The Trends of Greenhouse Gas Emission for Japanese Electric Utility Post Kyoto Protocol

Jeff Huang, Ken Nagasaka

Abstract*— Japan was on track achieve the Greenhouse gas (GHG) emission reduction target defined under the Kyoto Protocol. But what will be happen after Post Kyoto Protocol, especially by including the impact of devastating March 11, 2011 Earthquake (311 Earthquake) in northeast coast of Japan remained unclear. This paper will firstly describe the current situation of GHG emission and reduction target for Japanese electric utility industry. Followed by introduced the technique of Artificial Neural Network (ANN) to forecast trend of the electricity consumption and GHG emission in Japan, with and without the impact of 311 Earthquake. In the conclusion, we analyze the challenges faced by Japanese electric utility industry regarding the issue of GHG emission reduction Post Kyoto Protocol. According to the simulation result, decrease in electricity consumption coupled with the large increase in nuclear energy to be introduce into Japanese electricity generation, the GHG emission level is expected to significantly decline from 2012-2020. The electricity consumption level in 2020 will be 1% higher than 2010 level but the GHG emission is 3% lower accordingly. If we included the impact of 311 Earthquake into the simulation, the GHG emission generated by Japanese electric utility industry will reach to 656 million metric tons CO_2 in 2020. This is 311.4 million metric tons in excess of the forecast without the impact of the 311 Earthquake. This large increase amount will create a big pressure and challenge for Japanese electric utility in regard of emission reduction Post Kyoto Protocol.

Index Terms*— Greenhouse Gas (GHG) Emission, Post Kyoto Protocol, Emission Reduction, Forecasting, Artificial Neural Network (ANN).

I. INTRODUCTION

Japan is a country with scarce natural energy resources and relies heavily on importation. In an effort to balance energy security and the environment, nuclear energy has played a significant role in electricity generation in Japan. Nuclear power has not only improved energy security, but has offered a solution to the problem of Greenhouse Gas (GHG) emission. However, the devastating March 11, 2011 Earthquake (311 Earthquake) in northeast coast of Japan has exposed several issues surrounding nuclear power generation. As a result, the Japanese Government has decided to shut down all nuclear power facilities temporary, which will inevitably lead to changes in the structure and energy policy of the Japanese power system.

In this research, we began with an analysis of the changes occurring in the Japanese electric utility industry before and after the 311 Earthquake using Artificial Neural Networks (ANN) methodology. This involved a comparison and forecasting of electricity generation and GHG emission, with and without the impact of the 311 Earthquake. In the conclusion, we analyze the challenges faced by the Japanese electric utility industry regarding the issue of GHG emission reduction Post Kyoto Protocol.

II. BACKGROUND

A. Current status of GHG emission generated by Japanese electric utility industry

Under the Kyoto Protocol, Japan has made a commitment to reduce its GHG emission level by 6% compared to its 1990 level. However, the commitment does not clearly specify the reduction allocation and program for each Japanese industry to follow. As a result, most of Japanese industries have defined their own voluntary reduction target without any penalty applied. This is the same for the Japanese electric utility industry - it has planned to reduce CO2 emission intensity by 20% compared to its 1990 level under the "Environmental Action Plan" established in 1996 [1]. This target was based on the emission intensity value, not the amount of reduction, which was used by the electricity industry in other countries. As a result, the target is not directly related to the amount of total generation, but is more closely aligned to energy resource selection and efficiency of power plant.

According to the most recent data released by The Federation of Electric Power Companies of Japan (FEPC), Japan was on track to achieve its Kyoto Protocol target through the end of year 2010. But due to the replacement of nuclear energy by thermal power energy after the 311 Earthquake, emission intensity is expected to dramatically increase and will make achieving the reduction target difficult [2].

B. Medium and Long-term emission reduction target for Japanese electric utility industry

In 2003, the Japanese Government defined its own medium- (year 2020) and long-term (year 2030) energy targets under the "Strategic Energy Plan". This plan outlines the energy policy in Japan

Manuscript published on 30 April 2012.
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and is required to be reviewed at least every three years. From the latest revision in 2010, Japan has committed to reduce its GHG emission level by 25% compared to its 1990 level, conditional on other industrialized countries making similar reduction effort. To do this, the plan outlined the use of zero emission power source (that is, hydroelectric, nuclear energy and renewable energy), to produce up to 70% of National electricity generation by 2030. This includes at least 50% of generation from nuclear energy [3].

