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***ABSTRACT*:** Recently, smart grids are being promoted by many governments as a way of addressing energy independence, global warming and emergency resilience issues.
At first, we introduce the concept of smart grid society by showing the concrete
maps. And we appeal the importance of low-carbon society in terms of global warming.
Next, we illustrate some examples of smart grids' adoption in several countries.
And we execute the comparative analysis in each country.
Finally, we choose several Japanese companies based on financial data that contribute to the realization of smart grid society. And we draw the grand design of desirable smart grid society in the foreseeable future.

KEYWORDS: Smart Grid, Low-Carbon Society, Huge Earthquake in the east of Japan

1. INTRODUCTION

We utilize the IT functions such as a computer or the communication system to improve energy saving of the electricity, a cost cut, reliability and transparency (equitableness) . Smart grid raises the function of the existing electric power system and controls a flow of the electricity from both supply and demand side. It is the power network which allowed you to optimize the usage of electricity.

A social tide includes it and as for the world economy, Green New Deal is adopted as the measures not to sacrifice economic growth while largely reducing CO2 with low carbon. It is energy saving, renewable energy, and eco-car to be expected as green industry. We can grasp the smart grid as "infrastructure" of Green Era supporting these.

A smart meter (SM) is attached to the outer wall of a house and the parking lot. This can access it about the generation information such as the measurement, examination of the electric consumption and preservation related information, the dispersion power supply with the thing which let an automatic meter have a communications infrastructure and a connection function in real time. An in-house network (LAN) is built as a system performing domestic information exchange with air conditioning or the solar panel in this SM as a base. In addition, a system (WAN) carrying out SM and the exchanges of the information between the electric power company is built.

The following Figure 1. shows the conceptual diagram of Smart Grid House.

Figure 1. Conceptual Diagram of Smart Grid House

2. EXAMPLES OF SMART GRID ADOPTIONS EXCEPT FOR JAPAN

In this section, we will exemplify the Smart Grid Adoption from both U.S.A. and E.U..

2.1 Example in U.S.A.

U.S. initiatives include the birthplace of smart grid.

There are significant aging power infrastructure obsolescence, efficient management, anti-blackout, electric cars, even on the popular, so, the urgency is high in U.S.. President Obama advocates on the Green New Deal, where reducing CO2. Obama will revitalize the existing industries and foster green industry as "national strategy". And U.S. has to commit to a plug-in hybrid car industry, which assumes the existence of the power infrastructure to withstand power demand. Smart grid is expected to be a vast scale of operations.

Benefits through the introduction of smart grids in U.S. are as follows.

2.1.1 Consumers energy-saving custom and peak shift of electric power equipment utilization are realized. Low public awareness of energy conservation in the U.S. led to the use of luxury. So, there is much room for people to reduce power consumption. It is also possible to refrain from building new power plants by a peak shift.

2.1.2 Eco-car infrastructure is realized.

eco-car infrastructure is the key ingredient for the automotive industry that can revive the employment and economic strength.

2.1.3 Electrical power maintenance and safety are also realized. They can not understand the place of power outages without the phone call from the parties concerned. Large-scale high performance of the new power grid is urgently needed due to frequent power outages in the U.S..

2.2 Example in E.U.

The main purpose of introducing the smart grid of the EU is to introduce large amounts of renewable energy. The reason to focus on the renewable energy for EU is "energy security" and the like. Proportion of coal in the EU's energy consumption is high and the advance of aging facilities will also be more difficult to replace simple emission of CO2. In addition, the decay of the North Sea oil and gas fields are susceptible to geographic risks increasing of oil and natural gas imports from other countries. In addition, EU has wind power of the coastline in the north side and solar energy in the Mediterranean region. The dairy and upland forests of the interior are rich in biomass energy which can be effectively utilized as renewable energy resources. The introduction of renewable energy is necessary to develop the infrastructure and power adjustment. So, the arrangement of smart grid development is essential.

Benefits through the introduction of smart grid benefits in EU are as follows.

