The report of GRM, On-Site Practice, 10th to 13th, March, 2013 (QE)

ABDRAHAMANOV,Kanat.(PE,GS)
INUI,Toshie.(QE, GS)
MORIYAMA,Takuya.(QE, GS)
NISHI, Naomi. (QE, GS)
TAKETANI,Marie. (QE,GS)
ZIANG,Tain. (QE, SE)

The programme of Global Resource Management provides both of students of the graduate school of Social science, and science and engineering with fields to learn different knowledge so that students could utilize them as global leaders who can assist developing and emerging countries.

As the first onsite practice, we visited Miyakojima, Okinawa prefecture from 10th to 13th, March, 2013. It is a smooth island, composed of elevated coral reef (Ryukyuan limestome). Miyako Island is subject to drought and is frequently struck by typhoons. Therefore, it has been suffering from lack of water resource. Now Miyako has unique irrigation systems, which use geographic characteristic effectively. Moreover, Miyako city is one of 41 cities where the project called "Next Generation Energy Park", has been started. This project is admitted by Minister of Economy, Trade and Industry. It is for getting understanding new energy policy and examining renewable and sustainable resource such as solar energy system and wind-energy system in corroborating with proper system such as thermo power energy.

Through an onsite practice in Miyakojima, we visited four infrastructures facilities including one of Next Generation Energy Park, and had lectures from each professional to deepen our understandings on energy systems.

This report describes about the summaries of each facility we visited, and both social and engineering perspectives following to the schedule of this practice. As this is a group work, we divided each four part to social science students. Students put their own perspective as well. And a student who has engineering science filed pointed out each some related perspectives as his part. One from social science takes part of introduction and conclusion, and edits whole paper. Chapter number is following to schedule of onsite practice.

1. Miyako Island-Mega Solar Demonstration Facility

Today, energy is at the forefront of the global agenda. It is central to the issues of development, global security, environmental protection and achieving the Millennium Development Goals (MDGs). Moreover, according to existing projections, the world's population of 7 billion is likely to increase to 9 billion by 2050, which means growing demand for diminishing natural resources as never before. Besides, providing electricity to remote rural areas and isolated islands is another serious issue on the path of socio-economic development. Thus, both developed and developing countries have to find new innovative solutions in getting better advantage of available resources without compromising the needs of future generations.

Recognizing the existing threats to the global environment related to the climate change and urgent need to improve energy security, number of countries agreed under the Kyoto Protocol to reduce its green house gas emissions by approximately 20% before 2020. In order to achieve set targets the countries started to shift towards more eco-friendly energy in pursuit of more sustainable development. At the same time, challenging physical environment and low-density population in remote areas also pushed to development of smart grids and independent energy generation facilities. As a result, energy efficiency and support of renewable energies such as bio-fuels, hydro, wind and solar are among top priorities of energy policy in various countries.

In islands and remote communities, where grid extension is difficult and fuel transportation and logistics are challenging and costly, renewable energy is emerging as the energy supply solution for the 21st century, ensuring reliable and secure energy supply in such communities.

The deployment of renewable energy technologies is increasing globally, supported by rapidly declining prices and government policies and strategies in many countries, resulting in renewable energy solutions being the most cost-effective option in many markets today. For example, in 2011 the Special Report of the IPCC (Intergovernmental Panel on Climate Change) on Renewable Energy Sources and Climate Change Mitigation showed that approximately 50% of new electricity generation capacity added globally between 2008 and 2009 came from renewable energy sources. Therefore, the future of renewables as the base energy source for islands and remote communities looks very bright.

One of the most promising renewable energy is a solar power, the cleanest and most abundant energy source available. The potential of solar energy is beyond imagination. According to International Energy Agency (IEA) the surface of the earth receives around 120,000 terawatts of solar radiation (sunlight) – 20,000 times more power than what is needed to supply the entire world. Solar power generation, which produces electricity without emitting CO2 and provides clean and renewable energy, is becoming increasingly popular around the world. Obviously, its availability is greater in warm and sunny countries – those countries that will experience most of the world's population and economic growth over the next decades. Although, there are emissions associated with the manufacturing, transportation and installation of solar power systems, yet it is almost nothing compared to most conventional energy sources. Needless to say, that solar energy reduces our dependence on non-renewable energy sources and is an important step in fighting the climate change.

Japan is well known as leading country in promotion of alternative energy and reduction of green house gases. Besides, taking into account topographical factors, heavy dependency on imported fossil fuels and remote locations of some islands from the mainland creates additional incentives to develop solar power generation as a potential solution for meeting energy needs in those remote territories.

However, a large scale introduction of photovoltaic power still needs further research and development, mainly due to its high costs and abrupt output fluctuations. To manage this variability it is necessary to encompass a range of measures, such as a balanced supply technology portfolio, better forecasting tools, demand side management and appropriate storage solutions.

