is a home of various aloe products.

Sources: Translated from various sources, including Organization for Small and Medium Enterprises and Regional Innovation (SMRJ)

The Melon Fly Eradication

The melon fly had been a major pest species that damaged Okinawa's major agricultural products (Figure 8). The melon fly eradication project in Okinawa by the sterile insect technique (SIT) method was successfully completed on Kume Island in 1978, followed by the Miyako Islands in 1987, the Okinawa Islands in 1990, and the Yayeyama Islands in 1993 (see detail discussions in Kakazu, 2012-b). The total project costs during the eradication period amounted to ¥17billion ($70m), utilizing 320,000 man-hours. The SIT eradication method was not only the best strategy in Okinawa, where islands are relatively small and isolated, but also the method maximizes the project benefits in the long run, say after eight years, despite the high initial costs. After the complete eradication of melon fly, Okinawa became the "Fly Free Zone," and Okinawa could export fresh agricultural products such as bitter melon, mango, cucumber and other agricultural products to mainland Japan.

Figure 8: Life Cycle of the Melon Fly

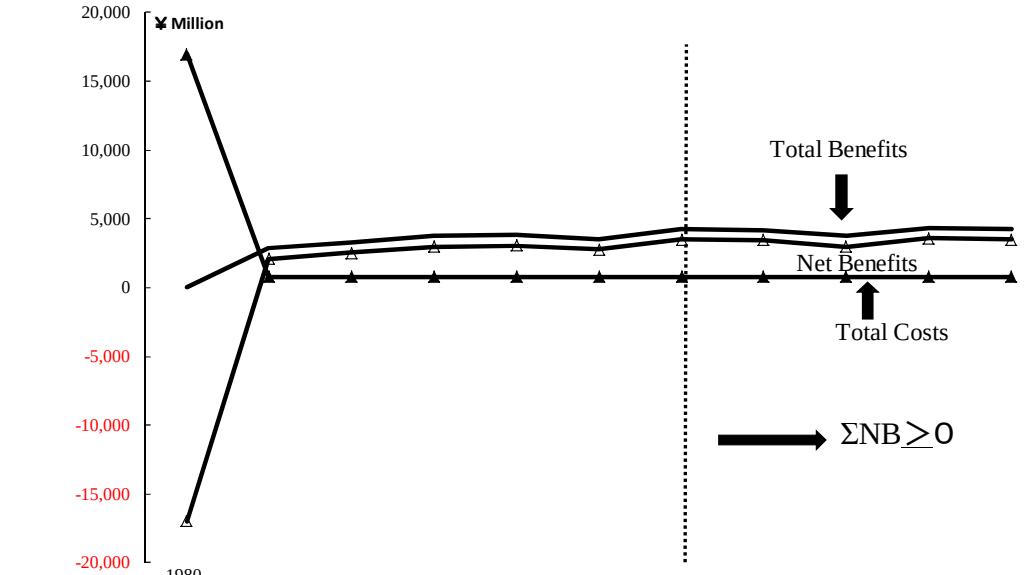


Source: (Kakazu, 2012)

After the completion of the eradication project, this author conducted a cost-benefit analysis for 1990-2000 (details can be found in Kakazu, 2012-b). In calculating the net present value (NPV) of the project, we used real discount rate of 3.26% during the

period. The rate is an average yield of 10-year national bond during the 1990s. We are assuming that the relatively high opportunity cost of capital in the construction period of the 1980s should be refinanced by the relatively cheap capital cost in the 1990s if the project was carried out on a commercial basis. As a matter of fact, the project was totally financed through public funds without having to worrying about cost recovery. As noted, the project pays for itself (self-liquidating) in 1998 with ΣNPV roughly equals to the total project costs of $172 million (Figure 9). Therefore, we can conclude here that the decision to implement the eradication project is well justified even from the standpoint of commercial basis.

Figure 9: Net Benefits (NB) of the Melon Fly Eradication Project in Okinawa: 1980-2000



	1980-1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Total Benefits	0	2,858	3,291	3,739	3,835	3,525	4,251	4,210	3,740	4,330	4,277
Total Costs	16,984	765	765	765	765	765	765	765	765	765	765
Net Benefits	-16,984	2,093	2,526	2,974	3,070	2,760	3,486	3,445	2,975	3,565	3,512

Note: Assuming zero discount rate, or zero opportunity cost of capital investment, the project produced net accumulated benefits after 6 years (1966) as indicated by the dotted vertical line.
Source: Kakazu (2002), Chapter 6, pp.145-162.