2.2.1 The introduction of renewable energy is necessary in order to enable a stable supply of energy supply.

2.2.2 Electrical power failure safety is essential for a renewal of aging facilities.

3. JAPANESE EXAMPLES

Circumstances surrounding Japan’s real smart grid is showing a great climax. The word already spreads in stocks, so-called smart grid-related projects such as electrical equipment manufacturers are preparing under the high expectations. In the broad scope of smart grid, there are businesses that are classified primarily related to the smart grid of existing distribution facilities in the project.

Benefits through the introduction of smart grids in Japan are as follows.

3.1 Effective utilization of electric power equipment with peak shift and energy-saving by consumers are realized. Japanese people are highly conscious of energy conservation. Electric company has boosted the peak shift of consumers through reduction of night time electric utility rate.

In addition, energy efficient activity such as the ESCO business is definitely progressing. However, we are needed to execute further promotion because of being required a significant reduction in greenhouse gases.

3.1.1 Introduction of renewable energy is required in Japan. Japanese government set up the goal of increasing the usage of photovoltaics for 20 times compared with 2005 by 2020. In wind power, Japan Wind Development Co., Ltd. began trials of a stable supply in Aomori Prefecture, the move to make renewable energy utilize is active.

3.1.2 Eco-car infrastructure is also required. Japanese car makers have been the world leader in the diffusion of technology development and high-efficiency cars. But, we can't see the final form of eco-cars.

3.1.3 Japan's system for supply reliability is fairly high. And the number of outage per family per year is relatively low standards as compared with other countries. Therefore, power failure with respect to electrical safety is closer to the goal of a smart grid. Thus, most important areas for smart grid deployment in Japan are introduction of renewable energy, peak shift energy saving and eco-car infrastructure. In addition, the introduction of smart grid urges creation of new businesses, encourages regeneration of existing industries and leads to the economic recovery by producing many employers.

In Table 1, we can show the top 20 companies that tackle with Smart Grid innovation in Japan. These companies are chosen based on the criteria of PER(=Price Earnings Ratio), ROE(=Return On Equity) and R&D factors. These factors are often used by the research analysts by referring to the financial report. Namely, lower PER is better and higher ROE is better for a company. Of course, if a company's R&D is higher than average among the same industries, we can guess that the company will invest more funds to Smart Grid related matters. Incidentally, if we will expand the investment objects from listed companies to unlisted companies, the selected companies may be different from.

Table 1. Smart Grid related companies in Japan

	Company Name	Category		Company Name	Category
1	NKG Insulators, LTD	Glass	11	Hitachi	Elect. Goods
2	Itochu Corp.	Wholesales	12	Toshiba	Elect. Goods
3	Tocalo	Metals	13	Mitsubishi Elec.	Elect. Goods
4	Shimizu Corp.	Construction	14	Fuji Elec. Holdings	Elect. Goods
5	Kandenkou	Construction	15	Takaoka Elec.	Elect. Goods
6	Daiwa House	Construction	16	TDK	Elect. Goods
7	Nihon Unisys	Telecommu.	17	Shin-Kobe Elec.	Elect. Goods
8	Itochu Solutions	Telecommu.	18	Sumitomo Elec.	Non-Metal
9	TEPCO	Elec.&Gas	19	Furukawa Elec.	Non-Metal
10	KEPCO	Elec.&Gas	20	Kawasaki Heavy Ind.	Transportation

4. MODEL OF SMART GRID DIFFUSION

In this section, we construct a model of the spread of a new innovation related to smart grid among cities. Suppose that the innovation is introduced into a community of *N* cities at time $t=0$, and let $x(t)$ define the number of cities that have adopted the innovation at time t. Clearly, $x(t)$ has integer values, but we approximate to it as a continuous function of time. Now, a city will generally adopt the innovation only after she has been told about it by a city that already uses it. Hence, we assume that the number of cities, δx, that adopt the innovation in a small time interval, δt is proportional to the number of cities $x(t)$ that have already adopted and the number of cities $N-x(t)$ that have not adopted. Thus, $\delta x=\alpha x(N-x)\delta t$ where α is a positive constant. Dividing by δt, and letting $\delta t\to 0$, we obtain the differential equation $\frac{dx}{dt}=\alpha x(N-x)$.

