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Possibility and Challenge of Smart Community in Japan

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Abstract

Under the Kyoto Protocol, Japan was supposed to reduce six percent of the Greenhouse Gas (GHG) emission. However, in the year 2012, the statistics suggested that the GHG emission increased 9% compared with the year 1990. Even with the leading energy saving technologies and a lot of experience on handling with environmental issues, Japan still could not meet the target set by Kyoto Protocol. The demonstration area of “smart community” suggests Japanese exploration for low carbon strategies. It is the shift toward the emphasis on the GHG emission control in civil sector. The Japanese version of smart communities also suggests the promotion on the use of renewable and untapped energy resource as well as the collaborative energy to be used in the district level. Much more important than the technology itself, the concept of smart community in Japan makes the community and the city as a whole, setting up a system of cooperation between the industry, government and residents. Taking the city of Kitakyushu as case study, this paper introduces the current development of smart community in Japan, focusing on analyzing its potential and challenges.

Keywords: Smart community, Greenhouse gas, Distributed energy resource, Kitakyushu

1. Introduction

The Kyoto Protocol was widely known as an international act to restrict the Greenhouse Gas (GHG) emission and 2012 was the fiscal year of the first period. Under its restriction, Japan was supposed to reduce six percent of the GHG...
emission, compared with 1990 (Takaaki Ishii 2004). However, the statistic suggested that, even though Japan has greatly improved its energy using efficiency and got a remarkable reward in the year 2009, its yearly GHG emission still increased 4.2% until the year 2010 (Malcolm Foster 2014). After Fukushima crisis, Japan cut down the nuclear energy. As a result, the carbon emission in the 2012 increased by 9% compared with 1990 (Ministry of the Environment 2015). Even with the leading energy saving technologies, Japan still could not meet the goal set by Kyoto Protocol.

The Japanese environmental policy implementation has been started from Second World War, with the booming economy (Michio Hashimoto 1988). The beginning stage started with the industrialization in the year 1950-1960. It caused environmental pollution in Japan and even led to many diseases concerning with the pollution in some cities. In order to tackle with these problems, in the year 1967, Japan set the first environmental policy: Law for Environmental Pollution Control. In the following year, Nature Conservation Act was released. The second stage marked by the oil crisis in the 1970s. It led to the development of energy saving technologies. After the late 1980s, Japanese government set energy use strategy as “Establishing a recycling oriented Society” to make good use of energy resources.

Owing to these efforts, Japan already possessed the higher energy generation efficiency than many of the countries in the world. However compared with other environmental pioneers, such as Germany, Japan is still weak in renewable energy usage. Under these conditions, the new strategy established in 2009 focused on the construction of the smart grid in Japan (Japanese Government 2010). It is a wider range action that involves urban development, energy use and IT technologies.

The “smart community” was emerged in the USA and the Europe. In the USA, the utility grid has problems in reliability that the outages always happened in many cities. Therefore, the smart grid focused on the improving the reliability of aging transmission and distribution infrastructures. The concept was put into practice in the project, Xcel Energy’s SmartGridCityTM (Denver, 2009), the world first smart community project in Boulder, Colorado. The projects will replace half of the oil import to renewable energy resource, 3000 miles grid and fix 40,000,000 families with meters. The government aimed to cut 14% of the GHG emission in the year 2020 and 83% in the year 2050, compared with the year 2005. It cost almost 100,000,000 dollars including the Smart grid infrastructure, Smart meters, MyAccount website and In-home smart devices. The research did by Soma Shekara Sreenadh Reddy Depuru (2011) which discussed various features and technologies that can be integrated with a smart meter. David Haynes (2012) proposed an alternative method of managing the electrical grid, using a district approach rather than centralized control paradigm.