We should be reminded, however, that the net benefits estimated in this study are those arising from the commercial shipments of melon fly host products. So that if we include environmental and preventive benefits such as pesticide-free farming, preservation of the natural enemies, and above all preventing the insect pests from further spreading into mainland Japan, the net private as well as social benefits far exceed the estimated commercial benefits. But because of time and data constraints, we could not estimate the indirect social benefits.

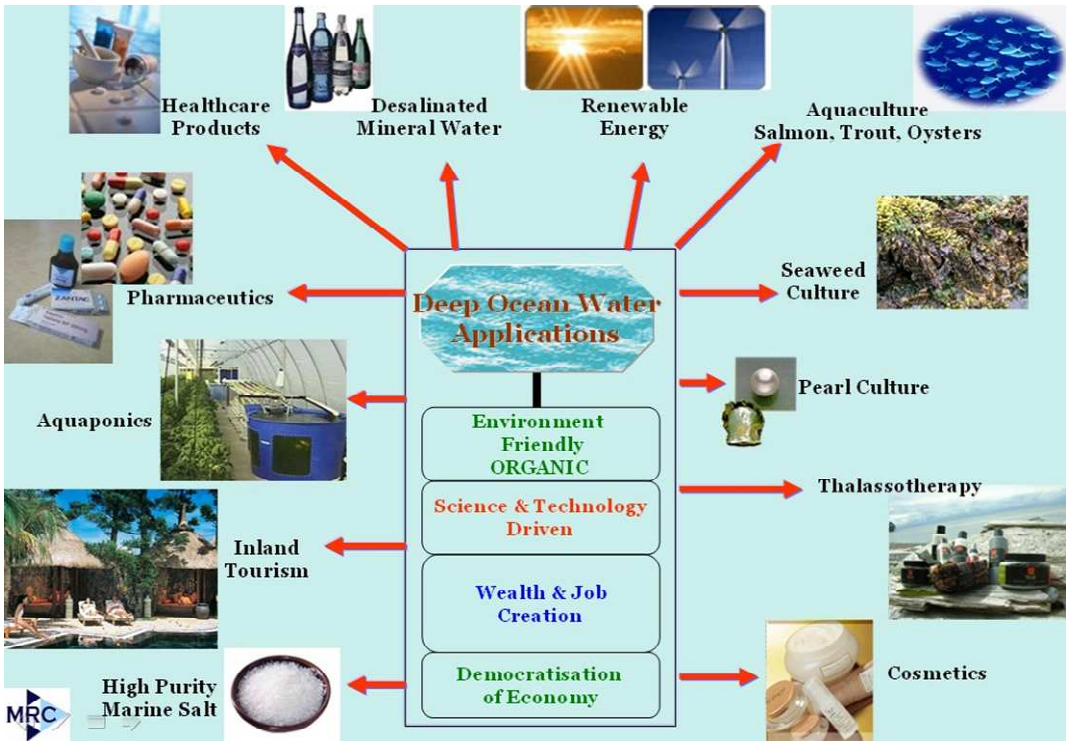
Any success story is accompanied by a great deal of painstaking effort, both in research and development as well as massive mobilization of human and capital resources. Most important, avid supports of the local people and public organizations, including the prefectural and central governments, were an integral part of the success story. The story probably contains more than it was told. Although continuous efforts to fight against potential intrusion of the insects are vital, the technological know-how and strategies for the success will be transferred successfully to infested areas worldwide, particularly to those Pacific islands.

Deep Ocean Water Applications

Deep ocean water refers to seawater offshore past the continental shelf that is too deep (about 200 meters deep) to be reached by sunlight. It is characterized in its low-temperature stability, inorganic nutrient richness and purity. Oceanic deep water is one of the advantageous resources for island regions. The largest deep-sea water facility in Japan located in Okinawa's Kumejima Island was completed in June 2000 with a total cost of about ￥6 billion. Two water pipes are used to pump up cold water of 13,000 tons per day from 612 meters deep (Kumejima Town, 2013).

