【《UH・UR合同シシポジウム》報告】Sustainable Energy as a Means of Promoting Self-reliance for Small Islands : A Comparative Study of Okinawa and Hawai'i

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《UH・UR 合同シンポジウム》報告

Sustainable Energy as a Means of Promoting Self-reliance for Small Islands: A Comparative Study of Okinawa and Hawai'i

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Abstract

Small islands are often faced with many developmental challenges that are unique due to their insularity and size. Small markets, limited natural resources, high transportation costs, and the fragmented nature of archipelagic geographies create numerous difficulties in the development and distribution of energy. As the costs of fossil fuels continue to rise, the economic base of islands that are fossil-fuel dependent continue to erode. However, there is great incentive to pursue alternative and renewable sources of energy. This study provides a comparative analysis on the progress of two island areas, Okinawa and Hawaii, in implementing alternative and renewable energy development as a means to reduce reliance on fossil fuels, promote energy independence, and to reduce greenhouse gas emissions. Okinawa Prefecture in Japan and the State of Hawaii are chosen for this analysis because of their individual efforts in promoting sustainable energy development and because of the Okinawa-Hawaii Energy Partnership. The study will examine policies and development in terms of new energy production technologies, energy efficient buildings, and transportation technologies.

1. Introduction to Okinawa and Hawai'i

Okinawa Prefecture maintains the distinction of being Japan's southernmost prefecture as well as being the only prefecture consisting entirely of small islands beyond Japan's four main islands often referred to as "the mainland". The prefecture consists of 160 islands of which 49 are inhabited and 111 are uninhabited. Within the prefecture, Okinawa Island is the most populous island, containing over 90% of the prefecture's total population of 1.4 million (Table 1). The prefectural capital, Naha, is also located in Okinawa Island. A flight from Tokyo to Naha is approximately three hours, traversing over 1,600km (1000 miles), making Naha Japan's most distant prefectural capital. Due to

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this distance, the prefecture is geographically closer to cities elsewhere in Asia, such as Hong Kong, Manila, and Shanghai (Figure 1). Other islands that contain significant population centers include Miyako Island, Ishigaki Island, and Yonaguni Island, the latter of which is Japan's western most extremity, within visual distance from the northeastern coast of Taiwan (Figure 2).

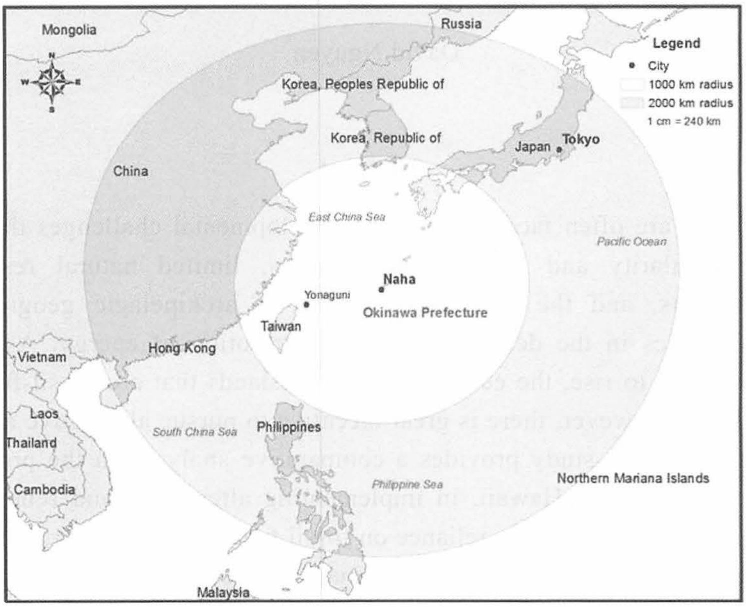

Figure1 : Okinawa Prefecture within the Asia pacific (Drawn by David Nguyen)

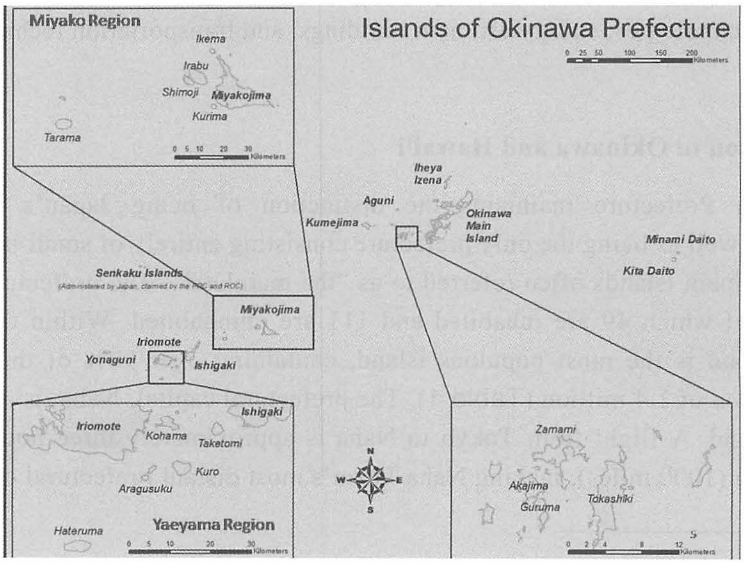

Figure2 : Regions within Okinawa Prefecture (Drawn by David Nguyen)

Okinawa Prefecture's total land area is significantly smaller than that of the state of Hawai'i due to the large size of the largest island, Hawai'i Island. However the largest island of Okinawa Prefecture, Okinawa Island, is close in size to O'ahu Island in both its population and physical land mass, while both islands also serve as the centers of economic and political activity in Okinawa and Hawai'i respectively. The climate in both Okinawa Prefecture and Hawai'i are similar as Hawai'i falls within the tropic zone and Okinawa within the sub-tropics, having slightly hotter and humid summers and colder winters in comparison.

Despite these similarities, there are also significant differences between the two island chains. Okinawa Prefecture is not as geographically isolated as Hawai'i as the prefecture is located relatively close to the Asian mainland and within major shipping lanes. The islands are not volcanic and consist primarily of corals, limiting the potential for nearby geothermic activity. In terms of demographics, while Okinawa Prefecture and Hawai'i share similar population sizes, its distribution is significantly different, as over 90% of the prefecture's population are concentrated in Okinawa Main Island, while only 70% of Hawai'i's population is concentrated in O'ahu (Table 1). In terms of the political economy, Okinawa Prefecture, as much of Japan, relies on centralized planning as much of the prefecture's development plans contain heavy input from Tokyo.

Table1 : Total area and population of Okinawa Prefecture and the State of Hawai'i & Okinawa Planning Department Statistics Bureau)

	Okinawa Prefecture	State of Hawai'i	Okinawa Main Island	O'ahu Island
Total Area	2,271.30 km^2 (877 sq. mi)	28,311 km^2 (10,930 sq. mi)	1,201.03 km^2 (463 sq. mi)	1,545.4 km^2 (596 sq. mi)
Population	1.4 million	1.36 million	1.28 million	953,207

2. Challenges of Facing Small Islands

Many small islands, whether they are independent states or sub-national entities, face obstacles towards sustainable development and face numerous vulnerabilities to sea level rise and natural disasters. While many islands tend be minor contributors to the release of global greenhouse gas emissions, they remain vulnerable to the overall global climate changes which may affect their islands at

Small islands in particular are faced with several disadvantages due to the size such containing a small population, susceptibility to natural disasters, fragile ecosystems, and geographical remoteness from major market centers (Abeyratne 1999). Due to their limited resource base and production capabilities, islands' ability to export primary products are low, while relying heavily on the importation of capital and consumer goods (Kakazu 2007). Island economies also tend to be specialized on a few industries while at the mercy of diseconomies of scale.