Compared with the USA, the European grids are more reliable. Therefore, the challenge for smart-grid is rapid integrating of renewable resource (S. Massoud Amin and Bruce F. Wollenberg, 2005). The European nations aim to 20% cut in greenhouse gas emissions compared with 1990 and equip 80% of the families with smart meters. Father, it pays more attention to the local district (DOE, 2009). The eco-friendly construction of smart communities in Dutch is an indication to hook for electric cars, solar panels, and household wind turbines. Until now, 1,100,000,000 Euro has been invested into the “Amsterdam Smart City” program, 500 households will pilot an energy-saving system and 728 homes will be equipped with smart meters (Koji Suzuki, 2009)(Mark Scott, 2009). The researches about smart are mostly about the using of renewable resource. Debora Coll-Mayora (2007) provided a general outlook of the definition of this future in the US and the European Union, compared two approaches—GridWiseTM and SmartGrid. Ersan Kabalca (2012) analyzed an monitoring and metering process that concerning renewable energy source in order to propose a solution for solar power system.

Based on experience in the USA and Europe, Japanese model of smart city also weigh on the use of renewable energy with the demand response system, battery infrastructures and smart meters (Takashi Kamitake, 2011). Furthermore, in Japan, the smart city concepts suggest a wider conversation in the all aspects of city infrastructure, such as transportation infrastructure, facility infrastructure, city life line, energy supply infrastructure etc. In the urban development aspect, it conveys the concept of smart growth with the Transit Oriented Development mode and compact city. In energy system aspect, the Japanese smart city models not only focus on the energy saving potential of distributed energy system but also weigh on its disaster resistance features. Yaser Soliman Qudaih proposed an operational scheme for a better performance of the power distribution system in the presence of distributed generation. An artificial intelligence technique has been introduced in form of artificial neural network (ANN) for voltage monitoring and generation output optimization (Yaser Soliman Qudaih, 2011). As one basic facility for the development of the renewable resource and the multiple using for the vehicles, battery infrastructure are civil and back
Kenichi Tanaka presented a methodology for optimal operation of a smart grid to minimize the interconnection point power flow fluctuation. This system consisted of photovoltaic generator, heat pump, battery, and solar collector. To achieve the proposed optimal operation, it used distributed controllable loads such as battery and heat pump (Kenichi Tanaka, 2012).

This paper firstly introduces the concepts and recent motivation of “smart community” in Japan. Further, taking the city of Kitakyushu as an example, it introduces the related projects and its process toward smart city.

2. The “Smart community” development in Japanese

2.1 The Japanese model of “smart community”

In Japan, the “smart community” is defined as an efficient control of electricity flow with fully utilizing IT technology and enables various new services for power suppliers and demand side users. It is a new social system with a network among energy resource, vehicles, homes, buildings, industries and infrastructures. The technologies cover the effective use of electricity and renewable energy resource, the traffic system and life style. The goal of such communities is more than the mere improvement of the living quality. Rather it is to meet the challenges of global environment and sustainable development. Monitoring and operating under the Information and Communication Technology (ICT), the renewable energy such as solar energy, wind turbine can offer to the families and buildings reliably corresponding to the timely demand. The visual management can promptly optimize the network between the energy generation and consumption.

The Japanese model of the smart community can be described as four parts: New information network (the second internet), New energy system, New transportation system and New urban development. Among them, the new energy system, different with the normal system, has two level systems, described in figure 1. The system in community scale, Community Energy Management System (CEMS), which run and monitor the facilities in the community, control the service, received energy demand and consumption information from the secondary energy system. The secondary systems are the energy systems in the building scale, including the Home Energy Management System (HEMS) for smart houses, Building Energy Management System (BEMS) for smart buildings and Factory Energy Management System (FEMS) for smart factory. They directly face to the users, offer the energy to the families, offices and even Electric Vehicles (EV), receive and send energy information to the CEMS.

![Figure 1 Distributed energy system for smart community (CEMS)](Source: Ministry of Economy, Trade and Industry of Japan (2013). Smart Meter Review Meeting)
2.2. The promotion of smart community in Japan

In Japan the government established the related policy and the organization to promote the development of smart community.

(1) The Japan Smart Community Alliance (JSCA)

The Japan Smart Community Alliance (JSCA) was established on April 6, 2010 with the aim to promote the concept of Smart Community through government-private cooperation. The smart community was incorporation of varied technologies, thus the cooperation is necessary. JSCA was the organization, to promote the smart communities by tackling various common issues such as deployment and research on smart grid standardization.