Water with about 10℃ will be utilized to cultivate sea vegetable, prawn, giant clam, puffer (fugu), abalone, sea-grape and pearl, to make cosmetic and pharmaceutical products, to promote thalassotherapie (water treatment), and for various other purposes (Figure10).

Figure 10: Kumejima's Deep Ocean Water Applications



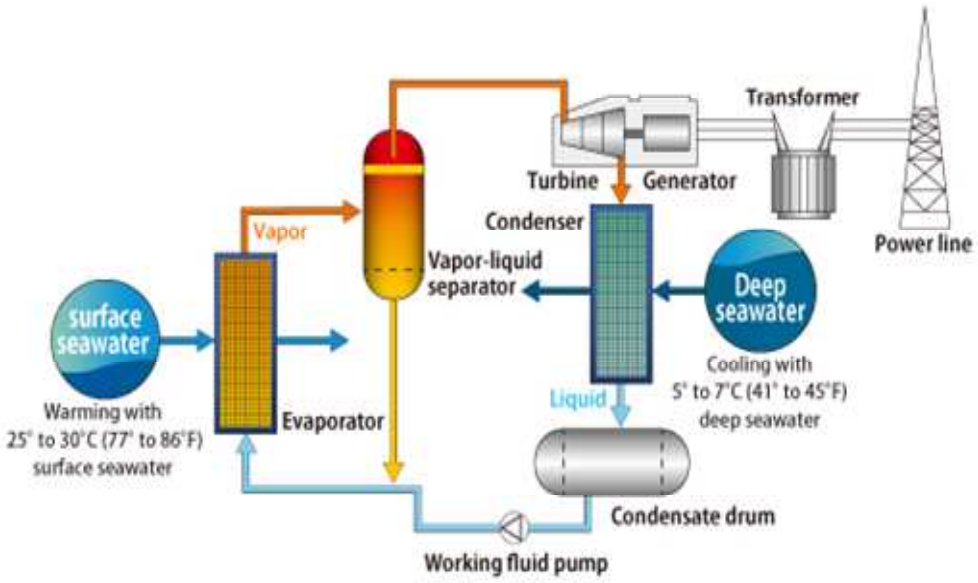
Source: Kumejima Town (2013)

Deep ocean water can also be utilized to generate electricity (OTEC : Ocean Thermal Energy Conversion). The Okinawa prefectural government initiated and funded the construction of an OTEC pilot plant on Kumejima Island in 2013. The plant demonstrates the cost effectiveness and commercial feasibility of the OTEC process by constructing 1.25MW OTEC power capacity. This would supply 10,600 MW of electricity per year, which accounts for 10% of Kumejima's total annual consumption. This would supply 10,600 MW of electricity per based on 1.25MW capacity is currently estimated as ¥25 which is lower than solar power, but higher than wind power as is discussed later.

An OTEC system is comprised of components such as an evaporator, condenser, turbine, generator, and pump (Figure 11). This system utilizes the temperature difference between warm surface seawater and deep seawater (taken from depths of 600 to 1000 meters) to generate electricity. This is done using a working fluid with the low boiling point that vaporizes as the result of heat transfer from the warm surface seawater in the evaporator.The vapor drives the turbine, which in turn drives a generator to produce electricity. The vapor then is passed through the condenser, where the

transfer of heat energy to the cold seawater returns the vapor to a liquid state.

