

Trend of Citizens' Attitude toward the Use of Nuclear Energy — Results of Continuous Opinion Survey on Nuclear Energy —

Yoshihiko SHINODA* and Yoshimi KAWAMOTO*

(Received February 6, 2015)

On the basis of the result of the opinion survey with the aim to assess the trend of citizens' attitude toward the use of nuclear energy, the authors analyze the trend of citizens' opinion for three years before and after the accident at Fukushima Daiichi Nuclear Power Plant (hereafter the accident) on March 2011. Japanese citizens generally had accepted the use of nuclear energy before the accident, but a large number of them have been getting more suspicious about the future use of nuclear energy after the accident. This change caused by the accident has continuously been seen over the three years after the accident.

Key Words: Nuclear Energy, Citizen, Opinion Survey, Trends in attitudes, Fukushima Daiichi Nuclear Power Plant Accident

1. Introduction

The Atomic Energy Society of Japan has conducted annual questionnaire survey on nuclear energy issues. The survey entitled 'Questionnaire about Nuclear Energy' (hereafter this survey) has been conducted once a year since 2009 until 2014 to investigate the trend of public opinion on the use of nuclear energy^{[1],[2]}.

This survey reveals the characteristics of attitude trend of 500 adult residents living within 30km-radius from the Tokyo railway station in Japan. The summary findings are published on the Nonprofit Public Outreach (Specified Nonprofit Corporation) WEB site. Under the restriction that be used only for academic and educational purposes, everyone can use the raw data of this survey.

This analysis proves the changes in attitudes to the use of nuclear energy after the accident. The citizens generally had accepted the use of nuclear energy before the accident, but a large number of them have been getting more suspicious about the future use of nuclear energy after the accident. After three years from the accident, their attitudes have continuously been changing into suspicious.

2. Outline of This Survey

2.1 Features of this survey

In Japan, before and after the accident, opinion surveys about the use of nuclear energy have been conducted by various organizations, for example Institute of Nuclear Safety System (INSS), Japan Atomic Energy Relations Organization (JAERO) and so on. Kitada^[3] or Yokote^[4] describes the impact of the accident on the basis of other continuous opinion survey by Kitada from INSS or Yokote from JAERO, respectively. This survey is one of a few time-series surveys that can be described the trend of public opinion on the use of nuclear energy in the three years before and after the accident. Therefore, from public attitude trend of the accident before and after three years, this survey can accurately assess the impact of the accident. This paper reports the results from the analysis of the attitude to the use of nuclear energy of the residents in Tokyo metropolitan area. These surveys were conducted in 2009, 2010, 2011, 2012, 2013, and 2104 by quota sampling and placement questionnaire.

2.2 Frame of this survey

Table1 shows the frame of this survey. Designed size of samples is 500 (n=500) and target population is the residents in Tokyo metropolitan area aged 20 or over

* Nuclear Power and Energy Safety Engineering,
Graduate School of Engineering

from all. This survey has a set of questions about nuclear energy and energy related issues and adopts a paper-pencil method.

Table 1 Frame of this survey

	Survey Period	Sample Size (n)	Survey method	Abbreviation
No.1	1st Survey December 2008	500	Quota/ placement	2009 survey
No.2	2nd Survey January 2010	500	Quota/ placement	2010 survey
No.3	3rd Survey January 2011	500	Quota/ placement	2011 survey
Great East Japan Earthquake / Fukushima accident on March 2011				
No.4	4th Survey January 2012	500	Quota/ placement	2012 survey
No.5	5th Survey January 2013	500	Quota/ placement	2013 survey
No.6	6th Survey January 2014	500	Quota/ placement	2014 survey

2.3 Remarkable questions

In this paper, the authors focus on the three remarkable questions as the determinants of attitude toward nuclear energy issues. It is beyond the scope of this paper to handle all the questions in this survey.