(2) The demonstration areas for the smart community were carried out in 2009;

There were four unique large-scale demonstration projects for the smart community in Japan, Kyoto Keihanna District, Yokohama City, Kitakyushu City and Toyota City.

1) Kyoto Keihanna District was the co-project developed by Kyoto Prefecture, Kansai Electric Power, Osaka Gas Kansai Science City and Kyoto University. It aimed to cut the 20% of the CO2 emission in the residential sector and 30% of the of the CO2 emission in the transportation sector. The real practices including: installing PhotoVoltaics (PV) on 1000 homes, EV car-sharing system; management of the coexist electricity supply between grid, PV and the fuel cell in the houses and buildings (visualization of demand); grant “Kyoto eco-points” for green energy usage.

2) Yokohama City was sponsored by Yokohama city, Toshiba, Panasonic, Meidensha, Nissan, Accenture. It set the target to cut down the 30% of CO2 emission by 2025, compared with 2004. The project included: the energy management system that integrated HEMS, BEMS, EV; PV system (27000kW); Use of heat and unused energy; 4000 smart houses and 2000 EVs.

3) Kitakyushu City was developed together by the Fuji Electric System, GE, IBM and Nippon Steel. It aimed to cut down 50% CO2 emission (compared with 2005). The projects included: real-time management of 70 companies and 200 houses; energy management using HEMS and BEMS; energy system that coordinate demand side management with overall power system.

4) The Toyota city project was supported by the Toyota city, Toyota monitor, Chubu Electric Power, Toho Gas, Toshiba, Mitsubishi heavy Industries, Denso, Sharp, Fujitsu, Dream Incubator, etc. Its object was to cut 20% CO2 emission in residential sector and 40% in transportation sector. The whole project included: Use of heat and unused energy in addition to electricity; demand response at more than 70 homes, the promotion of 3100 EV and the system of V to H (vehicle to house), V to G (vehicle to grid).

Figure 2 The demonstration areas for the smart community in Japan
(3) The road map of “smart community”

The mean policies and targets for the Japanese smart community and the over sea development can be described in the road map of “smart community”, displayed in figure 3. The road map set the road in three stages, covering from the building level to the district level. The policies at the district level focused on pushing forward the renewable energy, which including the two-way energy supply between the grid and the CEMS, the technologies of battery and smart censers. For the housing, the policies shed light on the developing on the smart meters and the EV (electric vehicles). Other office and commercial buildings aimed to the ZEB (Zero emission building).

Figure 3 Road map of “smart community”
(Source: NEDO Renewable Energy Technology White Paper, July, 2010)

3. Demonstration Project in Kitakyushu, Japan

The environmental recovery road of Kitakyushu is very typical in Japan and demonstration project of smart community can keep pace with the Japanese smart community road map. In that case, this research selected out the smart community in Kitakyushu as case study to estimate the low carbon potential of Japanese smart community.

3.1 The environmental recovery footprint of Kitakyushu

Kitakyushu lied in the northern part of Kyushu, the westernmost of the four main islands in the Japanese archipelago. Historically, Kitakyushu area served as Japan’s western gateway and played a major role in the intercourse between Japan and Asia. In 1901, the government-run Yawata Steel Company was established. Northern Kyushu soon became one of Japan’s four leading industrial regions and contributed greatly to the rapid economic growth of Japan(Kenichi Imai, 2009).

Kitakyushu City was created in 1963 with the merger of five neighbouring cities(Figure 6). The population of the city is 0.99 million and jurisdictional area is 487 km² in 2006. Kitakyushu boosted the economy by inviting heavy industries. Kitakyushu had booted itself as a centre for the cement industry, combining high quality limestone produced in the area and Chikuho coal. Large-scale factories sprung up in the area around Dokai Bay, forming the framework of the Kitakyushu Industrial Zone. The period of rapid economic growth was an era of heavy chemical industrialization and remarkable development of heavy and chemical industries, such as steel and machinery.

This boosted the economic growth at an average rate of 20% per annum till the first oil crisis in 1973. Reversibly, this industrialization was the main source of the environment pollution, which began with the “seven colored smoke”.