In terms of renewable energy, the insularity of many island settlements result in heavy reliance on energy imports, usually in the form of fossil fuels. Due to the smaller market, electricity generation is usually small-scale, and faces high distribution costs. In the case of islands that are part of archipelagos, the dispersed population centers can lead to expensive infrastructure required to connect each island to an electrical grid as in the case of Okinawa Prefecture where expensive underwater cables are required to bring electricity to neighboring smaller islands. In many cases, renewable energy resources on the island are under-utilized. However in the scenario where energy prices are high, the integration of renewable energy sources could provide an economically feasible solution that could provide lower costs, energy security, and reduced emissions (Jensen 1998).

3. Currentenergy Situation in Okinawa

Okinawa Prefecture's electricity is provided by the Okinawa Electric Power Company (often referred to as Okiden), which is the prefecture's sole electric utilities provider. According to Okiden, Okinawa consumes 7,476M KwH annually, or about a third less than Hawai'i's energy consumption despite having a slightly larger population. Okiden's electricity is overwhelmingly powered by fossil fuels, of which 77% is generated through the use of coal, while another 22% through diesel (Dones, 2006). Okiden has stated plans to reduce some coal use in favor for liquefied natural gas by 2013 ("電気をつくる" 2011). In contrast, renewable energies only constitute 1% of the prefectures energy production. Generators are generally found on major islands and fed to smaller neighboring islands via underground cables (Ichimura, 2010). Despite the low proliferation of renewable energy production in Okinawa Prefecture, there exists several types of generators throughout the islands, which include biomass, hydropower facilities, ocean thermal energy conversion plans, solar panels, waste to energy plants, and wind turbines (Figure 3).

Despite Okinawa Prefecture's reliance on fossil fuel imports to meet energy needs and its continued use in the near future, Okinawa has stated its intention to achieve energy security and the creation of a low carbon society by 2030. However, as of 2011, the prefecture has yet to list specific targets or a timeline in achieving this goal. On a national level, Japan's Ministry of the Environment is sponsoring the "2050 Japan Low-Carbon Society" project, which assesses quantitative roadmaps for introducing countermeasures and policies for CO_2 emission by 70% by 2050 at a 1990 base level (*Japan Roadmaps towards Low-Carbon Societies (LCSs)* 2009).

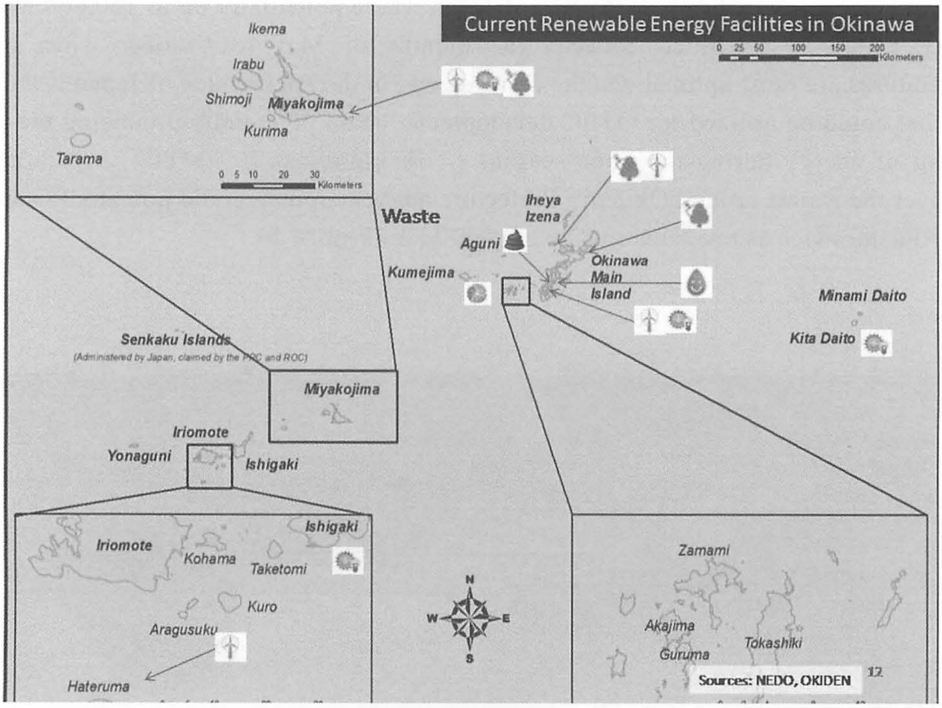

Figure3 : Current Renewable Energy Facilities in Okinawa Prefecture (Source: Okiden, NEDO)

Due to the demographic, economic, and geographical similarities between Okinawa Prefecture and the State of Hawai'i, the two governments signed a memorandum for the Hawai'i-Okinawa Partnership on Clean and Efficient Energy Development and Deployment (hence force referred to as the Hawai'i-Okinawa Partnership) in June 2010 ("Hawaii, Okinawa sign partnership on clean energy" 2010). This partnership involves research and cooperation at the national and local government, private, and academic levels, bringing together a variety of institutions. Much of the current attention in this partnership is focused on ocean thermal energy conversion (OTEC), bio-mass, efficient energy buildings, and development of smart grid systems (*Hawaii Okinawa Clean Energy Partnership* 2010).

4. Ocean Thermal Energy Conversion

OTEC is most optimal when the temperature difference between the warmer, top layer of the ocean and the colder, deep ocean water is approximately 20°C (36°F) (Kaplan 2010). In a chart developed by Lockheed Martin based on data from the US Department of Energy, Okinawa Prefecture lies in the optimal area where the average monthly temperature difference is more than 20°C but less than 22°C (Figure 4). Within Japan, there are three areas that could be utilized for OTEC, one which includes an area north of south-eastern Japan in the Sea of Japan where potentially up to 100,000 MW of energy could be generated between the months of May to October when ocean temperatures are most optimal. On the opposite end in the Pacific side of Japan is another area that could be utilized for OTEC development, again potentially producing the same amount of energy during the same seasons ("海洋温度差発電 (OTEC) とは" 2011). However the waters around Okinawa Prefecture are year-round, could potentially capable of producing twice as much energy, at 200,000 MW (Figure 5).

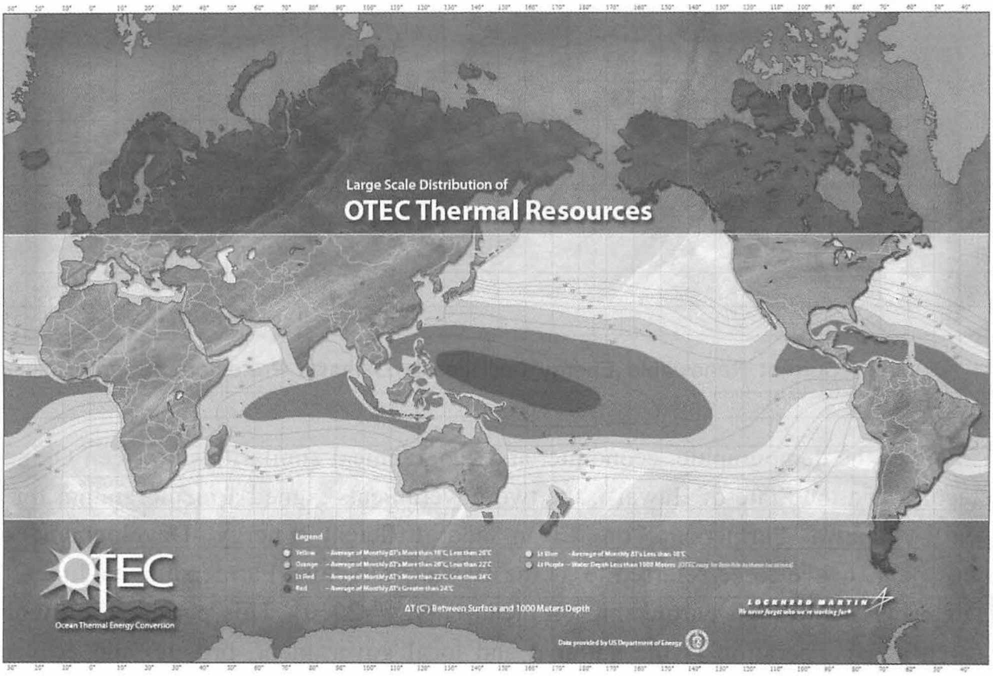

Figure4 : OTEC Thermal Resources (Source: US Department of Energy, Smart Planet, Lockheed Martin, 2010)