In this regard, recognizing the vast potential of solar power contribution to overall goals of Japan's energy policy, the government of the country (Ministry of Economy, Trade and Industry) decided to support research and development of large scale PV power generation and subsidized in 2009 the project called Mega-Solar Power Demonstration Facility in

Miyakojima (Okinawa Prefecture) with the main objectives to find out solutions for existing obstacles in installation of large amount of photovoltaic equipment into small independent grid of isolated islands.

Miyako Island is an ideal location for this research due to its characteristics: 300km away from the Okinawa mainland and is approximately 205 Km2 with a population of 55,000 people and approximately 25,000 houses. The average temperature on Miyako is a balmy 23°C. The island is in a location where typhoons do occur, so the photovoltaic panels installed were built with heavy duty supports capable of withstanding strong winds, the panels were also inclined at 5 degrees to help prevent the wind from catching and to minimize installation area. The Photovoltaic research facility has 4,000 newly established PV systems with a capacity of approximately 50,000kW per year which gives an estimated Co2 emission reduction of 4,000 t. a year. This is complimented by the addition of storage batteries NAS (Sodium – sulfur) to mitigate unstable power quality of energy produced from the PV. The NAS battery is free of self-discharge, featuring high energy density and high efficiency. The NAS batteries are probably one of the key elements of the project and quite expensive with the average costs exceeding 10 million US dollars per item. Large capacity batteries of this type also have been made. The NAS battery is excellent in response performance and can absorb abrupt fluctuations of PV output that cannot be compensated by a thermal generator. It should be noted however, that it is necessary to maintain specified temperatures in the inner cell by a heater, since sodium and sulfur are used in liquid phase. According to the staff of the project the NAS batteries are excellent in response performance and can absorb abrupt fluctuation of PV output that cannot be compensated by a thermal generator.

As we have learned from the visit to Miyako Mega-Solar power facility, after converting solar energy into electricity using a PV cell made of a semiconductor material, there is a need from time to time adjust the supply and demand equally to maintain nominal frequency (60Hz) constant. In order to do that, it is needed to fine-tune the output of generators sensitively. If supply is less than demand, the frequency would decrease, if reverse supply is greater than demand, then the frequency would increase. Unless the balance between supply and demand is constant, frequency would be fluctuated and as result it can have negative impact on power quality, hence the quality of products in factories.

For determining the impact of introduction of large volume PV power generation into distribution system, and demonstration of effectiveness of stabilization of the system, the project has developed a special simulated power distribution system. This system equipped with polycrystalline silicon and thin film silicon PV panels of Sharp, Kyocera, and Kaneka. Each manufacturer offers different advantages such as high conversion effectiveness, product life time or maximum output capacity. The largest share belongs to Sharp due to its better technical characteristics and cost efficiency. In addition, the system is divided on 4 consumer blocks supported by 8 NAS batteries (0.5MW), step voltage regulator (SVR) and static var compensator (SVC). The line length of simulated power distribution can be set as desired in the range of 0-20km.

An interesting fact about this system, which is operated by the Okinawa Electric Power Company (OEPC) is that it can simulate ordinary household and school load (4kW and 150 kW PV respectively) to determine optimum capacity of storage, while also studying the prediction technique of PV output, for more smooth system operation. It also provides 4kW lithium ion storage battery to 25 residencies as addition part of monitoring.

The project also aims to validate frequency fluctuation control effect of following combination storage battery + PV + wind turbine. However, since the wind turbine power is a separate subject, this report is focused only on aspects related to solar power generation and its distribution.

The technologies presented here are not currently cost competitive with the storage technologies discussed above. However, they are under development and may someday become mainstream technologies. Since the research and development (R&D) focuses on improving technical performance rather than cost reduction and there are few or no full-scale installations of these technologies, reliable cost data are generally not available for these technologies.

Storage technologies are undergoing rapid advancement, and there is as yet no clear winning technology. However, as experience with these technologies grows, their advantages and constraints are becoming clear.

There might be several interesting implications of this project. For instance, adding storage increases the first cost significantly. However, according to some estimates it also allows for a 25% reduction in diesel use. It does so largely by allowing the diesel generator to operate at higher loads (and thus higher efficiencies) and to switch off entirely when loads are low, as we were explained during our visit to Miyako Second Power Station and Miyako Gas Turbine Station. But it is important to have precise prediction of load, since diesel power is very slow in reaction and it may take around 2 hours to start the engine work at a required level. The gas turbine is faster and often used to compensate the gap during peak times, so this combination is also used in different cases.

PV as a supplement to a diesel generator without accompanying storage is unlikely to be a financially attractive choice although it may be worth considering as an interim step to introduce PV technology on a large scale. Combining diesel generators, solar power and storage can be the lowest cost option, based on levelised cost. However, such systems are complex and technologically sophisticated.