Figure 11: OTEC Pilot Plant in Kumijima Island

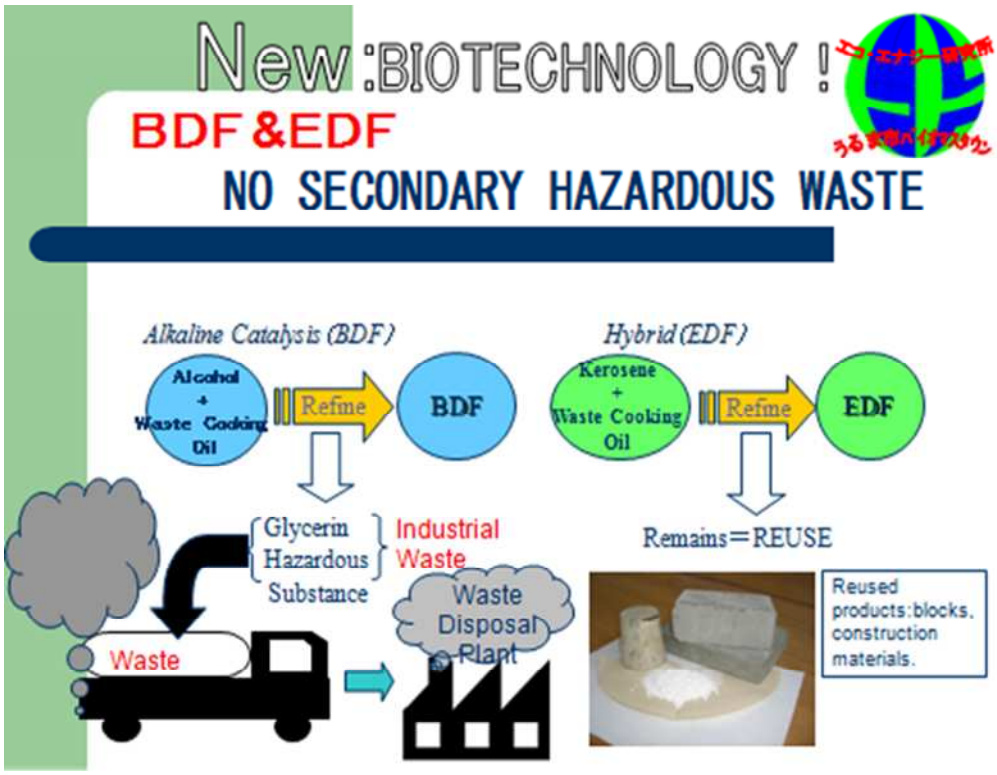


Source: Same as Fig.10.

Biomass

Production of diesel oil from used cooking oil is also a useful technology not only for island regions but also for other island countries. A plant of so-called Eco-Diesel Fuel (EDF) is constructed with relatively inexpensive cost (Figure 12). The price of the smallest EDF plant is around US$ 130,000 according Mr. Nakamura, President of Eco-Energy Institute. Mr. Keijio Bien, Public Works Minister of the Republic of the Marshall Islands, visited the Eco-Energy Institute to introduced this technology to his country where their abundant coconut resources can easily be converted into EDF (Ryukyu Shimpo, 2009).

Figure 12 : Biomass: Eco-Diesel Fuel (EDF)



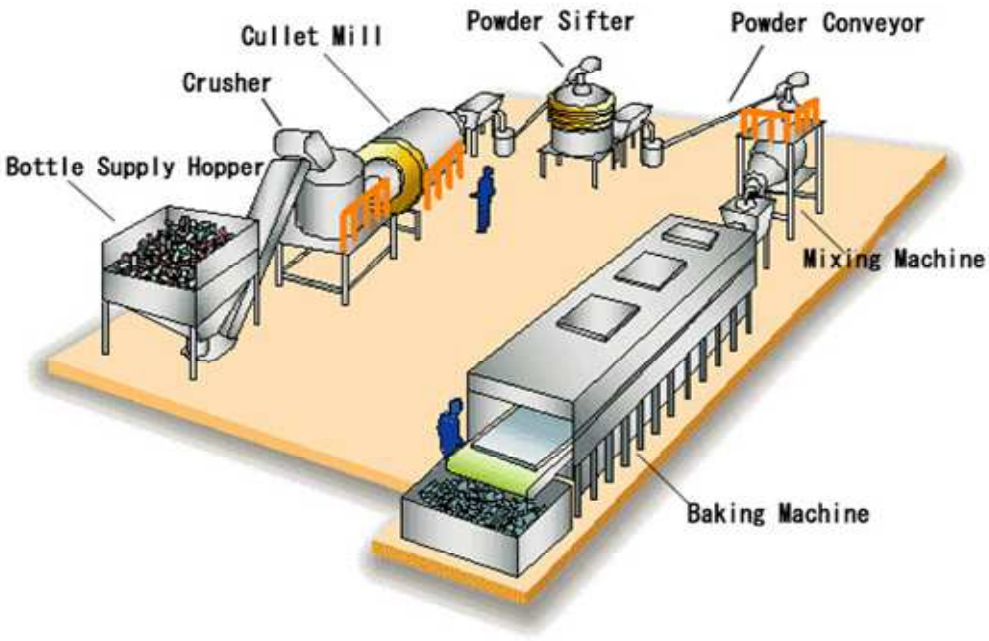
Source: Kakazu (2010)