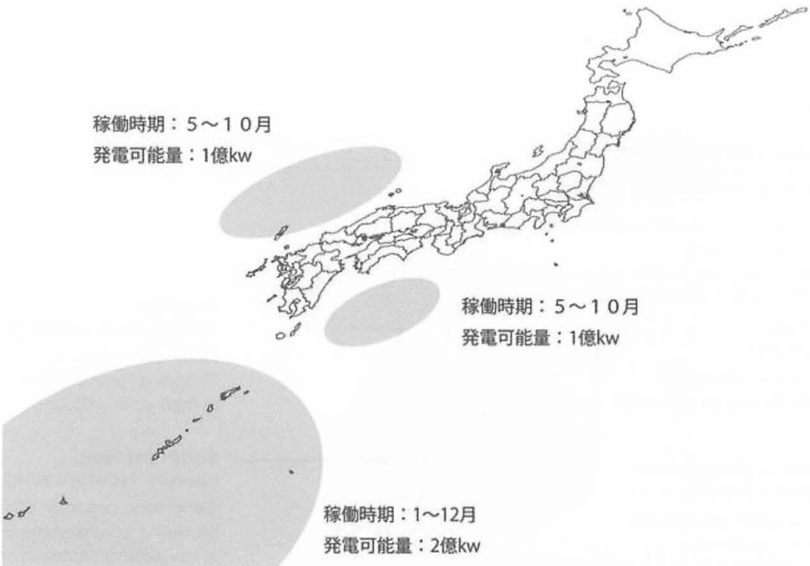

Figure5 : Optimal areas for OTEC utilization in Japan. Top label describes period of utilization in months while the bottom text describes output in hundred millionths (Source: MMK-OTEC, 2011)

As of December 2011, OTEC is currently being researched on Kumejima, a small island of 8,900 residents, located about 80 kilometers from Okinawa Main Island. The Deep Sea Research Center on Kumejima draws water from 612 meters below sea level and pumps approximately 13,000 tons of sea water daily. Should a 1 MW plant be built, it could potentially provide up to 10,600 MWh of electricity, or 10% of the island's annual consumption. The amount of water pumped could theoretically be increased to 100,000 tons. The development of a plant could also generate up to 1,500 jobs ("Power generation by Ocean Thermal Energy Conversion Kumejima, Okinawa considering experiment for development" 2011).

5. Energy Efficient Buildings

In the tours of Hawai'i's delegation to Okinawa Prefecture, several structures stood out as an example of energy efficient architecture. The first is Itoman's City Hall, the southernmost city on Okinawa Main Island ("Itoman City Hall" 2008). The building is surrounded in layers of solar panels that could generate up to 211,400 kWh per year. The design of the building also allows excellent air circulation leading to reductions in heat that could save 42,049 kWh per year through reduce air condition usage. Elsewhere, the newly established Okinawa Institute for Science and Technology (OIST), is designed with energy efficiency from its inception, and utilizing wind and solar power generators throughout its campus which is managed by its own energy storage system (Figures 6 & 7).

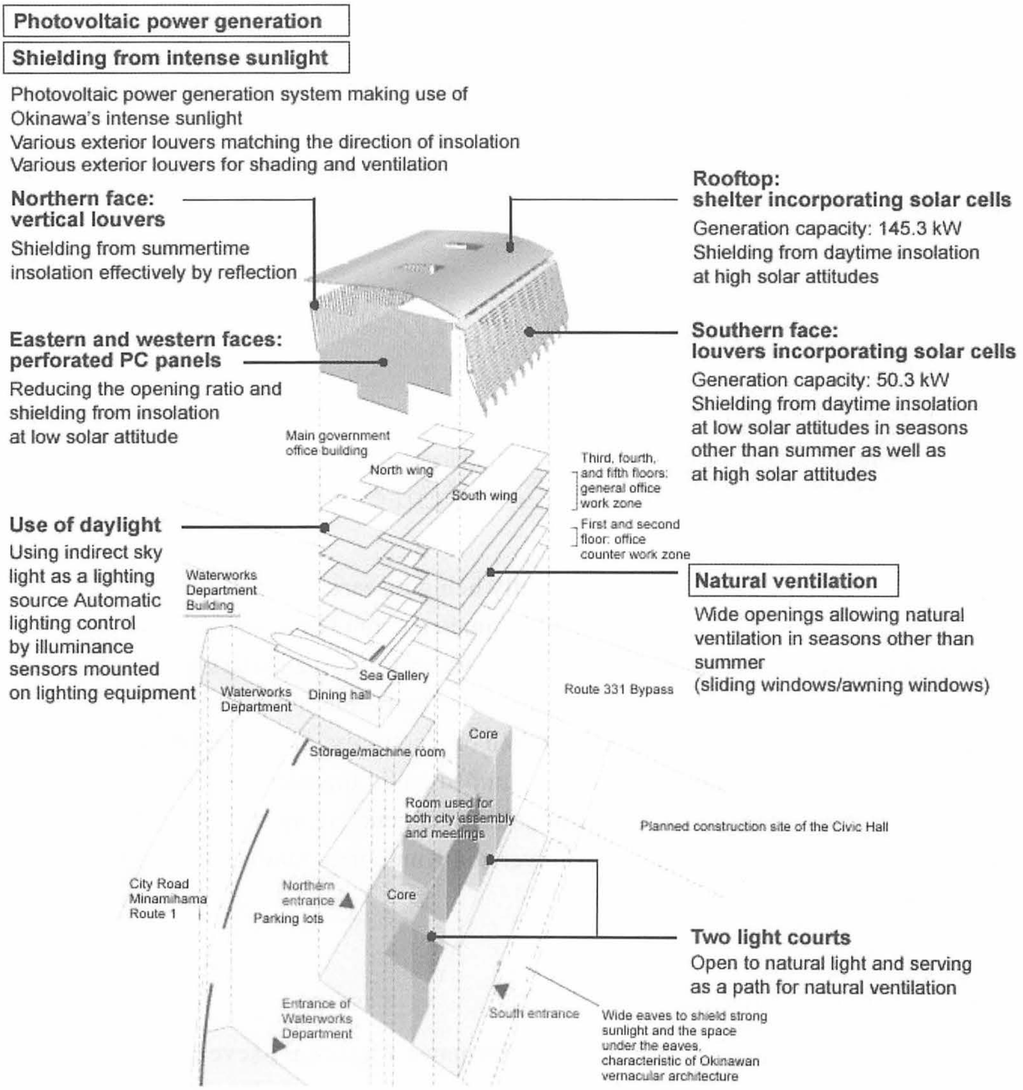

Figure6 : Diagram of Itoman City Hall's Natural Energy Oriented Design (Source: Japan Sustainable Building Data Base)