We can write the solution as $x=\frac{Ne^{\alpha Nt}}{N-1+e^{\alpha Nt}}$ assuming that $x(0)=1$. This form is similar to logistic equation.

If a central government would urge to adopt smart grid innovation to a city through subsidy, this could well play a significant part in the adoption process, particularly in its early stages. Suppose that in the small time δt, the number of cities being influenced through the subsidy is proportional to the number of cities that have not adopted the innovation $\beta(N-x)\delta t$ where β is a positive constant. The governing equation is now

$\delta x = \alpha x(N-x)\delta t + \beta(N-x)\delta$ giving the differential equation $\frac{dx}{dt} = (\alpha x + \beta)(N-x)$.

This is again a variables separable equation which we can readily solve, since

$\int \frac{dx}{(x+\chi)(N-x)} = \int \alpha dt$, where $\chi = \beta/\alpha$.

Thus, $\frac{1}{(N+\chi)}\int\left[\frac{1}{(x+\chi)} + \frac{1}{(N-x)}\right]dx = \alpha t + A$

i.e. $In\left[\frac{x+\chi}{N-x}\right] = (N+\chi)(\alpha t + A)$,

and writing the arbitrary constant as

$InB = (N+\chi)A$, we have $\frac{x+\chi}{N-x} = Be^{(N+\chi)\alpha t}$.

Solving for x, and with the initial condition $x(0) = 1$, gives $x = \frac{(\alpha+\beta)Ne^{(\alpha N+\beta)t} - \beta(N-1)}{\left[(N-1)\alpha + (\alpha+\beta)e^{(\alpha N+\beta)t}\right]}$.

This is also a sigmoid type growth.

5. COMPATIBILITY BOTH LOW-CARBON AND ECONOMIC GROWTH BY SMART CITY

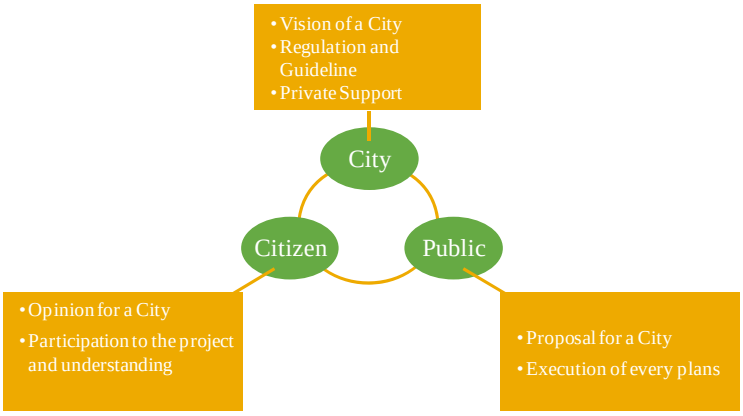
When we consider the treatment of smart grid, the view point of “cost and benefit” is essential for the society. There is a tendency that if an individual company will behave only for its economic rationality, the prospect of “social optimality” will not be realized. Social experiment by the unit of a city will be a catalyst of social optimality. Smart grid for a city will be a differentiate factor among industry, investment and people.

In addition to energy infrastructure, transportation, waste, water, and buildings, "smart city" which makes the overall infrastructure low-carbon society in an integrated manner can be regarded as one of such a city strategy. "Marketing" which is deemed as a complete social system is very important for city strategy of smart grid. The global expansion to other nations will be a next step after completing of one’s own country.

Business opportunities of such a smart city that is compatible with a low carbon and economic growth can’t receive only for the advantage of individual technological factors. Under "Connect" role, it is important to have international competitiveness.