In this regard, Miyako Mega-Solar Demonstration Facility has very clear objectives and expected outcomes such as to:

- Validate methods of controlling fluctuations caused by sudden output from the PV
- Determine the required capacity of the storage battery
- Study the technique of predicting PV output
- Study the technique of predicting remaining power in the storage battery

If the project will be successful in meeting its expectations, then it will be a significant step towards development of alternative energy and provision of electricity to remote areas, as well as reduction of green house gas emissions. Besides, it will also have global impact through contribution to wide spread of PV power in developing countries via knowledge sharing and transfer of technology.

Of course, financial aspect still remains a key obstacle in introduction of solar power, although high efficiency solar cells helps to lower the overall cost of solar power, but it only accounts for half of a costs related to typical solar installation. The other half consists of operation and maintenance, grid integration, and so on.

Nevertheless, with effective policies in place, PV on residential and commercial buildings could achieve grid parity – i.e. with electricity grid retail prices – by 2020 in many regions. In this scenario, utility-scale PV could become competitive in the sunniest regions by 2030 and provide 5% of global electricity by 2050. As PV matures into a mainstream technology, grid integration and management and energy storage remains key issues. The feed in tariff can be a good tool for stimulation of renewable energy, but it will also have its limitations and possible side effects. Therefore, it is important to have a complex approach with incentives to private households to use PV power for long term energy security and more sustainable development. In this regard, Mega Solar Power Demonstration Facility is an important project for unlocking solar power potential and can significantly help to provide access to clean, reliable and affordable energy that has a profound impact on multiple aspects of human development.

2. Science and Engineering perspectives

This section is going to show two more technical ideas as perspectives from Science and Engineering studies: wind and solar power generation.

2.1. The wind power generation system

The wind-energy system is one of the oldest energy systems invented in Mesopotamia and Egypt from more than 5000 years ago. Also it is a famous symbol of the Netherlands, however most of them were built around 15 century. As it is shown, human being have been trying to develop new resources. One of challenges led the emerging of steam engine by James Watt in Scotland, United Kingdom, developed it as practicable. It made a start of the era of depending on fossil fuels through sifting from natural energy into fossil fuels energy.

There is, however, still the windmill and it has been necessary for our livings, even new resources have been developed. Why does it not go out of use? As one of my perspectives, it might be a cause of people's preference. For example, the wind power generators can get attention from tourism industry and there is the tour of it. In this sense, it may work and not bad

1) [1] NEDO, 日本における風力発電設備・導入実績, http://www.nedo.go.jp/library/fuuryoku/index.html

idea using it as landmark. Then again, in practical term it cannot be said that wind power generation contributes. According to NEDO's data[1], the output power of developed power such as wind power generating plant and other power plant are,

- Thermo power is 3,000 times than wind
- Water power is 300 times than wind

It is an important point that there is a huge difference between energy by natural fluids. In addition, the final goal of urging renewable energies is sifting from fossil fuel energy so that due to purvey thermo power generation by wind power generation, it is necessary to resolve great differences. Therefore, it does not seem to be a realistic idea.

One of the methods to increase an output of wind power is to make wind power generations bigger. Its calculation formula is below.

$$P = 1/2 \cdot \rho \cdot S \cdot V^3$$

Where P is wind power energy (W), ρ is air density (kg/m^3), S is the area of bladed wheel (m^2), V is wind speed (m/s). By Betz's law, its wind generating power can expand in proportion to the area of bladed wheel.

In Germany, a wind power generator, 6,000kW, was invested. It, however, is doubtful to reach and change from water and thermo elect energy because it is difficult to develop it bigger.

Moreover, the rate of utilization in thermo, water and nuclear power generation is decided by each project. However, it is difficult to consider wind and solar power generations, which I will describe in the next section, can provide 100% in rate of utilization because main resources are unstable natural energy directly. Even if it works, the wind does not blow in everywhere. Miyako Island is one of the best conditions for wind power generation because of a sea breeze; on the other hand, there are not much places where same condition is assured in Japan, and it is difficult to build in near where people live. Moreover, it may give influence to fishers and cause conflicts against local residents. From these points, the wind energy power generation is exceedingly at a disadvantage.

2.2. The solar power generation.

The solar power generation can maintain a stable generating power if the weather is fine comparing the wind power generation because it has fewer restrictions on location. It needs less maintenances of equipment than others.

Also, as NEDO and other institutes shows [2-4], if we can spread the solar cells on the Gobi Desert, it will be able to cover all of the energy that is currently used by people all over the world. From these points, the solar power generation seems idealistic energy.