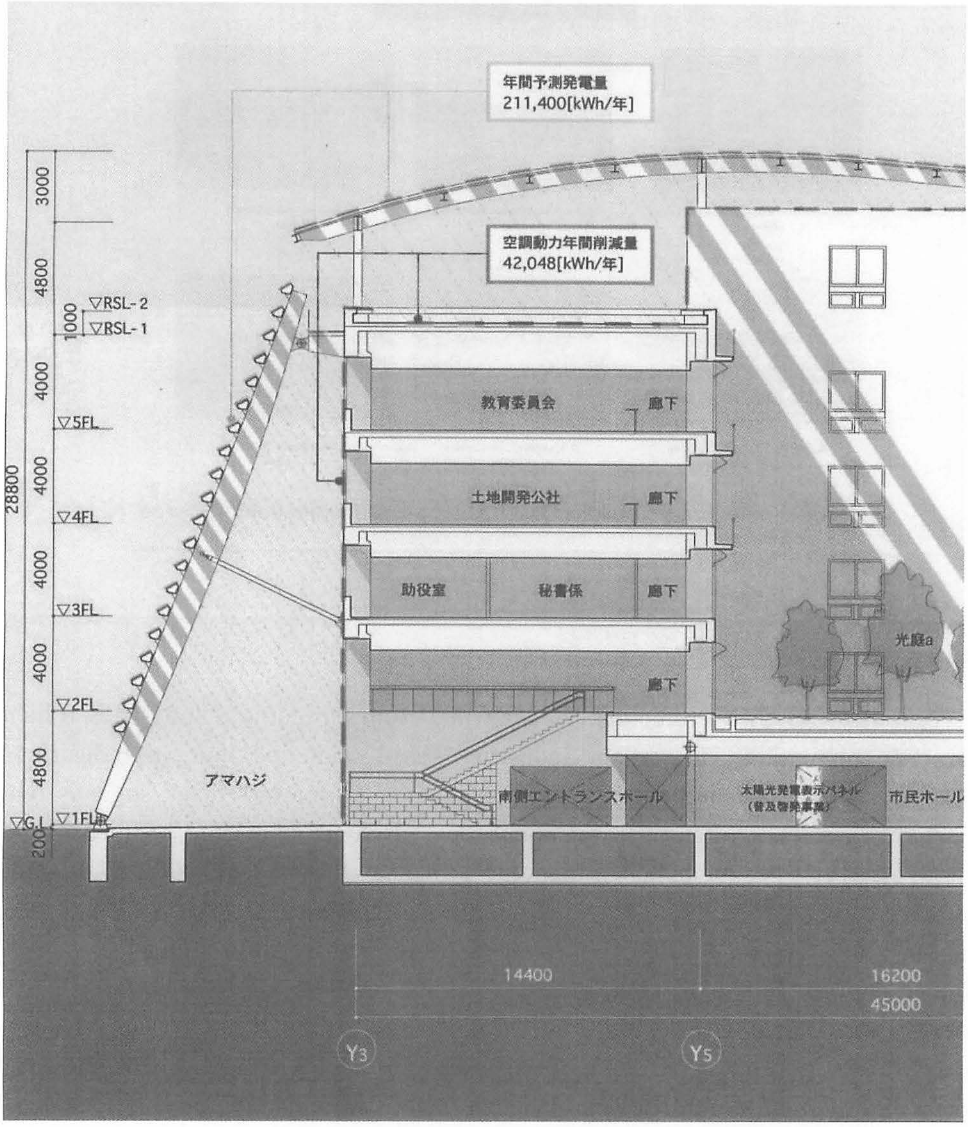

Figure7 : Layout of Itoman's City Halls, top box describes energy production by solar panel while the bottom box describes energy savings in AC use reduction (Source: Itoman City)

Older buildings have also been modified to reduce energy consumption and produce its own energy. For example, the University of the Ryukyus has installed solar panels on its rooftop that could provide up to 40 MW of electricity. Elsewhere, solar panels have been installed on public schools, nurseries, and municipal housing facilities (沖縄グリーン電力基金事業の終了について 2011).

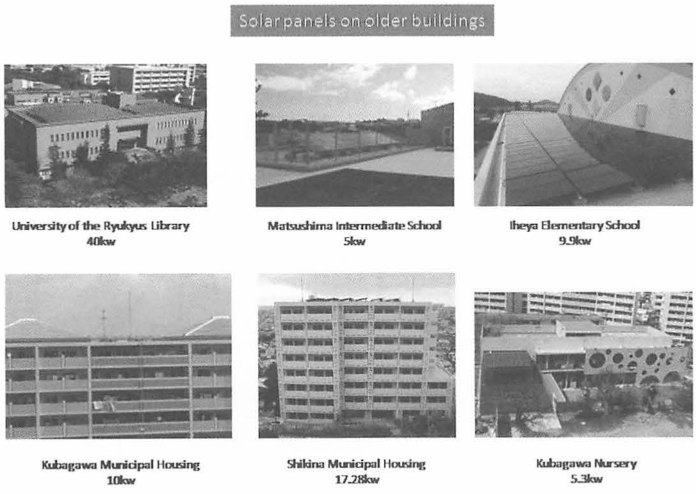

Figure8 : Select older buildings with solar panel installations (Source: NIAC)

6. Biomass

Although Okinawa Prefecture has switched from agricultural industries reliant on sugar cane plantations, to tertiary industries based upon the tourism industries and military bases, sugar cane continues to be planted as Okinawa's black sugar is renown throughout Japan and often used for many local products consumed by local residents and tourists, such as sātā andāgī (a famous Okinawan donut). One of the byproducts of sugar cane production is molasses, which traditionally, has been either discarded into the ocean, or fed to cows. However by fermenting the molasses, bio-ethanol fuel could be produced and utilized as an alternative for vehicle gasoline, or for electricity purposes ("Energy from Sugar Cane Produced Locally" 2009). The Ryuseki Corp facility on Miyakojima estimates that one tone of molasses, created from 33 tons of sugarcane, can produce 200 liters of bio-ethanol fuel (Kaneko 2006). As sugar cane plantations could be found all over Okinawa Prefecture, many islands could contribute to the production of bio-ethanol.

7. Model City Miyakojima

From April to May of 2010, the Japanese government launched applications for the "Eco Model-City Project" (EMC), to promote the Japan's transformation into a low-carbon society, and showcasing its achievements based on settlement sizes. As a result 13 EMCs were selected out of 82 applicants. These EMCS were divided into four categories based on population sizes: Major cities, Regional core cities, Small cities and towns, and the Special Tokyo Ward. Specifically, these EMCs are designed to redevelop itself into a compact city, develop transportation infrastructure, transform residential styles, utilize widespread renewable energy, and to conserve and utilize forested land (*The Eco-Model City Project and Future Directions* 2011). Each city has separate goals in the reduction of carbon emissions (Table 2)

Table2 : Reduction targets set by 13 Eco-Model Cities (Source: Regional Revitalization Bureau 2011)