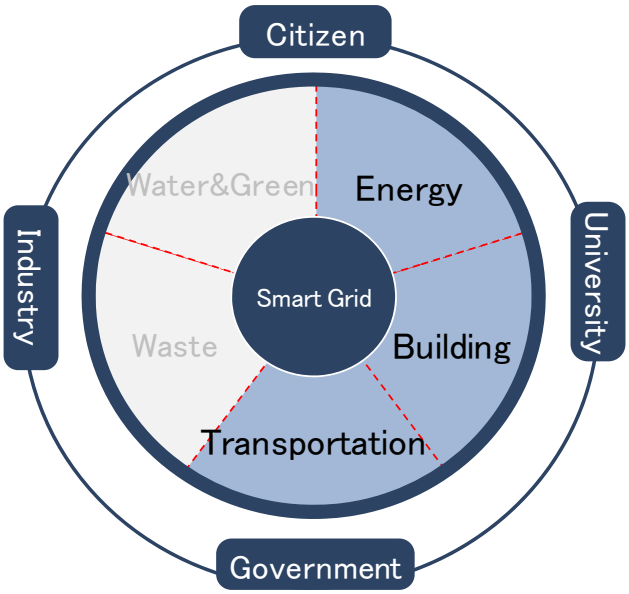
While, smart grid of a low-carbon society is necessary for cooperative framework among local community, utility and citizens from Figure 2.

Figure 2. Solution for “Social Optimality”



Concerning water, green and waste, we must promote the tackle based on the existing plan. In addition, we must arrange the accelerated low-carbon package utilized the smart grid related technology for energy, building and transportation. The concept of it is shown at Figure 3.

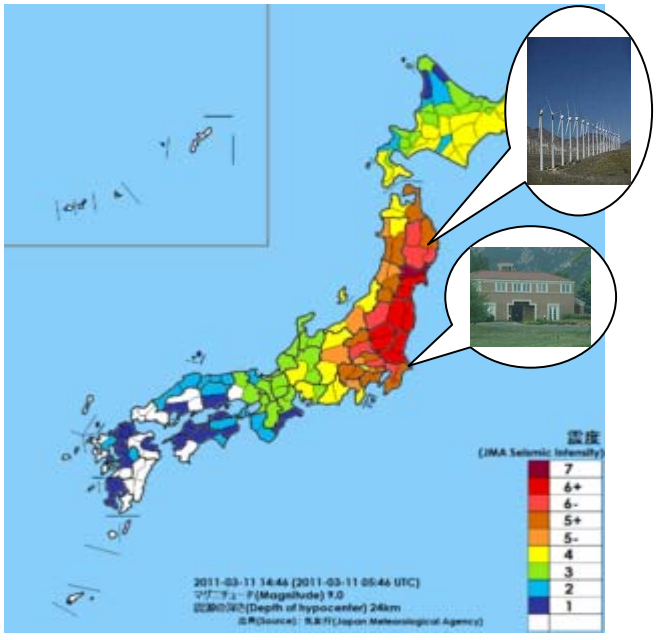
Figure 3. Construction of a “Feasible Solution”



6. GRAND DESIGN OF CONSTRUCTION FOR "SMART GRID SOCIETY IN TOHOKU AREA"

The east of Japan was heavily devastated by the unprecedented huge earthquake and formidable "Tsunami" on March 11th. Especially, east coasts of Tohoku areas were smashed by Tsunami and only remain the ruins. If we look at the bright side of the things, we can change the ruins as the model cities by adopting the Smart Grid Concept. Now, Japanese government is trying to furnish with 225 billion dollars for the revitalization of Tohoku area. Especially, Iwate, Miyagi and Fukushima prefectures can become model cases. For example, the scale of Smart House related products will be 250 billion dollars by 2020 in Japan. While, the scale of Smart City will become 2,250 billion dollars by 2020 in the world. Judging from Figure 4., the western parts of Tohoku area are suitable for wind power, because there is little sunshine and strong wind during winter period. While, the eastern part of Tohoku areas are suitable for solar power all the year round. The optimal combination of smart grid technology will accelerate the pace of the recovery of Tohoku area

Figure 4. Earthquake Map and Smart Grid



7. CONCLUTION

Nowadays, many developed countries are in a recession. Smart grid industry has the hidden power to conquer it. Creation of new businesses and revitalization of existing industries yield to many employees, as a result, they will lead to economic recovery. In addition, many Japanese companies have technological superpower that can lead to smart grid industry. Long-term investment in these companies for individual investors will lead to not only their profits, but also social contribution.

Smart grid industry is a global one and if we can hold these standards and standardization, it will continuously produce enormous benefits. In fact, Japan is losing ground to China and other emerging countries and it seems that Japan is behind. Japan should put more emphasis on this area and create a global smart grid industry.

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