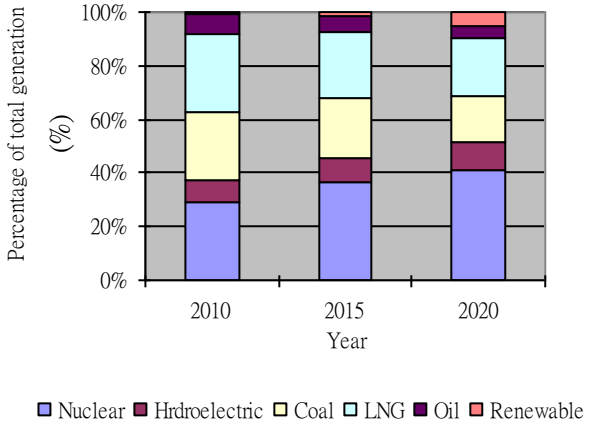

Fig.1. Percentage of Energy Source for Electricity Generation in Japan

A key component of Japan meeting the 25% reduction target will be this increased dependency on nuclear energy. However, the 311 Earthquake has made achieving this target difficult - there was a huge lost in nuclear generation capacity and the safety of nuclear generation was in doubt. The Japanese Government has considered the issues and recognized the need for another review.

III. METHOD

A. *Artificial Neural Network (ANN)*

An Artificial Neural Network (ANN) is a very attractive technique in solving engineering problems, especially for the problem including complex non-linear characteristic. ANN has ability by learning from the relationship between input and output pattern to formularize the problem. This feature is especially useful when solving problems in forecasting. The most commonly used architecture of ANN in power system is the feed forward multi layer perception (MLP) with back propagation (BP) learning algorithm. This network architecture has been widely used for different power system applications, in particular load forecasting [4]. Therefore this type of ANN architecture been applied to forecast the electricity consumption in Japan during 2012-2020 in this research. Furthermore, based on the forecasting result of the electricity consumption, we then analyze the trend of greenhouse gas emissions in Japan post Kyoto Protocol.

The structure of an ANN with BP learning algorithm is shown in the following figure (Fig.2). This structure contains three layers: the input layer, hidden layer and output layer. The nodes within each layer are fully connected to the previous layer. For the BP algorithm, the input data is transmitted through the network, layer by layer until output is calculated. The calculated output is compared to the desired output value to generate the error signal, this error signal is then propagated backward through the hidden layers changing or adjusting the weight and biases in each layer in order to reduce the level of the error signal. The network will train continuously until the desired level of error will be achieved. Once the optimum result is achieved the network will be ready to apply for forecasting problem [5].

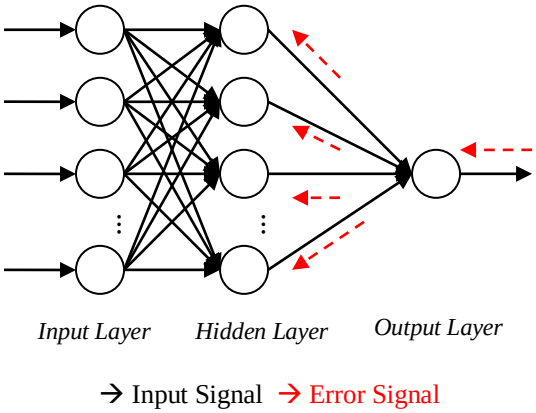

Fig.2. Flow of Signal of ANN with BP Algorithm

A. *Structure of ANN model in this research*

Training is an important process in calibrating the neural network. The accuracy of the forecasted results is heavily dependent on the sufficiency and the relevance of input data for neural network training. From the historical data, we recognized the factors such as GDP (Gross Domestic Product), Population, Household Number, Past Electricity Consumption Data, Index of Industrial Production (IIP) and Weather Data are highly correlated to the level of electricity consumption in Japan [6].