However, actually it is not realistic idea. There are 2 reasons; costs and time. At first, the cost of solar cell itself is expensive. Secondly, it takes costs for transformation of electrical energy and electric power transmission to far area. It takes not only costs but also energy to transmission. And, as we learned from this onsite practice, it requires costs for the stores of power from solar power generation.

In case of the time, it is also unrealistic idea because of massive square. As some data shows as I exampled above, the idea seems sustainable and clean. However, in fact, the square measure of the Gobi Dessert is approximately $130 \times 10^4 km^2$, and it is approximately 3.5 times than Japanese land. Even if the solar cells are spread in $10 km^2$ per a day, it takes more than 360 years.

Since massive earthquake happened in Japan in 2011, the diminution of nuclear power generation has been considered and discussed. Now I would like to discuss the possibility of solar power generation as a substitute for nuclear power generation. So generating power is 1×10^6 kW, which is equally matched in an atomic power plant[2].

It is needed to produce 8.33×10^6 kW calculated with the average of utilization factor of solar cells in Japan; 12%. And the conversion efficiency is set average 10%. For the sunlight around 1 kW per 1 square metre reaches on the surface, the output power is 100W per one square metre. So, the necessary square measure as a substitute of nuclear power plant is $83.3 km^2$, which is as much wide as 1800 times of Tokyo Doom. That is to say, it is not

1) [2]関西電力，原子力発電所の運転状況，
http://www1.kepco.co.jp/gensi/monitor/live_unten/u_real.html

realistic theory that the solar power generation can be main resource in a place of the nuclear power generation in a present circumstance in Japan.

3. Miyako Second Electric Power Plant

Miyako Second Electric Power Plant is located in the northwest coast of Miyako Island. With other 2 internal combustion power plants, the total electric power generation capacity is approximately 74000kW. These power plants also service Irabu island in the west of Miyako Island. The demand of electricity in Miyako Island and Irabu Island is at most 550,000kW in summer. Because there is no large scale factory in the islands and main part of demand for electric power comes from civil households, peak time for demand is from 7 p.m. to 8 p.m.

When we visited Miyako Second Electric Power Plant in the afternoon, the generating power was approximately 30,000kW. Among this amount, 26,000kW was from internal combustion power plants. The other 4000kW at the time was from wind power generations and solar power generations. The maximum ratio of renewable energy which is available to be produced in the islands is 25% among total production.

3.1 Internal Combustion Power Plant

Miyako second power plant has four diesel-powered generators. Electric power generation capacity of each generator is 10,000kW. It means that the total capacity of Miyako second power plant is 4000kW.

A type of diesel engines which are used in Miyako second power plant is V-type 8-cylinder twin engine. Unlike other diesel engines which consume light oil, the engines in Miyako second power plant consume heavy oil. Miyako second power plant has 40 days oil-storage for emergency. This storage is especially for typhoon season which keeps oil tankers from approaching to the island.

Generating power of internal combustion power plants is automatically controlled by computer to adjust generating power of renewable energy. Since generating power of renewable energy fluctuates depending on weather condition like wind power and sunshine, it is necessary to adjust the fluctuation by other electricity. However, diesel-powered generator cannot be controlled quickly responding to weather change. For this reason, storage batteries are used to adjust the fluctuation of generating power from renewable energy.

[Figure 1]
Diesel-powered engine generator

[Figure 2]
Control Monitor

Gas Turbine Power Plant

In addition to diesel-powered generators, Miyako Island has gas turbine power plant. Gas turbine power plant is smaller and cheaper to build comparing to diesel-powered generator. However, gas turbine power plant in the island is just for emergency use because generating efficiency of it is lower than diesel-powered one. They have three gas turbines whose generating capacity is 5000kW. The total capacity from gas turbine power plant is 15,000kW.

Small Hydroelectric Power Plant

Miyako second power plant has a small hydroelectric power system which uses discharged engine-cooling water. The engine cooling water falls from height of 13 meter to the ocean. This stream of water-fall rotates the water turbines and produce electricity. The capacity of power generation is at most 65kW.

[Figure 3]
Small Hydroelectric Power Plant

Challenges and Personal Review

Electricity system in Miyako Island has some challenges to become more reliable system which can be installed in other places. The main challenge is how to stabilize electricity's frequency. It is still difficult to control frequency of electricity from renewable energy because the frequency from renewable energy often fluctuates due to weather condition. While fluctuating frequency is acceptable in Miyako Island where almost all electricity demand comes from ordinary household, it is unsuitable for other regions with precision machine factories which require exact electric frequency.

In the lecture, it was said that "*high-quality electricity*" means the electricity with stable frequency and voltage. According to the lecture, it is easier to stabilize frequency and voltage by large-scale energy source such as thermal power and nuclear power plant rather than by small-scale renewable energy sources. Once renewable energy is installed to electric power network, the quality of electricity will decline.