Size	Cities	Population	Area (km2)	Reduction (Mid-Term)	Reduction (by 2050)	Base Year
Major Cities	Kitakyushu	0.99 million	488	30% (2030)	50 - 60%	2005
	Kyoto	1.47 million	828	40% (2030)	60%	1990
	Sakai	840,000	150	15% (2030)	60%	2005
	Yokohama	3.67 million	434	Over 30%/head (2025)	Over 60%/head	2004
Regional Core Cities	Iida	110,000	659	Household sector 40 – 50% (2030)	70%	2005
	Obihiro	170,000	619	30% (2030)	50%	2000
	Toyama	420,000	1,242	30% (2030)	50%	2005
	Toyota	420,000	918	30% (2030)	50% or 70%	1990
Small Cities and Towns	Minamata	29,000	163	33% (2020)	50%	2005
	Miyakojima	55,000	205	30-40% (2030)	70 - 80%	2003
	Shimokawa	3,900	644	32% (2030)	66%	1990
	Yusuhara	4,000	237	50% (2030)	70%	1990
Special Tokyo Ward	Chiyoda	45,000	12	25% (2020)	50%	1990

Okinawa's sole representative in the EMC project is Miyakojima City on the island of Miyakojima. Selected in 2008, Miyakojima's medium term goals for carbon emissions is to reduce it between 30 to 40% by 2030, while its long term goals is to increase that to 70 to 80% in 2050 (Table 2). To achieve this goal, Miyakojima is spearheading several renewable energy initiatives, some of which are the first within the nation. Its top priority revolves upon the implementation of a micro-grid or smart grid system which expands upon existing renewable and non-renewable energy production on the island, as well as taking into consideration new developments.

Miyakojima's smart grid addresses concerns over the potential of the fluctuations of energy production by wind and solar generators by channeling electricity into a central control system where an electric storage system ensures stability by managing the distribution of electricity (Figure 9). The current smart grid system utilizes both renewable energy such as wind and solar power generation, in addition to thermal and gas turbine generation. In order to boost the electrical production on the island, a large solar farm was constructed in 2010 by Toshiba, encompassing 4.5 hectares and capable of producing an output of 4mw. In addition, a bio-ethanol plant was also constructed the same year, utilizing the byproducts of sugarcane production that could be found all over the Miyako region.

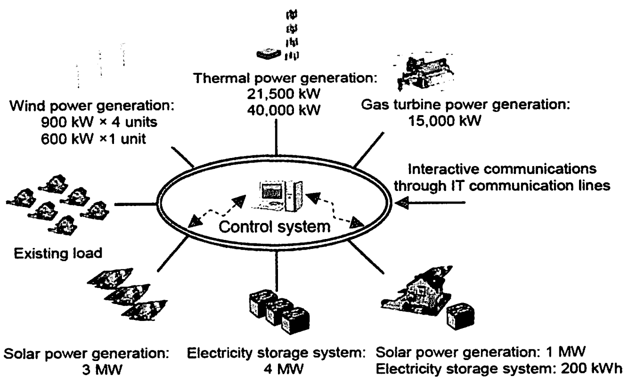

Figure9 : Diagram of Miyakojima's smart grid system (Source: METI)

In terms of vehicle emissions on the island, Miyakojima has began installing a series of electrical vehicle charging stations around the island in order to promote and improve the accessibility of electrical vehicle use. These charging stations are also a part of the island's smart grid system. The city has stated a mid-term goal of having 40% of all the island's vehicles to be electric vehicles by 2030. Currently about 100 of the public vehicles either run on bio-ethanol or electric ("2030年のEV車率40%目指す" 2011).

In May 2010, the Joint Bureau for Regional Revitalization released an evaluation of the progress of Japan's 13 EMCs. In this report, four cities received an A grade, seven cities received a B grade, and the two remaining cities receiving a C (Table 3). Theoretically, these cities could receive an S grade, where local initiatives lead national policies, for example the United State's federal government adopting policies created by California. Within Japan, none of the EMC's have yet to achieve an S ranking.

Based on the EMC report, Miyakojima City received a B grade. In terms of promoting a self sustaining energy supply, the city has achieved progress as planned, as it increased sugar cane yields through breed improvement experiments and pest and disease control while strengthening the supply of bio-ethanol production activities. Its conversion of biomass into usable energy is also going as planned. In terms of efforts to use solar energy, the installation of solar powered water heating and air conditioning system is also on time, with solar powered generation systems installed in 38 houses producing about 150 kW. Where Miyakojima is ahead of its planned progress is the introduction of the mega solar farm, which is currently four times larger than the initial plan. In addition, the start of the remote island micro-grid project began during this time, testing stabilization technologies and control methods. In the social arena, the island is on progress through the creation of network and strengthening eco-activities with residents, and holding a symposium of the spread of electric vehicles that are part of the smart grid system (*Progress of Main Projects in 13 Eco-Model Cities and Evaluation by the Joint Bureau for Regional Revitalization in Cabinet Secretariat* 2010).

While four other cities received a higher grade than Miyakojima, in comparison to other small towns and cities, Miyakojima fared very well, with only Shimokawa surpassing Miyakojima in this category. In the case of Shimokawa, the town exceeded early estimates, constructed more biomass facilities and eco houses than predicted, and ahead of plan. Several of its initiatives, such as developing new uses of willow, included the participation of those outside of the town, while the CO_2 reduction contest, received a very high turnout for its area.

Table3 : Follow-up on progress of 13 EMCs' projects (Source: Regional Revitalization Bureau 2011)

City	Evaluation Grade
Kitakyushu	A
Kyoto	A
Sakai	B
Yokohama	C
Iida	B
Obihiro	B
Toyama	A
Toyota	B
Minamata	C
Miyakojima	B
Shimokawa	A
Yusuhara	B
Chiyoda	B

S	Extremely distinguished progress, for instance, by exercising local initiatives that lead national policy
A	Excellent progress, for instance, by implementing a pioneering project ahead of schedule
B	Good progress, for instance, by implementing a project on schedule
C	Good progress, for instance, by implementing a project on schedule

Overall, nearly all of Miyakojima's 26 projects are making progress as planned or ahead of plan, where efforts at reduction or absorption effects account for 50% of 19 projects that resulted in implementation. In particular, the study expects great progress to be made since the implementation of the smart grid system as it is considered to have a great influence on the introduction of energies in Japan as an independent low-carbon system, unique to islands in a warm climate (*Progress of Main Projects in 13 Eco-Model Cities and Evaluation by the Joint Bureau for Regional Revitalization in Cabinet Secretariat* 2010)

8. Cooperation with other Pacific Islands

The Hawai'i-Okinawa Partnership's interest in the development of a smart grid system culminated in exchanges between stakeholders involved in Maui's smart grid project with their counterparts in Miyakojima. On November 22, 2011, Hawai'i Governor Neil Abercrombie signed a $37 million agreement that will allow Japan's New Energy and Industrial Technology Development Organization (NEDO) to develop a smart grid demo in Maui, as part of the partnership. The project includes the construction of a smart grid utility control system in Kīhei to improve the integration of photovoltaics and electric vehicles (Isotov 2011).

Also in November 2011, a 17 member delegation consisting of the Miyakojima Municipality and the Japan International Cooperation Agency (JICA), cooperated with the Samoan Water Authority in introducing the "Miyakojima Model" to Samoa. The project is multi-faceted and involves work in the areas of water business, renewable energy, and waste management ("Samoa welcomes Okinawa" 2011). As of December 2011, the delegation continues to travel to other Pacific island countries, and is currently in discussions with the Fijian and Tongan governments ("Japanese Water Business Study Group from Okinawa Islands visits Tonga" 2011).

In May 2012, Okinawa Prefecture held the 6th Pacific Island Leaders Meeting (PALM) at t Nago City on Okinawa Main Island. The summit level meeting is held every three years and provides opportunities between governments to discuss various issues facing Pacific Island countries, and to build close cooperative relationships ("Expert Committee for the Sixth Pacific Islands Leaders Meeting (PALM 6)" 2011). Issues related to climate change and support towards renewable energy projects and island resource were the primary agenda of the summit.