(1) Opinion to favor or oppose the use of nuclear energy (hereafter Q1:UTILIZATION)

This question is as follow:

'To what extent do you agree or disagree to use nuclear energy for electricity in Japan?'

Table2 shows the response percentages (rates) of respondents as results of this question between the 2009 and the 2014 surveys. There are five response choices as 'agree', 'tend to agree', 'neither agree nor disagree', 'tend to disagree' and 'disagree'. In this paper, choices are marked as 'A', 'TA', 'N', 'TD' and 'D', respectively.

(2) Sense of usefulness of nuclear energy (hereafter Q2:USEFULNESS)

This question is as follow:

'To what extent do you agree or disagree that it is useful to use nuclear energy for electricity in Japan?'

Table3 shows the response percentages of respondents as results of this question between the 2009 and the 2014 surveys. There are five response choices as the same choices as the question in "Q1:UTILIZATION".

(3) Perception toward nuclear power plant safety (hereafter Q3:SAFETY)

This question is as follow:

'To what extent do you agree or disagree that nuclear power plants in Japan are safe?'

Table4 shows the response percentages of respondents as results of this questionnaire between the 2009 and the 2014 surveys. There are five response choices as the same choices as the question in "Q1:UTILIZATION".

Table 2 Results of Q1:UTILIZATION

	A	TA	N	TD	D
2009	13.2%	28.6%	42.0%	12.6%	3.6%
2010	11.2%	28.6%	43.0%	12.2%	5.0%
2011	14.2%	29.6%	42.4%	11.2%	2.6%
2012	5.8%	14.8%	30.4%	27.0%	21.8%
2013	5.6%	17.6%	26.6%	31.2%	19.0%
2014	4.6%	14.4%	28.0%	29.2%	23.6%

Note: Statistical significance of difference
 ↓ ++, ↓ + == p<.01, p<.05 increase
 ↓ --, ↓ - == p<.01, p<.05 decrease

A	Agree
TA	Tend to Agree
N	Neither Agree nor Disagree
TD	Tend to Disagree
D	Disagree

The percentages in the table may not always add up to 100% due to missing values and rounding.

Table 3 Results of Q2:USEFULNESS

	A	TA	N	TD	D
2009	17.0%	38.4%	37.8%	4.8%	2.0%
2010	17.2%	37.0%	37.2%	5.6%	3.0%
2011	21.2%	40.6%	32.8%	4.4%	1.0%
2012	11.2%	29.6%	34.8%	13.2%	11.0%
2013	11.2%	30.4%	32.8%	14.2%	11.4%
2014	7.8%	32.2%	32.0%	14.6%	13.2%

The percentages in the table may not always add up to 100% due to missing values and rounding.

Table 4 Results of Q3:SAFETY

	A	TA	N	TD	D
2009	2.6%	14.2%	33.8%	36.2%	13.2%
	↓ -				
2010	0.8%	14.2%	34.8%	39.0%	11.2%
2011	1.6%	17.0%	31.6%	39.0%	10.8%
		↓ --	↓ --		↓ ++
2012	0.6%	4.6%	24.0%	35.4%	35.4%
2013	0.4%	5.6%	20.2%	40.0%	33.8%
2014	1.6%	6.2%	24.0%	34.6%	33.2%

The percentages in the table may not always add up to 100% due to missing values and rounding.

2.4 Results

Before the accident, the results of Q1:UTILIZATION in the 2009, the 2010 and the 2011 surveys present that the Japanese public was supportive of the use of nuclear energy for electricity in Japan. There were as many respondents in favor of nuclear energy ('agree' 13.2%, 11.2%, 14.2%, 'tend to agree' 28.6%, 28.6%, 29.6%, and total agree¹⁾ 41.8%, 39.8%, 43.8%, in the 2009, the 2010 and the 2011 survey, respectively) as against it ('disagree' 3.6%, 5.0%, 2.6%, 'tend to disagree' 12.6%, 12.2%, 11.2%, and total disagree²⁾ 16.2%, 17.2%, 13.8%, in the 2009, the 2010 and the 2011 survey, respectively). About four in ten of respondents (42.0%, 43.0% and 42.4%) had no opinion or were hesitant to answer.