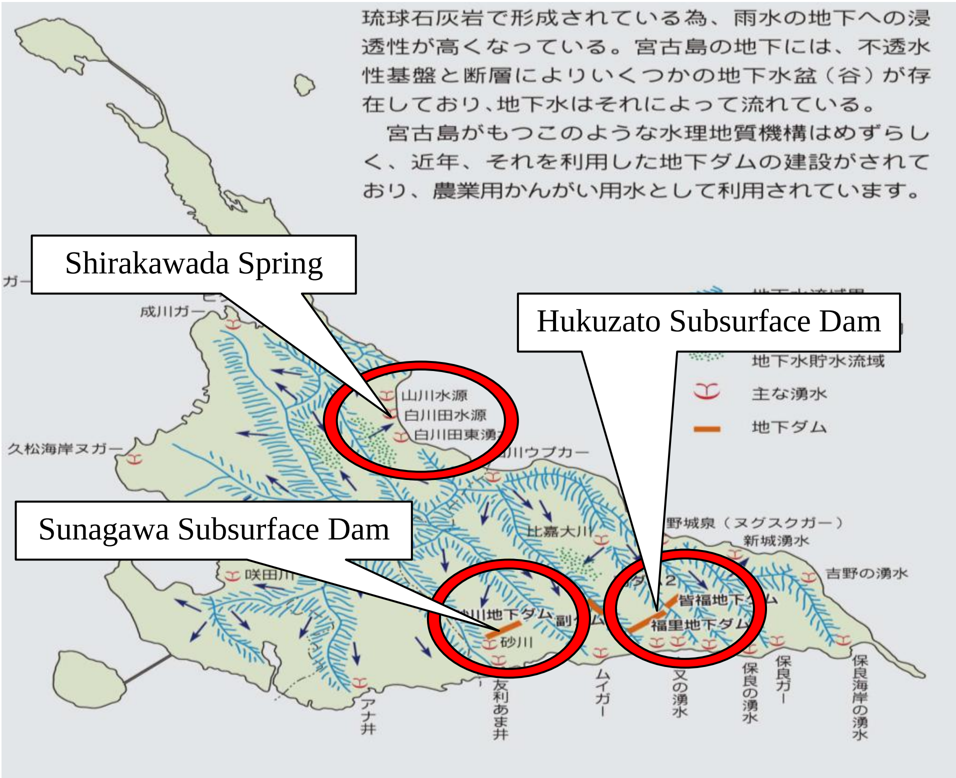
However, for my personal opinion, this does not mean the necessity to rely more on large-scale energy sources which have many risks such as uncontrollable nuclear wastes and global warming. What we should do is not only developing new energy sources, but also reconsidering the way we consume energy. So long as we cannot get perfectly sustainable, reliable, stable, safe, and clean energy, it is necessary to rethink our society and one's lifestyle and reduce our energy consumption.

4. The Museum of the Subsurface Dam in Miyakojima Island

Japan is usually said that it has a lot of water sources like rivers. However, Miyako Island does not have one. Then, how do the people in Miyako Island get the water for drinking, agriculture and so on? The answer is that they almost depend on Shirakawada Spring for drinking, Sunagawa and Hukuzato Subsurface Dams for agriculture. This part will provide the mechanism of the subsurface dam which was provided at the Museum of the Subsurface Dam and then the author will finally remark the visit there as a conclusion.

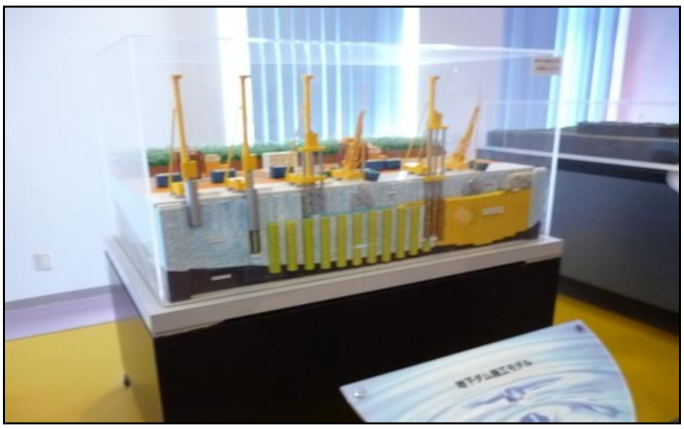
Map 1 shows the locations of the Shirakawada Spring, Sunagawa and Hukuzato Subsurface Dams. The spring is mainly for the drinking water and 2 dams are for agriculture. The 2 dams' total volume of water kept in store is 20 million tons and it corresponds to 16 times larger than that of the Tokyo Dome. The breakdown is that Sunagawa is 9.5 million tons and Hukuzato is 10.5 million tons. Their total length is 4.6km and their maximum height of the wall is 60m. It is not exaggeration to say that the 2 subsurface dams sustain the farming in Miyako Island.