9. Electrified rail and small islands

Due to Okinawa's insularity, few places in the world share Okinawa's unique transportation and carbon reduction challenges. Electrified rail, such as those utilized by monorails and light rail systems, could reduce both carbon emissions through the reduction of gas consuming vehicles and utilize local energy production sources as seen with Miyakojima's EV charging stations where vehicles can be connected to its smart system. Table 4 presents a list of cities on islands that share rough similarities to Okinawa in terms of area, population size, and population density. All of these islands experience significant levels of traffic congestion and have either implemented a rail system or have seriously considered the construction of one. In some cities such as Mallorca of Spanish island of Palma and San Juan in Puerto Rico, there is more than one rail line (Railway Technology 2011). According to the results collected in table 4, nearly every island city that has either established a rail system or considering rail, have either adopted LRT or have seriously considered it as an option. For example, Honolulu has examined LRT routes in its 1984 and 1999 long range transportation plans before deciding upon an elevated rapid transit line (Binckerhoff 1999; UMPO 1984). Mallorca, which has a metro subway system and a rapid transit running underground and at grade is considering a third rail line that could utilize LRT while Puerto Rico has decided to build a new LRT line to extend rail into San Juan's bedroom communities and complement the Tren Urbano Rapid Transit, instead of extending the Tren Urbano itself (Freemark 2010). Cities that are currently considering LRT include Hobart on Tasmania Island in Australia, the island nation of Mauritius, and Reykjavik in Iceland, which have all done various feasibility studies and are at different stages of implementation (Fontaine 2011; Republic of Mauritius 2012; Wills-Johnson 2011). It is worth noting that France's Reunion Island in the Indian Ocean cancelled an LRT project in 2010 that was scheduled to open in 2013 due to financial issues (Alves 2010).

Table4 : A comparison of the demographics of island cities that have either considered rail transit or are currently operating it (Sources: Alves 2010, Binckerhoff 1999, Freemark 2010, Fontane 2011, Railway Technology 2011, Republic of Mauritius 2012, Wills-Johnson 2011)

Place	Transit population	Density	Considered LRT?	Current / Proposed System	Type	Year	Length	Stations
Okinawa Island, Japan	1,200,000	1,000/km²	Yes	Yui Rail	Monorail (elevated)	2003	12.8km	15+4
Honolulu (PUC), US	733,000	1,696/km²	Yes	HART	Rapid Transit (elevated)	2015-9	32km	21
Tenerife, Spain	908,555	435/km²	Yes	Tranvía de Tenerife	LRT (grade separated)	2007	12.5km	20
San Juan, Puerto Rico	2,617,000	509/km²	Yes	San Juan – Caguas Rail	LRT (separated)	2020?	27.4km	5
				Tren Urbano	Rapid Transit (elevated, subway, grade)	2004	17.2km	16
Mallorca, Spain	870,000	238/km²	Yes	Palma De Mallorca Metro	Rapid Transit (subway)	2007	8.3km	9
				Servis Ferroviaris de Mallorca	Rapid Transit (subway/grade)	1993	3 lines	29
Reunion, France	839,500	330/km²	Yes	Reunion Tram-Train	LRT (grade separated)	2013 cancelled	41.5km	26
Hobart, Australia	250,000 – 500,000	895/km²	Yes	Hobart LRT	LRT	?	48.2km, 2 lines	42
Mauritius	1,286,000	630/km²	Yes	LRT	LRT (grade)	?	25km	13
Reykjavik, Iceland	120,000	259/km²	Yes	Keflavik Airport – Reykjavik Line	LRT (grade)	2021?	?	?

10. Vulnerabilities to natural disasters

Okinawa Prefecture experiences the highest occurrences of typhoons in East Asia. In addition, it also experiences the strongest typhoons, with winds surpassing 250km per hour. Within Okinawa Prefecture, Miyakojima has a history of being hit by some of the strongest typhoons in the recent history of Japan (Table 5). As Miyakojima's terrain is relatively flat and lacks any large hills or mountains, there are no natural windbreaks on its landscape. As a result much of its infrastructure and residences are highly vulnerable to wind forces.

Table5 : Past Records of Japan's Strongest Typhoons in Terms of Maximum Instantaneous Wind Speed (Source: Japan Meteorological Agency)

Rank	Location	Wind Direction & Speed	Date	Typhoon Name
1	Miyakojima (Okinawa Pref.)	NE 85.3m/s	9/05/66	2nd Miyakojima Typhoon (Cora)
2	Murotomisaki (Kochi Pref.)	WSW 84.5m/s	9/16/61	2nd Murotomisaki Typhoon
3	Miyakojima (Okinawa Pref.)	NE 79.8m/s	9/22/68	3rd Miyakojima Typhoon (Della)
4	Nase (Kagoshima Pref.)	ESE 78.9m/s	8/13/70	Typhoon #9
5	Miyakojima (Okinawa Pref.)	NNE 78.0m/s	9/23/68	3rd Miyakojima Typhoon (Della)
6	Murotomisaki (Kochi Pref.)	WSW 77.1m/s	9/10/65	Typhoon #23
7	Miyakojima (Okinawa Pref.)	N 74.1m/s	9/11/03	Typhoon #14 (Maemi)
8	Naha (Okinawa Pref.)	S 73.6m/s	9/8/56	Typhoon #12
9	Uwajima (Ehima Pref.)	W 72.3m/s	9/25/64	Typhoon #20
10	Ishigakijima (Okinawa Pref.)	SE 70.2m/s	7/31/77	Typhoon #5

In 2003, Super Typhoon Maemi landed on Miyakojima on September 11 with wind speeds of 74.1m/s. Casualties caused by Maemi included 1 fatality, 97 injuries, and approximately 20 houses completely damaged with another 1300 structures suffering damages of varying degrees (Okuda 2003). In particular, all seven of the Island's wind power generators were damaged, with three destroyed completely as they were either uprooted from its base or were severely bent (Kikitsu, Okuda & Okada 2004). The replacement of the three destroyed wind turbines would not come until November, 2007 when four 900kw Enercon turbines replaced the two 400kW Micon turbines in Miyakojima City, and one 500kW Enercon turbine in Gusukube Town (Nitsche 2008) .

Other islands within Okinawa Prefecture are similar to Miyakojima in that their low elevations and lack of mountains, leads to vulnerability to natural disasters. In addition to the threat of typhoons, the islands are also threatened by flooding, caused by tsunamis as well as sea level rise. Figure 10 displays some of the flood zones in different areas of Okinawa based on different levels of flood water height. In Kumejima, for example, the Deep Sea Research Center used for OTEC lies within a 0.5M inundation zone, while the three of the windmills found in Miyakojima are also vulnerable to inundation (Figure 12). Sugar cane plantations, which could be found on many islands, are also heavily at risk as farms such as those in Tarama, can be found in many inundation zones (Figure 11).