Waste Glass Bottle Recycling

Waste bottle recycling technology was developed by an Okinawan private company.Waste disposal is a pressing issue for many Pacific islands. Reduce, recycle and reuse (3Rs) are the key words to address this problem. The Waste-Glass Recycling Plant consists of 9 machine units, a bottle supply hopper, a bottle conveyor, a crusher, a cullet mill, powder conveyors, a powder sifter, a mixing machine, a baking machine and a Supersol sizer; and automatic control panels (Figure 13). The bottle supply hopper can hold about 4.5 m^3 of waste glass, which is crushed into cullet of less than 6 mm in size by the crusher. The cullet is then milled into glass powder. The glass powder is sent to the powder sifter, which removes foreign objects and powder grains that are not of a specified size. The mixing machine mixes glass powder, and continuously sends the resulting powder mixture to the baking machine. Most conventional glass recycling machines crushes glass only into cullet. The resulting cullet is used for making glass again if it is transparent or brown. More than 70% of

these machines have originally been developed and patented by Trim, an Okinawan company.

Figure 13: Production Stages and Machine Units



Source: Trim Company (2012)

Powder mixture produced by the mixing machine is baked to make a light porous foamed material, or Supersol which has a wide range of application, such as a light embanking material in civil engineering, a culture medium or an inorganic soil amendment in horticulture and agriculture, a purification material in water purification and an insulator in architecture (Figure 14). It is now used in various areas for various purposes.

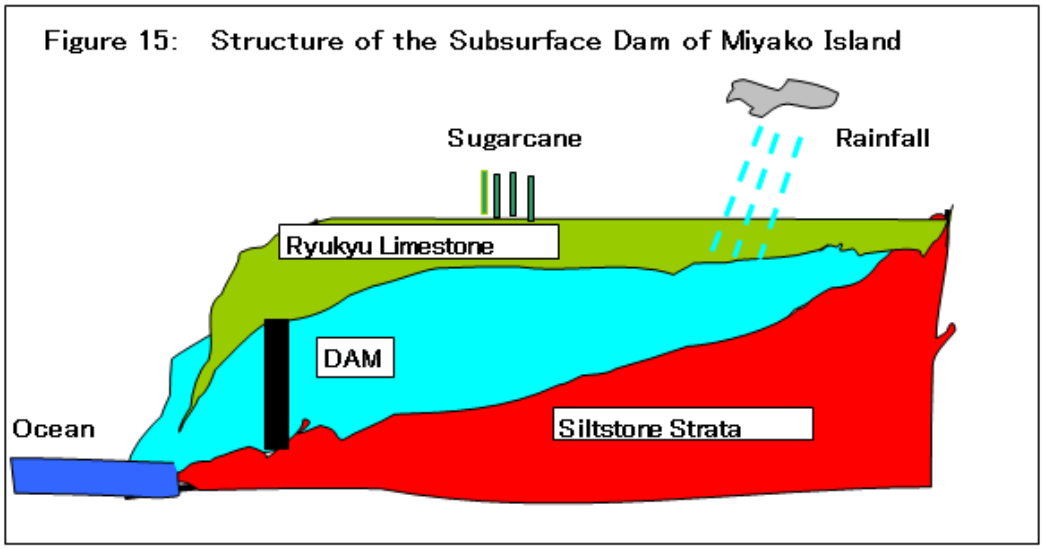
Figure 14: Supersol Products

According to the *Okinawa Times* (July 26, 2014), this waste bottle recycling plant was exported, first time, to Taiwan.

Underground Dam System

Miyako Island has been a showcase for occasional water shortage and droughts because of its flat topographical conditions. The island has no river. Thus, groundwater has been a lifeline for nearly 50,000 islanders. The islanders, however, discovered that they could store rainfall water underground by constructing subsurface or underground dams. As is depicted in Figure 15, an underground dam is defined, "an artificial structure constructed in geologic strata containing groundwater flow that is blocked and stored for use" (Miwa, Yamauchi and Morita, 1988, pp. 121-126).