[Map 1]



Map Source: 宮古島市上下水道部「宮古島の上下水道」19 頁。 http://miyakojimajyouge.jp/2011panf.pdf downloaded on 16th March 2013. The author touched up the figures on the map.

How subsurface dams are constructed? Figure 4 shows the construction model of a subsurface dam. The yellow-collared large machine tools are called tri-axial auger drill (三軸オーガードリル) and their height is about 25m. The tri-axial auger drill has three axial drills as the name expresses. The drill digs until Shimajiri Mudstone which is third nature of the soil from the surface of Miyakojima Island and the figure about its soil is showed below. Also, the large holes are dig at 90cm intervals. The axial drills are extracted from the holes with pouring cement into them.



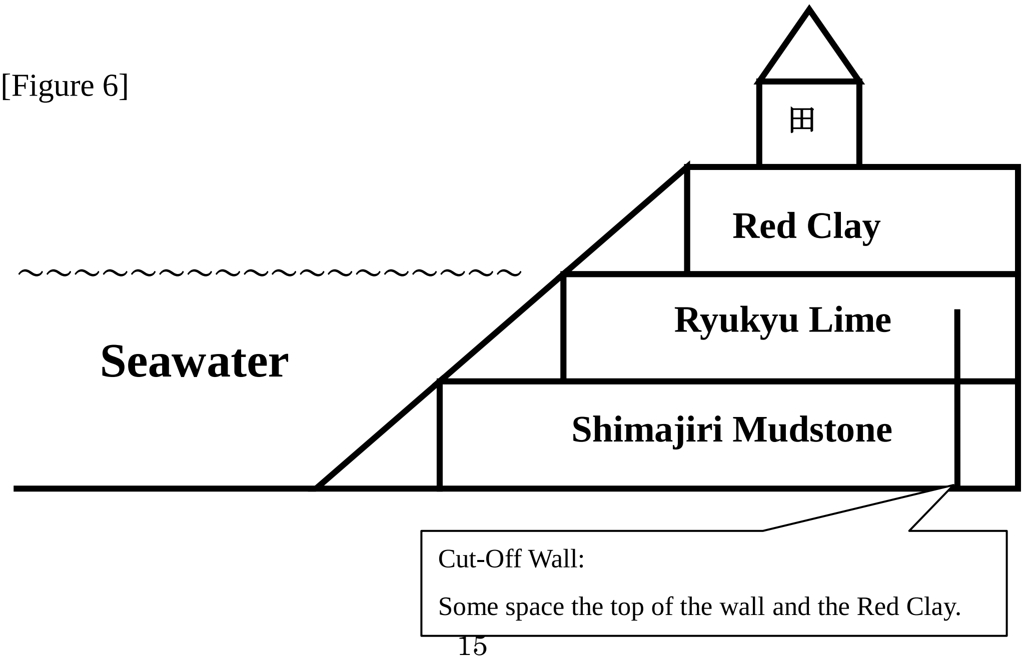
[Figure 4]

The construction model of a subsurface dam at the Museum of the Subsurface Dam in Miyakojima Island.

[Figure 5]
One of the cut-off walls of the Hukuzato Subsurface Dam

After the drills are pulled the holes, the dirt which was produced during digging is put back to the holes. Then, the cut-off walls are completed at last. Figure 5 shows one of cut-off walls of the Hukuzato Subsurface Dam. So as not to flood the water in the dam during raining, there are some spaces between the top of the wall and soil called Ryukyu Lime which is the second nature of the soil from the surface of Miyakojima Island. Because of the way of constructions and the location of dams, the water in the subsurface dams has little plankton and the surface of the island is able to be used for farming. Figure 6 shows the soil of this Island.

[Figure 6]



The water content of the red clay is only about 10%. The most of water from rain is not saved into the soil. It almost flows into the sea. Therefore, it is really important for the island to have the kinds of dam. The suitable conditions for the subsurface dams are that first, the soil is easy to carry water, second, the land has lots of rain and finally the topography of the underground is like valleys. Thus, Miyakojima Island is suitable for subsurface dams.

The way of distribution of the water from the dams for farm lands is very simple. There are a lot of wells located around the dams and the drawn water from them goes to ponds called farm ponds. Then, the water is distributed directly to farmlands thorough pipelines.