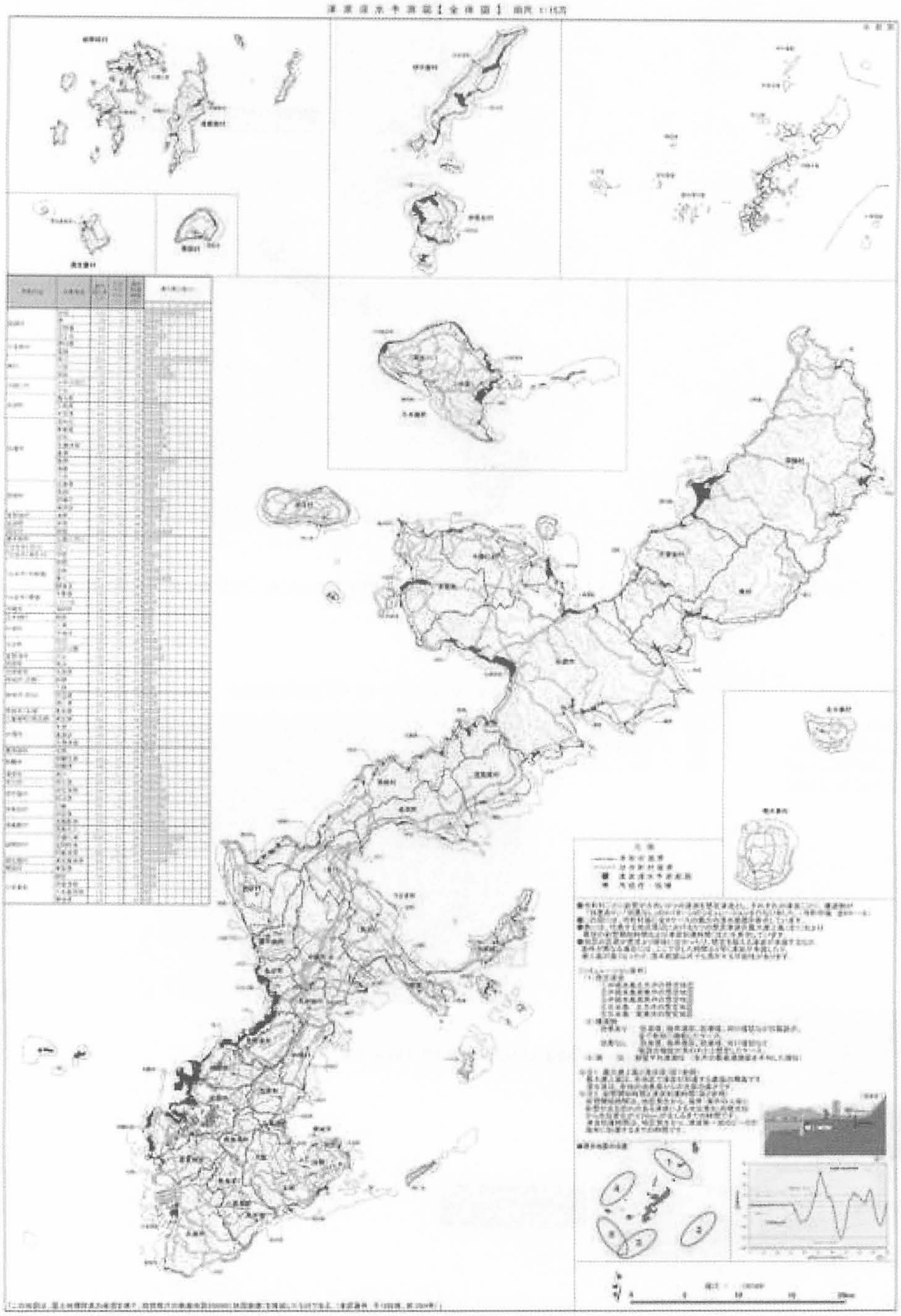

Figure10 : Inundation Areas on Okinawa Main Island and Surrounding Islands (Source: Okinawa Prefecture)

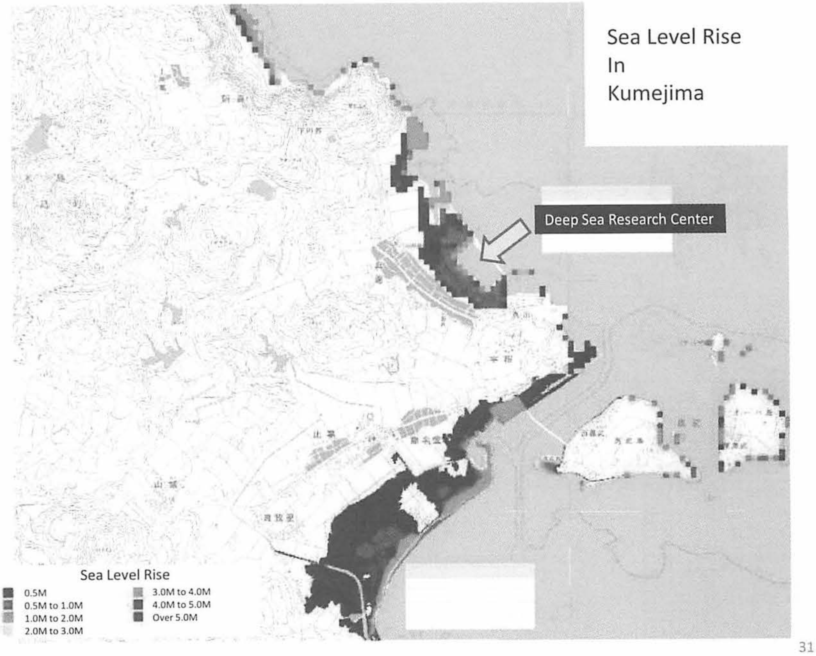

Figure11 : Effects of Sea Level Rise in Kumejima(Source:Okinawa Prefecture)

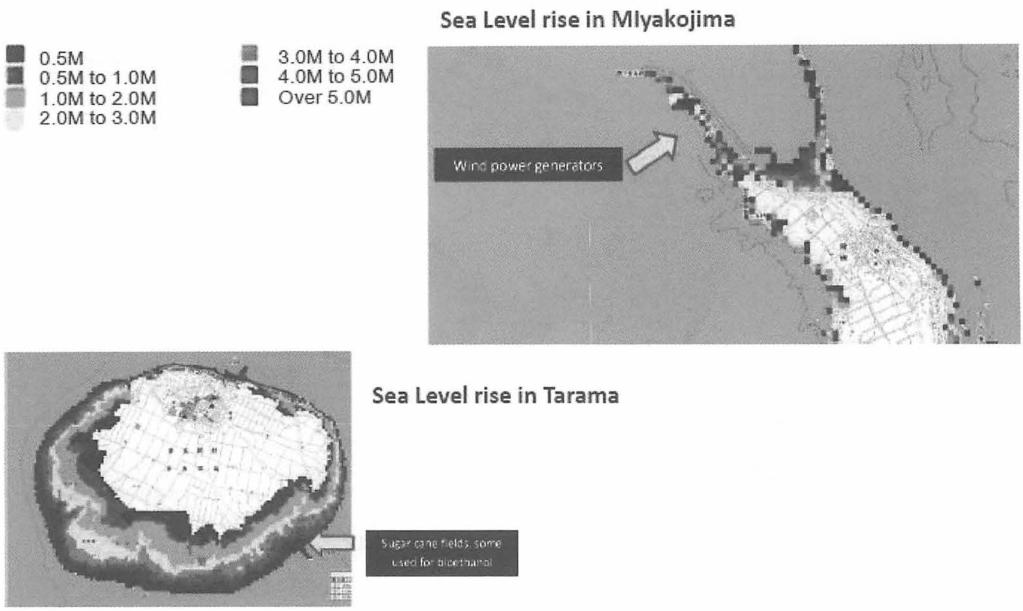

Figure12 : Effects of Sea Level Rise From in Miyakojima and Tarama(Source:Okinawa Prefecture)

Okinawa Prefecture also lies within the "Ring of Fire", lying between the subduction zone of the Philippines Plate, and the Eurasian Plate's continental rift boundary/oceanic transform fault line. Fortunately, Okinawa Prefecture has so far escaped the level of seismic activity found in other parts of Japan, with the last significant earthquake being the Yaeyama earthquake of 1771 (M7.4) and the 1911 Amami Oshima earthquake (M8.0)[1](*Seismic activity in Japan – Regional perspectives on the characteristics of destructive earthquakes* 2008). Despite the infrequency of powerful earthquakes, Okinawa Prefecture remains vulnerable to the effects of powerful earthquakes elsewhere in the Pacific as the 1960 Chilean Earthquake (M9.5) killed 142 people in Japan (*Great East Japan Earthquake: Update on damage and recovery (2nd report)*, 2011).