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<tr>
<th>Grid/CEMS</th>
<th>House</th>
<th>Buildings</th>
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<tr>
<td>*The popularity of PV panel leads to the price decrease</td>
<td>*Installation of smart meters</td>
<td>*Demonstration of ZEB (Zero emission building)</td>
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<tr>
<td>*Measures to maintain power quality.</td>
<td>*The development of HEMS;</td>
<td>*Demonstration of ZEB (Zero emission building)</td>
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<tr>
<td>*Energy storage system will be installed.</td>
<td>*Demonstration of EVs</td>
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<tr>
<td>*The technologies for CEMS</td>
<td>*The integration of HEMS &amp; CEMS</td>
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<tr>
<td>*The cost of the battery decreased because of the technology</td>
<td>*The home service developing</td>
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<td></td>
<td>*EVs used for power storage</td>
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<th>Today</th>
<th>2020</th>
<th>2030</th>
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<tr>
<td>*Decreased PV price stimulate the installation</td>
<td>*ZEB will realize a great reduction of CO₂ emission</td>
<td></td>
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<tr>
<td>*CEMS contribute to Regional energy (RE) generate</td>
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<tr>
<td>*Declining battery price increase installation</td>
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<tr>
<td>*The distribution and transmission that enable two way communication (the distributed energy supply &amp; grid)</td>
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<td>*The cost of using RE will be less than fission price.</td>
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<td>*EMS that can provide an optimized balance in terms of economy and security between CEMS and grid</td>
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<td></td>
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<td>*EMS will charge EVs and can supply back to the grid as regional cooperation</td>
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<tr>
<th>Today</th>
<th>2020</th>
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<tr>
<td>*New public buildings realize the ZEB</td>
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Most specially, in the 1950s and 1960s, Kitakyushu, as one of the leading heavy chemical industrial complexes, suffered serious environmental pollution problems.

Today, the concerted effort of the citizens, universities, enterprises and city government to surmount pollution has proved successful shown in Figure 4. Of all the large cities of Japan, Kitakyushu City, with its clean skies and blue sea, enjoys one of the most comfortable environments. Kitakyushu City is rich in a variety of environmental technologies as well as human resources and has a tremendous amount of expertise gained through these 30-40 years’ struggle.

![Figure 4 The environmental recovery of Kitakyushu](Source: Kitakyushu City)

### 3.2 Countermeasures to improve the environment

The environmental recovery experience of Kitakyushu is different from the other place. Besides the latest technologies to tackle with the pollution, the city set up a cooperative system between the government, industry and the residences. In that way, it not only emphasized environment but set the system that has co-benefit the economic, environment and the society. It can be suggested in the “Ten Principles of Environmental Action for the People in Kitakyushu” (figure 5). The people who live, learn, and work in Kitakyushu, will adhere to these principles and take action to ensure a successful outcome. Through realizing the importance on the creation of a sustainable society, the people of Kitakyushu, practice and promote the following actions by all sectors of society and in all aspects of living, learning, working and playing in Kitakyushu.

![Diagram of Ten Principles of Environmental Action for the People in Kitakyushu](source: Kitakyushu City)
3.3 The way to “Smart”ness

There were three important empirical projects in Kitakyushu stepping to the smart city, the Eco-town project, Hydrogen town project and Smart Community Creation Project. Figure 6 displayed their location and image.

3.3.1 Eco-Town Project

Kitakyushu Eco-Town is the first Eco-Town in Japan that was approved by the government in 1997. The project is a practice to build a resource recycling-oriented society that reduces waste to zero by utilizing all waste products of one industry as the raw material of another. The Eco-Town Center, Hibiki Recycling Complex and Comprehensive Environmental Complex were at first the only targeted areas of the Eco-Town Project. Kitakyushu City then applied for a change in their Eco-Town plan so that the area could be expanded into the whole Hibikinada area in 2002, and then into the whole Kitakyushu City in 2004. The expansion intended to invite new recycling business and incorporate the existing industries. Kitakyushu Eco-Town aims to be “Asia’s International Resource-Recycling and Environmental Industry Base City.” The “vein industry” had been clustered as a unique regional development measure to integrate environmental conservation with industrial promotion in the first phase of the plan (1997~2002). Kitakyushu City formulated the second phase of the Eco-Town Plan in 2002 (2002~) shown in Figure 7. Kitakyushu developed Eco-Town, Japan’s largest research base for the recycling industry, leading the effort in Japan to create a recycling-oriented society, and is now promoting a Cleaner Production project, which combines increased productivity in the course of implementing environmental measures. Kitakyushu invested 120 billion yen in its recycling industry, which created jobs for 1,300 citizens. Presently, the Eco-Town Project has accomplished 17 facilities on the practical research and 23 industrial plants under operation, leading to the reduction of waste and minimizing CO2 emission together with the efficient utilization of resources and energy, which are beneficial to the environment conservation and economic development in recent years.
3.3.2 Hydrogen town project