1. GDP (Gross Domestic Product): The total market value of all final goods and services produced in a country in a given year. It has been used as an indicator of economic trends and closely related to the amount of electricity consumption.
2. Population/Household Number: Population and Household number are closely related to electricity consumption. For example, the demand for electric demand will increase in proportion to the population/household number.
3. Past Electricity Consumption Data: Historical data always can give a good indication for the coming trend of electric consumption.
4. Index of Industrial Production (IIP): Index which indicated the growth of various sectors in an en economy for a given period of time.
5. Weather Data: The temperature is related to electric consumption closely. In the summer or winter days, large consumption on cooler/heater which causes a big share of electricity demand.

In this research, we incorporated the historical data of the above-mentioned factors from 1985 to 2005 in the forecasting model. The proposed neural network models were then trained and tested extensively using different numbers of hidden layers until the most accurate result was achieved.

IV. RESULT AND DISCUSSION

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Actual historical data of electricity consumption from the period between 2006-2010 was compared to the forecasting result for measuring the accuracy of the forecasting model used in this research. Table 1 compares the forecasted result to the actual market data. The result shows the error generated was small enough and the model is ready for target forecasting problem (2012-2020).

	2006	2007	2008	2009	2010
Actual Data (billion kWh)	889	920	889	859	906
Forecast Result (billion kWh)	838	842	859	868	871
Error (%)	*5.8*	*8.5*	*3.4*	*1.1*	*3.4*

Table.1: Forecasts Error 2006-20010

A. *Forecast with out impact of 311 Earthquake*

Based on the slow growth in population and economic development, the electricity consumption in Japan is expected to decline significantly in the period of 2012-2020 compared to the consumption in the 90's. According to the simulation result, the electricity consumption in Japan will expect to reach 990 billion kWh in 2020 with average annual 0.9% increase between the period of 2012-2020. This growth rate is similar to the period of 2000-2010 (0.8%) but much lower compared to the time back in the 90's (2.4% annual average in 1990-2000).

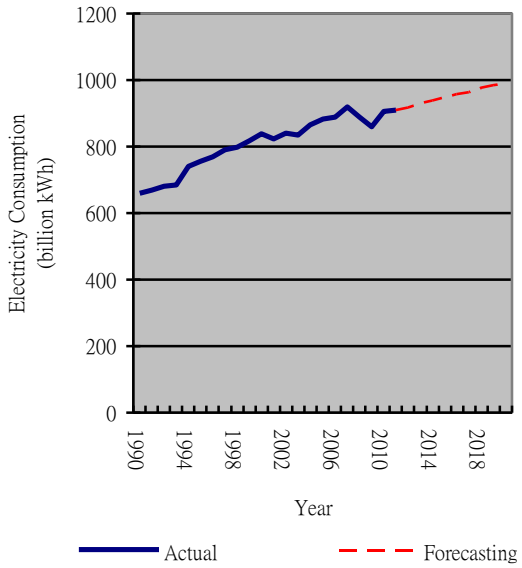

Fig.3. Electricity Consumption Forecasting 2012-2020

Due to the decrease in electricity consumption coupled with the large increase in nuclear energy (scheduled under the Strategic Energy Plan) to be introduce into Japanese electricity generation, the GHG emission level is expect to significantly decline from 2012-2020. Indeed, GHG emission level should decline due to the large increase in nuclear energy even if consumption increases. According to the simulation result, the electricity consumption level in 2020 will be 1% higher than 2010 level but the GHG emission is 3% lower accordingly.