As a conclusion, the subsurface dams in the island are constructed well by utilizing the topography. At the same time, the land of Miyakojima Island is flat and there is little difference of altitude between the sea and top of the hill. Because of these points, the water collected into pond is well distributed to the farmland. It is probably difficult for developing countries which face the lack of water to introduce the dam. In the case of Rwanda which has a lot of rain, it looks suitable to construct such dams there and there are some positive impacts by the dams because its main industry is agriculture. The investigation into stratifications is required at first, but the location of the country is so problematic. Rwanda is located between altitude 1,500m and more than 2,000m. The attitude is large, so the high techniques to draw and distribute the water to the farmlands will be required. It will be impractical for Rwanda to introduce subsurface dams into the country from the perspective of the maintenance and management. However, the structure of the dams will be able to be applied and referred in some ways in Rwanda.

4. Visiting water and sewer division of Miyako-jima City

In this section, I will make a report based on the lecture of Dr. Kajiwara, and add other information as appropriate. Dr. Kajiwara is expert on water resource management of Miyako-jima city office. He has also been working on technical assistance toward Independent State of Samoa. In the first part, I'd like to mention problems related to waterworks system and what has been done in Miyako Island. In the next part, I'll cover international cooperation running by Miyako-jima city water authority. I'll go into more detail about problems in water supply business in the last part.

4.1 Between cost performance and public welfare

Water is the most essential element for life. Securing safe drinking water is urgent issue for all of us. As Dr. Kajiwara said, water authority is public "business". Needles to say, the primary responsibility of water authority is to ensure a water supply and provide safe drinking water to people. In addition, water authority should be independent financially and politically from other administrative system. All the costs including labor, maintenance/operation of the facilities and systems have to be financed by water fee. Administrative officers have to place importance on the perspective of cost performance to some extent. What they have to consider here is whether or not water fee can cover the cost associated with infrastructure.

It is commonly acknowledged that Japan has high standard of water-purity for tap water, and that we have access to clean and safe drinking water anywhere. The number of characteristics to be inspected is about 3 to 4 times higher than that of bottled mineral water. Water quality standards have to comply with Waterworks Act requirement. It also has to be based on the result of the examination of water carried out by local government. On the other hand, safety inspection of mineral water is based on Food Sanitation Act.

Because of these structural peculiarities, there must be dilemma between public welfare and cost-effectiveness. If water fee become too high, it could cause some people inaccessible to water. In what follows, I will introduce the practices in Miyako Island.

Miyakojima city consists of six islands—Miyako, Irabu, Shimoji, Kurima, Ogami. Water supplied population is 54,663 (Statistic 2010), and 99.95% of them are served by water supply. In Miyako Island, other Islands area in the world alike, available water resources are limited. Moreover the existing resources are under unstable environment. Because there're no fresh water resources on the surface of the ground, they have to depend on groundwater in order for acquisition of water supply to be stable.

Miyako Island was known as "no-water land" for a long time.

Getting water was urgent priority for islanders. It is noteworthy that Miyako Island enacted Japan's first ordinance of groundwater conservation in 1965 based on the concept that groundwater resource is for public use. However, groundwater is vulnerable. It is easily affected by the condition of surface of the ground. What is written in Silent Spring be easily occur. Once pesticides polluted ground water, it takes an awful lot of time to be clean again. So if one pursues cost-effectiveness, then s/he has to be environmental-conscious. However, if remote islands want to survive, they have to rely on resort development. This is also difficult problem we should bear in mind.

And there're some geological characteristics to be considered. In Miyakojima, water is pumped up from limestone zone, so the water contains high level of minerals such as magnesium and calcium. So there is need to reduce water hardness to make it smooth to drink. However, soft water is easily oxidized and it could cause water pipe spoiled rapidly. Therefore, Miyakojima water division set a standard to keep water hardness around 100 mg/L.

Above all water pumping or other special treatment process consumes electricity. Small population and absence of major consumer may cause decline of water fee, and may push the system on a negative spiral. There is need to create a social system to make water project sustainable.

4.2 Feedback the experience each other

Miyakojima city office has joined international cooperation project to independent state of Samoa located in the middle of Pacific Ocean. Dr. Kajiwara told us that the problem in Samoa is not shortage of water. The main problem is operation and maintenance. According to estimate, leak rate in Samoa is 60 to 80 %, and there's no accurate map of pipe reticulation.

One of the most difficult issues here is misunderstanding towards water treatment. The project aimed to introduce slow sand filtration system or ecological purification system (EPS). EPS doesn't need electricity, chemical. In addition it cost very little, has low impact on environment, and highly adaptable to disaster. However, if one misunderstood operation, then it might be a counterproductive way.

EPS was empirically known way to purify water, the latest study claims that microscopic ecosystem was the key factor. What is needed is to keep algae alive, i.e. enough light, suitable tank (round-shape tank).