The Kitakyushu Hydrogen Town project was newly launched in January 2011, in Yahata Higashisa district, Kitakyushu. The project marks as the world-first attempt to use a pipeline recycling the hydrogen generated in the iron manufacturing and operating the fuel cells as an energy supply to the district. The demonstration testing is processed jointly by Fukuoka Prefectural and city gas utilities. The 1.2 km pipeline connected with the hydrogen station and fourteen hydrogen fuel cells that installed in buildings in this district. These fuel cells generate electricity by combining hydrogen and oxygen.

Figure 8 the world-first hydrogen pipeline implementation in Kitakyushu
(Source: Kitakyushu, smart community)

3.3.3 Smart Community Creation Project

Including the hydrogen town project, Kitakyushu also started the Smart Community Creation Project. The government invested 16.3 billion yen over the five-year period from 2010 to 2014. The project was developed beyond the Hydrogen project in the same area. It had four scenarios, smart life, smart office, smart mobility and smart factories (figure 9). Higashida district is the demonstration area of green village, Higashida district has already cut 30% of the CO2 emission compared with the other place in the city. However, the target for the smart community was to cut 50% of the existing emission, still 20% need to get.
The urban structure has been changed in the past few years under the concept of “Environmentally Growing Town” and “Creation of a Shared Community.” Commerce, entertainment, museum and residential buildings were introduced into this area, which made a “compact district” with mixed function. The district energy supply and generation also suggested an indication with regional cooperation.

One of the characteristics of the project is the participation of citizens in the use of energy. It optimized the demand and supply of regional electricity by utilizing IT technology that revolve around energy-saving station. The energy-saving stations are the control centres responsible for operating the smart grid. On one side, the energy-saving stations will send the energy-saving guidance according to the demand-supply situation and the customer can pick up the information by the smart meters. On the other side, the timely energy consumption information and the solar power generation is send back to the energy-saving stations. The advice from the smart meters can help the customers to smooth out the energy fluctuation and improve the efficiency of energy using in the district. At the same time, the consumers can also benefit themselves, including reduced electricity rates by using power in a “smart” manner by introducing dynamical pricing system.

4. Conclusions

This paper introduces the resent Japanese motivation on smart community which aim to cut 50% of the CO2 emission in near future.

Compared with smart city in the USA and Europe, the Japanese smart cities suggest a wider range of concepts that cover from urban development, transportation infrastructure, energy supply infrastructure, city lifeline and information infrastructure. In the energy sector, it suggests great concern on the regional cooperative energy using in district scale with introduction of distributed energy resources. Furthermore, compared with the USA and Europe, the Japanese smart city model not only focus on the energy saving and low carbon effects but also the disaster resistance as well. In that case, most of the Japanese smart cities consist of two models, the normal-time model and the emergency-time model under the disaster. All the concepts and features of Japanese smart city are embodied in the trial smart communities, covering from the building level to the district level. In the building level, it promotes the renewable energy resource and EV using for housing, and ZEB for office and commercial. In the district level, it conducts a two-way energy supply system between the district energy system and the grid.
Among the four trial areas for “smart community” in Japan, the Yahata higashida area in Kitakyushu is a regenerated industrial area, with commercial buildings, residential buildings, office, and industrial areas. It is a much more typical case to suggest the cooperative energy use concept, especially the cooperative energy using between civil sectors and industrial sectors. This suggests a great potential of future smart city model in Japan.

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