Figure 15: Structure of the Subsurface Dam of Miyako Island



Source: Kakazu (2012)

The first underground dam was completed in 1979 with 0.7 million ㎥ storage capacity for irrigation (mainly sugarcane fields). The second and third dams were

completed in the 1990s to the total storage capacity of 20 million ㎥ which are enough to irrigate entire sugarcane fields.Miyako Island is formed by the porous Ryukyu limestone, which has high permeability rates. Rainfall percolates rapidly into the ground and is stored as groundwater in between limestone strata and siltstone strata (bed rock). It should also be noted that the structure of the underground must meet a condition that bedrock ground water intake installation capable of surely preventing the fresh water lens from being brined. Thus this technology cannot be applied to any island site unless the above conditionis met (Kuronuma, 2013).

Although, generally speaking, these technologies developed in Okinawa, are useful for island regions, they need to be modified to be appropriate for each island region from the standpoints of island environments and operational costs.

Renewable or Green Energy Development

Unlike the Hawaiian power supply, the Okinawa Electric Power Corporation (OEPC) supplies all electricity needs on the islands. Renewable energy sources such as windpower and solar account for less than 2% of the total energy sources compared to Hawaii's 18%, due mainly to high production costs, unstable supply, and site constraints. Unlike Hawaii, where electricity user rates differ by island, reflecting the cost of power generation, the OEPC has applied common rates for all islands. Okinawa's electricity rates, applied to household users, are about 15% higher than mainland Japan's. In addition to costly electrical power generation and distribution to remote islands, Okinawa is too small to build a nuclear plant. This may be a blessing considering a hard fact of the nuclear energy crisis triggered by the 3.11 earthquake cum tsunami disaster.

Taking a grave lesson from Fukushima's nuclear energy crisis, the Ministry of Economy, Trade and Industry (METI) implemented ambitious promotion measures for introducing alternative or renewable energy in July 2012. The ratio of renewable energy to primary energy supply will be increased to 20% from the current 6%. The most important and ambitious element of the new energy is the introduction of a feed-in tariff (FIT). The FIT scheme will be the most effective policy to promote renewable energy use as is experimented in many countries. FIT typically include three key provisions, namely (1) guaranteed grid access, (2) long-term contracts for the electricity produced and (3) purchase prices based on the cost of generation. Under a feed-in tariff, eligible renewable electricity generators (which can include homeowners, business owners, farmers, as well as private investors) are paid a cost-based price for the renewable electricity they produce. This enables a diversity of technologies (solar, wind,

geothermal, hydro, biogas, wave, etc.) to be developed, providing investors a reasonable return on their investments.

It is important, however, to note that the Special Measure Act on Renewable Energy allows electric utility operators, mainly electric power corporations, to pass the costs of purchasing renewable electric energy on to end-users. Table 5 shows purchase prices of renewable energy sources. The purchase price of solar generated energy (42-yen per KW) is considered to be particularly attractive to prospective suppliers.

Table 5 Japan's Purhase Price of Renewable Energy, 2014

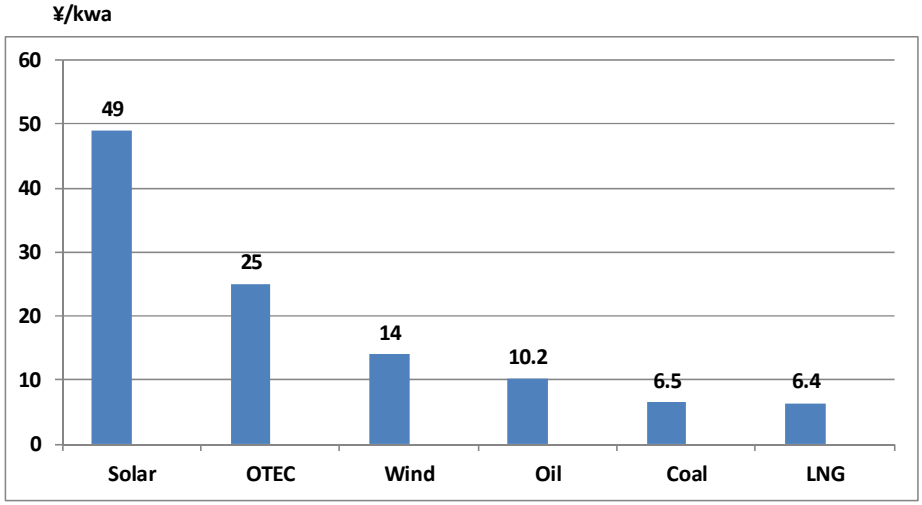
Capacity (kw)	**Price (¥) per kw**	**Period (year)**
Solar (PV)		
less than 10	**37**	**10**
10 & above	**37**	**20**
Wind		
less than 20	**57.75**	**20**
20 & above	**23.1**	**20**
Geothermal		
less than 15,000	**42**	**15**
15,000 & above	**27.3**	**15**
Hydro		
200-less than 1000	**30.45**	**20**
1000-less than 30,000	**25.2**	**20**
Biomass (wood)	**25.2**	**20**