The results of Q2:USEFULNESS show that respondents tend to more favorable than that of Q1:UTILIZATION. Many respondents have the cognition about usefulness of nuclear energy for electricity in Japan ('agree' 17.0%, 17.2%, 21.2%, 'tend to agree' 38.4%, 37.0%, 40.6%, total agree 55.4%, 54.2%, 61.8%, in the 2009, the 2010 and the 2011 survey, respectively) as against it ('disagree' 2.0%, 3.0%, 1.0%, 'tend to disagree' 4.8%, 5.6%, 4.4%, and total disagree 6.8%, 8.6%, 5.4%, in the 2009, the 2010 and the 2011 survey, respectively). Roughly six out of ten respondents had regarded nuclear energy as useful energy source of Japan.

By contrast, the results of Q3:SAFETY show that the respondents tend to be less favorable than that of Q1:UTILIZATION or Q2:USEFULNESS. Nearly half of the respondents were anxious about the operation of nuclear power plants. Fewer than 20% of the respondents

have the perception about nuclear power plant safety ('agree' 2.6%, 0.8%, 1.6%, 'tend to agree' 14.2%, 14.2%, 17.0%, and total agree 16.8%, 15.0%, 18.6%, in the 2009, the 2010 and the 2011 survey, respectively) as against it ('disagree' 13.2%, 11.2%, 10.8%, 'tend to disagree' 36.2%, 39.0%, 39.0%, and total disagree 49.4%, 50.2%, 50.8%, in the 2009, the 2010 and the 2011 survey, respectively).

After the accident, the result of the 2012 survey indicates that opposition to the use of nuclear energy for electricity in Japan has risen sharply. The accident caused this dramatic change.

First, as for the results of Q1:UTILIZATION, comparison of the 2011 and 2012 surveys show the statistically significant difference as 8.4 % point, 14.8% point and 12.0% point decrease at response choice as 'agree', 'tend to agree' and 'neither agree nor disagree', while 19.2% point and 15.8% point increase at 'disagree' and 'tend to disagree', respectively.

Likewise, as for Q2:USEFULNESS, comparison of the 2011 and 2012 surveys show the statistically significant difference as 10.0 % point and 11.0% point decrease at response choice as 'agree' and 'tend to agree', while a 10.0% point and 8.8% point increase at 'disagree' and 'tend to disagree', respectively.

For the last question, Q3:SAFETY, comparison of the 2011 and 2012 surveys show the statistically significant difference as 12.4 % point and 7.6% point decrease at response choice as 'tend to agree' and 'neither agree nor disagree', while 24.6% point increase at 'disagree', respectively.

The surveys conducted in 2012, 2013 and 2014 after the accident show that the results of the three questions do not show the significant difference. Therefore, the accident has continuously been affecting over the three years. This survey reveals that the accident has had an impact on public opinion. The most important point is that only few percentages of respondents have selected choice 'agree' at Q3:SAFETY overall the survey period. Before the accident, many respondents had already been concerned about the nuclear power plant's safety.

3. Analysis

In order to evaluate the results of three questions in this survey, the response choices are quantified as numerical indication based on the scale from -2 to 2, while -2 means agreement and 2 means disagreement. This scale indicates a favor/oppose index in regards to

nuclear energy issues from the view point of utilization, usefulness and safety.

Table 5 shows the mean opinion score and unbiased estimate of population variance from sample variance of three questions in all surveys. Here, a mean opinion score indicates the overall tendency of opinion, and a variance of opinion score indicates the dispersion of opinion. It is possible to have a full grasp of the overall attitude of respondents toward nuclear energy issues using this numerical set of score.