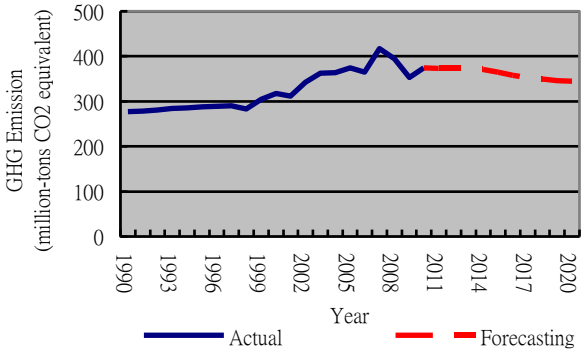

Fig.4. Greenhouse Gas Emission Generation Forecasting 2012-2020

B. *Forecast by including the impact of 311 Earthquake*

Between 2008-2010, 62.7% of electricity in Japan was generated by thermal power, 9.3% by hydroelectric power and 28% by nuclear power. This proportion has stayed almost constant since the early 90's. However, after the 311 Earthquake, large capacity of nuclear power was shut down, and the electricity generated in Japan by nuclear energy has dropped from 28% to 19%. This caused a shift towards thermal power generation, especially the Coal and LNG-fired [7]. According to the Electricity Generated and Purchased Report by FEPC, the amount of Coal and LNG consumed for electricity generation between April-December 2011 had nearly doubled compared to the average consumption in the period of 2008-2010[8]. Currently, the Japanese Government has decided to halt the operation of all nuclear power facilities indefinitely. The last nuclear power facility is scheduled to shut down in April 2012, and this will put an end to nuclear power generation in Japan. In this research, we have assumed that nuclear power will not come back into service and the entire power lose will be replaced fully by thermal power generation, which consist of half Coal-fired and half LNG. According to the simulation result, GHG emission generated by Japanese electric utility industry will reach to 656 million metric tons CO2 in 2020. This is 311.4 million metric tons in excess of the forecast without the impact of the 311 Earthquake. The simulation result is as followed:

ZZ **Fig.5. Electricity Consumption Forecasting, with and without 311 Earthquake in 2012-2020**

According to the Electricity Generated and Purchased Report by FEPC, the electricity consumption after the 311 Earthquake (April-March, 2012) was 3.9% lower compared to the average of last 3 years data (2008-2010). There are two main reasons behind this significant reduction. Firstly, the electricity companies in Japan introduced “Rolling Blackout Policy” inside their service area. Secondly, the Japanese Government was calling for electricity conservation by household and businesses sectors right after the 311 Earthquake. The 311 Earthquake

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has resulted in the loss of 25% of nuclear power generation capacity. The effectiveness of the "Rolling Blackout Policy" and the call for electricity conservation has helped Japan to reduce its electricity consumption and prevent a major blackout. These two activities are expected to continue until nuclear power generation capacity returns to acceptable levels [1]. In this research, we have assumed the percentage of reduction in electricity consumption remains the same till 2020. As a result, the electricity consumption will equal to 951.4 billion kWh in 2020, which is 38.6 billion kWh reduction compared to the forecast without the 311 impact from previous section.

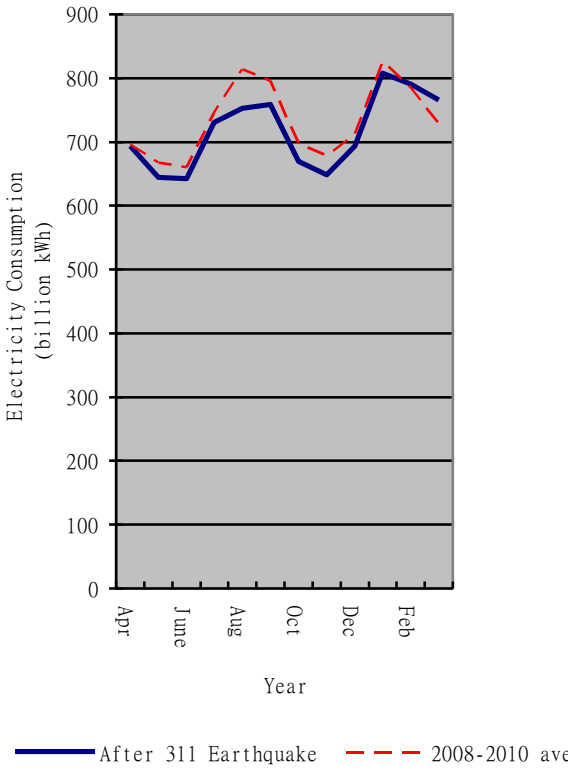
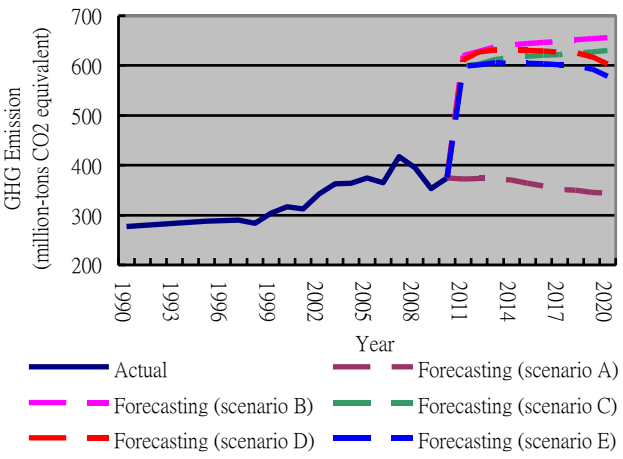