Note: PV = Votovoltatic power generation
Source: The Ministry of Economy, Trade and Industry (METI)

Although solar energy is 4-5 times more costly than current oil and coalenergy sources, the costs have been rapidly reduced through continuous innovations and scale-merits (Figure 16). The introduction of new incentive systems such as FIT, subsidies, and smart grid will accelerate the use of renewable energy.Based on *The Okinawa Enetopia Island Project*, the OEPC has been experimenting a “micro smart

grid" system in Miyako Island with a population of 50,000. Mega-solar (4000KW or 4MW) and windpower energy will be stored in 500KW Sodium Sulfur (NaS) Battery through the Microgrid Energy Management System.

Figure 16 Okinawa's Cost of Generating Electricity by Sources of Energy, 2010



Notes: There are no hydro and nuclear energy sources. OTEC is experimenting at Kume Jima.
Source: Okinawa Electric Power Corporation and others.

CONCLUDING REMARKS

In order to succeed in island production and consumption strategy through import-displacement or replacementstrategy, other interrelated questions must be answered. Contrary to the general belief that arable land is extremely scarce and labor is underemployed in many Pacific islands, including Okinawa, our field research reveals some convincing evidence that the chief scarcity factor is not land but labor (Kakazu, 2010). Young male laborers, who are most needed in production activities, are the most likely members of the population to migrate to the urban centers. Despite the serious unemployment problems in the urban centers, these migrated workers are most likely to stay there or migrate further to the overseas or mainland urban centers.

We should also caution that policy prescriptions derived from the present analysis may differ according to the stage of socioeconomic development, natural resource endowments and the importance of the subsistence sector. The best available policy mix for each island economy cannot be found without answering the interrelated issues such

as possible changes in technology, demographics and decision making process at all levels.

Sustainable development or self-reliant development is easy to talk about, but difficult to pursue. We can find sustainable or self-reliant development plans in virtually all development strategies proposed in the various international forums. The simple model discussed in this paper indicates a danger of specializing in one resource specific non-renewable export good. The theory of comparative advantage may work for large economies where there are alternative resources for exports, but it is not suited for very small island economies. For very small island economies, the exhaustion of non-renewable exportable resource means the complete collapse of external trade and a return to a subsistence economy with a real possibility of falling below the level of pre-trade due to the loss of traditional subsistence skills and the consequences of global warming. Planners should seriously think of how to prevent some of the resource-poor island economies from falling back into what Fisk (1982) calls "subsistence poverty." Okinawa's situation and experience could be useful in terms of developing appropriate models for sustainable island development in the region.

We conducted the field work and related symposium focused on how to transfer sustainable island technologies and innovations from Okinawa and Hawaii to the Pacific islands. As we have discussed, Okinawa, in particular, has developed or adapted and applied various subtropical and island-based "zero-emission" or "renewable" technologies and know-how. Any or all of which may be applied to the South Pacific island economies with appropriate modifications. Waste disposal, for example, is a pressing issue for all South Pacific islands, and reduce, recycle and reuse (3Rs) are key to addressing the problem. However, adaptations of all such technologies and innovations need to consider each island region's or even each island's environment, including culture, history, geography, institutions, economies, and tips and trends of socioeconomic development.

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