EPS's purifying speed is not actually "slow". In high temperature area, the system can be more effective. So filtration time can be reducible to a large extent in hot weather area like Samoa. In Sodeyama treatment plant, where 70 % of water needs are supplied for residents and tourists, there're 9 ponds and 7 of them are at work. Filtration speed is 7 meter a day, and it's enough for around 70,000 people. In Samoa, the temperature is higher than Miyako, it means they can accelerate the speed.

In Dr. Kajiwara's lecture, there're several points worth noting. For one thing, administrative officer cannot put scientific knowledge or theory into practice immediately. If they have no confirmation of safety, they cannot even try these ideas. For, peoples' very lives depend on it. Secondly, I keenly feel the need to negotiate the "acceptable risk." Zero risk is impossible. What we have to do here is to negotiate to what extent we can accept risk.

Third, international cooperation is not just helping others, but also get feedback from the experience and improve our practices. In Samoa and Japan alike, adherent to high-tech is strong among people. In Samoa, Japanese experts introduce basic skills and techniques like leak detection with listening bar. I also fell that now we are at the point of rethinking our way. We should review basic and simple ways in order to maintain systems by ourselves. Forth, we need to adjust our approach to suit the condition of each area. For example, in Samoa each community controls water resource. There is principle of the community, but not concept of broader public. What they do there is to deal with the situation by understanding their point and their culture. This can be applicable when we operate waterworks in Japan, for we have different social relations and systems, and environment.

4.3 The future of Water management in Japan

In this part, I'll mention the current situation in Japan regarding water supply business. It is said around 70 % of smaller municipality won't be able to handle water supply business by themselves in the future. Throughout Japan, there're about 43,000 km end-of-life water pipes.

There are three conceivable problems; financial, technical and operational. Due to financial difficulties and falling population, more and more smaller municipalities have difficulty in operate/maintain facilities. In fact, water pipe-related trouble such as burst of water pipe is increasing. To improve the situation, we need to make use of merit of scale. As you see, smaller municipalities don't have the "scale" in the first time. However, there are few private companies which are able to manage inter-municipal water supply business. There're also problems in technical transfer. Local governments exclusively take a role in water supply business, so private company doesn't have know-how. If foreign company come into Japanese market, and then Japanese company might be thoroughly purged. We should be more careful about developing private company in the context of public-private partnership.

However, small and isolated island like Miyakojima cannot rely on merit of scale. So I think to some extent, they have to rely on subsidies from the government. Miyakojima is under Remote Islands Development Act, and also one of the remote islands regions prescribed in item iii of Article 3 of the Okinawa Promotion and Development Special Treatment Act (Act No. 14 of 2002). However, it seems the subsidy goes to hakomono such as concrete construction, or logistic expense.

We and the government as well have to be more serious about water supply business, or we won't be able to get safe drinking water in the near future. In the midst of globalization, even if it is public works, we have to pay attention to world trend. In terms of international cooperation, we have to find out our advantage based on international relationship. As Dr. Kajiwara told us, we have learned from history of ODA, what we value is to take time and build up trustful relations. In terms of internal affairs, we can learn from what is going on outside Japan. It is reported that international water majors purchased local water supply business, and what they do is to raise the price of water on unilateral basis. We cannot say this won't happen here in Japan.

We could learn many lessons from the experience of Miyako Island. What we have to do is to try to make the most of these lessons, and try to get the situation improved.

Conclusion

The experiments in Miyako Island are practiced with good use of own environment, industry and life style. These may not be put into efforts to other situation easily even in same country. For instance, as it was described above, the wind power generation cannot generate electric power if the wind does not blow continuously. The solar power generation cannot work well if there is no sunlight, and the crowds influence it easily. And the solar panels need a huge place if it is required for high-energy consumption. The hydropower generation needs water resource and a head of water. Moreover, it is conducted with the examined data of local life style and demands. As there is no factory for precision machine in Mikako Island, it can be said, it accepts and challenges renewable energy plan besides to environmental condition. In main land of Japan, it is essential to maintain high quality of electric power for precision machine so it needs to reconsider the way carefully.

When we see the news about energy resource and energy problem, we often do not realize those points even it is simple knowledge. And as Miyako Island has severe environment, the way to figure out problems of Miyako city might give us some keys for tackling each studies.

Visiting four infrastructures in Miyako Island was not only to have widen and deepen our understandings about infrastructures and renewable resource but also to let us realize what we need to learn for future our study in GRM programme. For instance, during the lectures and explanations, social science students had been encountered at lack of knowledge of science and engineering. There is a pros and cons, however it made clear which kind of basic knowledge we have to prepare and learn later. For science and engineering student, the lecture gave some clues and key points such as: Why we shall promote international cooperation and what we have to care about when we work internationally in practice.

Also this onsite practice gave us an opportunity to understand infrastructures system from experiences by visiting there. It is required for GRM students to do our best to make use of the knowledge acquired, and we have to keep learning basics and several cases for making each study richen.