Fig.6. Electricity Consumption before and after 311 Earthquake

Furthermore, the Japanese Government has decided to increase the amount of National's electricity generated by renewable energy resource from the original 5% under Strategic Energy Plan to 20% in 2020. To accomplish this, 8% of power is to be generated from hydroelectric and 12% from renewable resources. Using the abovementioned assumptions and the average of 2008-2010 CO2 emission intensity of energy source, we were able to estimate the amount of electricity consumption and GHG emission in 2012-2020 with the impact of the 311 Earthquake. According to the simulation result, GHG emission generated by Japanese electric utility industry will reach to 578 million metric tons CO2 in 2020. This is 233 million metric tons in excess of the forecast without the impact of the 311 Earthquake. The simulation result is as followed:



Forecasting (scenario A): Without impact of 311 Earthquake
Forecasting (scenario B): All nuclear down, replaced by LNG/Coal
Forecasting (scenario C): All nuclear down, replaced by LNG/Coal. And 4% consumption reduction
Forecasting (scenario D): All nuclear down, replaced by LNG/Coal. And 20% renewable energy for electricity generation
Forecasting (scenario E): All nuclear down, replaced by LNG/coal. 4% consumption reduction and 20% renewable energy for electricity generation

Fig.7. Greenhouse Gas Emission Generation Forecasting 2012-2020

C. Challenge

After the 311 Earthquake, the general public in Japan has demonstrated a strong awareness for electricity conservation. The average electricity consumption between was 3.9% lower than the average consumption in the period of 2008 -2010. However, electricity conservation will remain a great challenge ahead for the Japanese public as its economy returns to a recovery path. Furthermore, the Japanese Government also faces a great challenge – its plan to increase the amount of National's electricity generated by renewable energy resource to 12% in 2020, which is 2.4 times more than the original target under Strategic Energy Plan. The Japanese Government will need to ensure the constructions of renewable energy technology for electricity generation are in line with its ambitious target.

V. CONCLUSION

In this research, we began by presenting the current situation of GHG emission and reduction target for Japanese electric utility industry. Followed by introduced the technique of Artificial Neural Network (ANN) to forecast trend of the electricity consumption and GHG emission in Japan, with and without the impact of 311 Earthquake. In the conclusion, we analyze the challenges faced by the Japanese electric utility industry regarding the issue of GHG emission reduction Post Kyoto Protocol. According to the simulation results, without the impact of 311 Earthquake, the electricity consumption level in 2020 will be 1% higher than 2010 level but the GHG emission is 3% lower accordingly. On the other hand, if we including the impact of 311 Earthquake into the simulation, the GHG emission generated by Japanese electric utility industry will reach to 656 million metric tons CO_2 in 2020. This is 311.4 million

metric tons in excess of the forecast without the impact of the 311 Earthquake. Even considering the recent consumption reduction exercises and the proposal of renewable energy increase, the GHG will still reach to 578 million metric tons CO_2 in 2020. From the above simulation results, we understand the lost of nuclear energy from 311 Earthquake which created the big pressure and challenge for Japanese electric utility in regard of emission reduction Post Kyoto Protocol. Therefore, How Japanese electric utility industry is going to response and adjust the position between the energy security and environmental issues will become the main topic to be study in the future research.

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