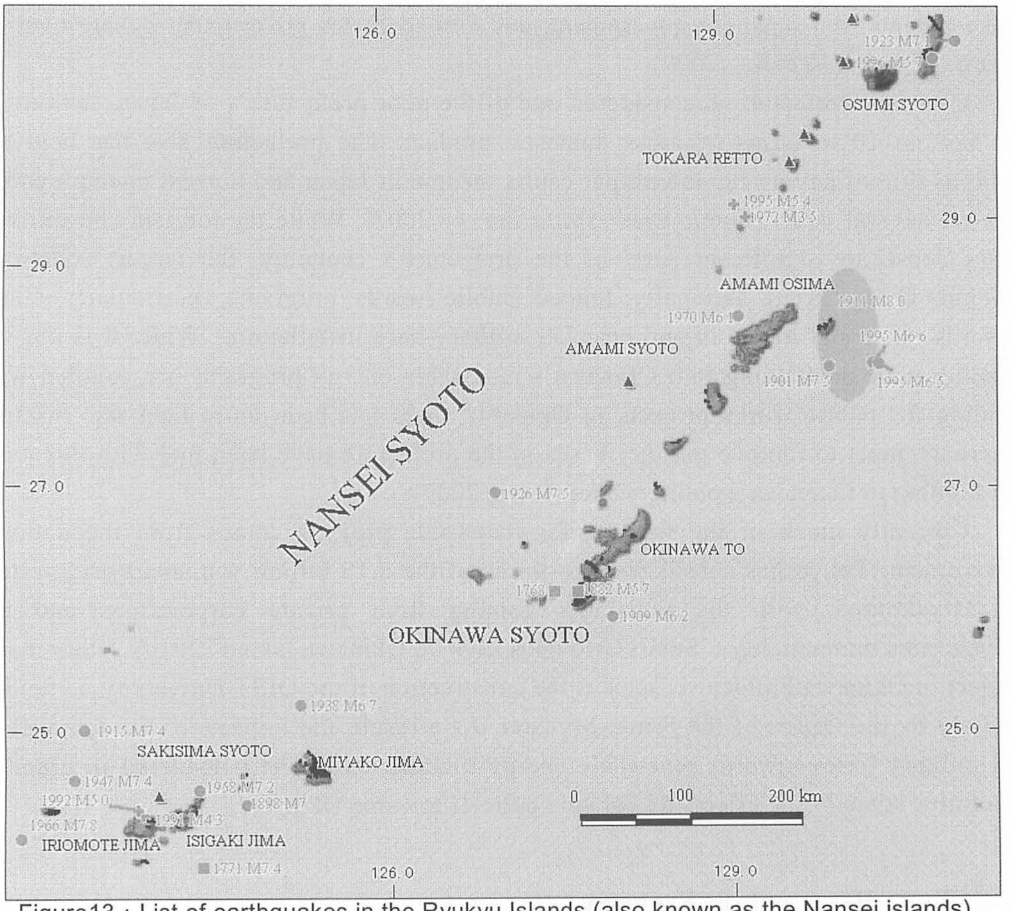

Figure13 : List of earthquakes in the Ryukyu Islands (also known as the Nansei islands) and surrounding areas (Source: The Headquarters for Earthquake Research Promotion 2008)

[1] Although Amami Oshima and surrounding islands are part of the Ryukyu (Nansei) Archipelago and historically linked with Okinawa, it is currently administered as a part of Kagoshima Prefecture since 1953.

11. Military Bases and the Economy

Okinawa Prefecture currently hosts nearly 75% of the US military bases in Japan, constituting over 40,000 troops and their dependents combined, or approximately 3% of the prefecture's population. Most of these troops are stationed in one island, Okinawa Main Island, where 33 military facilities consume nearly 20% of the island's area. In terms of electric consumption, Okiden reports that the impact of the military bases results in the consumption of 9.4% of the island's energy production. The report also suggests that this consumption could be reduced between 1.4 – 3.4% if certain facilities are returned to Okinawa's jurisdiction. While Okiden refrains from mentioning specific installations, it is likely referring to the controversial Marine Corps Air Station in Futenma, whose fate remains unclear as disagreements between Okinawa's government and residents, the Japanese government, and United States government debate over its future (経営参考資料集　2009).

Okinawa Prefecture is considered one of the poor prefecture's of Japan, ranking in the bottom 10 in terms of gross domestic product. The prefecture also has held the dubious title of having the lowest per capita income in Japan and highest unemployment rate for several years (*Employment Status Survey* 2007). While the tourism and military bases constitute significant parts of the prefecture's economy, the largest source of revenue comes from nationally funded public works programs, particularly aimed towards cities and towns in and near US military base installations. While it is unclear whether national funding into Okinawa's renewable energy programs are coupled with funding for public works projects in Okinawa, there has been more than one instance where attempts to remove military bases in the prefecture have been met with threats to cut funding to Okinawa's public works (Inoue 2007).

Currently much of the funding for renewable projects comes from the national government. Tokyo has subsidized two-thirds of the 6.15 billion yen smart grid system on Miyakojima, with the remainder coming from private corporations and the Miyakojima municipality ("Smart Grid goes Live on Okinawa Island" 2010). Other major project in Okinawa Prefecture, such as the construction of the OIST University, is funded entirely by the Office of the Prime Minister. As a result, the impacts of the removal of US military bases towards renewable energy funding should be considered in order to determine some of the effects of Tokyo's policies towards Okinawa.

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13. Conclusion

Due to Okinawa Prefecture's insularity, the islands face developmental problems due to its small size, limited market, limited resources and vulnerability to external events. In particular, these islands rely heavily on the importation of fossil fuel to provide energy needs, which are often expensive due to the costs of transportation involved, and the high distribution costs that are due to the small market and fragmented population distribution over multiple islands. However success in Miyakojima could spread the smart grid system to the rest of Okinawa, and then nationally, providing a source of energy security for the islands. Renewable energies utilize Okinawa's geographic advantages to reduce carbon emissions and also create jobs, which is also vital as the prefecture maintains the distinction of maintaining Japan's highest unemployment rate for several years.

However significant obstacles exist as the implementation of renewable energy technologies can be prohibitively expensive. The finance of these projects have relied on money from Tokyo which may be problematic due to the coupling of national public works money spent on Okinawa and the ongoing issues over the relocation of US military bases. This is complicated by the fact that while the US military base is a significant consumer of the island's energy resources, the money given to Okinawa for infrastructural projects, is also due these bases, given to cities in the prefecture as inducements to continue hosting these bases.

In addition, Okinawa Prefecture's geographical advantages are also its disadvantages as the islands lie in a region of the highest typhoon activity in East Asia, with six of the ten strongest typhoons hitting Okinawa within the past 50 years. The prefecture's low elevation also creates high vulnerability to tsunami flooding and sea level rise, potentially inundating many coastal residences and energy production facilities. While the prefecture does not experience the same frequency or intensity of earthquakes like other parts of Japan, the islands of Okinawa Prefecture nevertheless, remain vulnerable to earthquakes as it lies between the Eurasian and Philippine Plates, as well as being susceptible to powerful tsunamis caused by earthquakes elsewhere in the Pacific region.

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