Table 5 Mean and Variance of three questions

	UTILIZATION		USEFULNESS		SAFETY	
	Mean	Var.	Mean	Var.	Mean	Var.
2009	-0.35	0.96	-0.64	0.79	0.43	0.95
2010	-0.29	0.98	-0.60	0.88	0.46	0.81
	↓ -		↓ --			
2011	-0.42	0.91	-0.77	0.75	0.40	0.89
	↓ ++	↓ ++	↓ ++	↓ ++	↓ ++	
2012	0.44	1.33	-0.17	1.29	1.00	0.83
2013	0.40	1.31	-0.16	1.33	1.01	0.80
						↓ +
2014	0.53	1.29	-0.07	1.31	0.92	0.96

Note: Statistical significance of difference
 ↓ ++, ↓ + == $p < .01, p < .05$ increase
 ↓ --, ↓ - == $p < .01, p < .05$ decrease

Note: 'Var.' in the table denotes unbiased estimate of population variance.

Numerical score in the table bases on the scale from -2 to 2 where -2 means agreement, 0 means neutral and 2 means disagreement.

Before the accident, the mean opinion scores of Q1:UTILIZATION are in the range of -0.29 to -0.42, in other words, these values indicate that respondents had slightly favored to use nuclear energy for electricity in Japan.

The mean opinion scores of Q2:USEFULNESS are in the range of -0.60 to -0.77 before the accident. The mean opinion scores of Q3:SAFETY are in the range of 0.40 to 0.46 before the accident. Overall opinion about usefulness of nuclear energy has more favorable than that of the use of nuclear energy for electricity. However, overall opinion about nuclear power plant safety has less favorable than that of the use and usefulness of nuclear energy.

The respondents thought that nuclear energy can play an important role in meeting the Japanese electricity

needs, even if respondents had suspicion about safety of nuclear power plant in Japan. Many respondents had ambivalent feeling between the usefulness of nuclear energy and nuclear power plant safety^{[5],[6],[7]}.

After the accident, the mean opinion score of Q1:UTILIZATION in the 2012 survey became 0.44, and the mean opinion scores of the 2012, the 2013 and the 2014 survey after the accident are in the range from 0.40 to 0.53. These values indicate that respondents had slightly opposed the use of nuclear energy for electricity in Japan by the impact of the accident.

Next, the mean opinion score of Q2:USEFULNESS in the 2012 survey became -0.17, and the mean opinion scores of the surveys conducted after the accident are in the range from -0.07 to -0.17. These values indicate that the respondents do not completely deny usefulness of nuclear energy after the accident.

Finally, the mean opinion score of Q3:Safety in the 2012 survey became 1.00, and the mean opinion scores of the 2012, the 2013 and the 2014 survey are in the range from 0.92 to 1.01. These values indicate that the respondents became more suspicious about safety of nuclear power plant in Japan after the accident.

Comparison of the 2011 and 2012 surveys show that as follows: In regard to Q1:UTILIZATION and Q2:USEFULNESS, there is statistically significant difference in mean opinion score and variance between the 2011 and the 2012 surveys. However, in regard to Q3:SAFETY, there is statistically significant difference in mean opinion score and no statistically significant difference in variance between the 2011 and the 2012 surveys. The overall opinion about Q1:UTILIZATION and Q2:USEFULNESS shifted toward negative position and the distribution of opinion was spread. However, the overall opinion about Q3:SAFETY also shifted toward more negative position, in contrast, the distribution of opinion was skewed.

It should be noted that the statistical test for significance of the difference between the two means is applied Welch's T-test^[8] and the statistical test for significance of the difference between the two variances is applied F-test^[9].

4. Discussion

By the way, Japanese general elections were held three times after the accident. The 46th general election of the House of Representative was held on 16

December 2012, and the 47th election was held on 14 December 2014. In addition, the 23rd election of the House of Councillors was held on 21 July 2013. At all the general elections in Japan after the accident, Liberal Democratic Party (LDP) had landslide victory. This party does not deny the future use of nuclear energy as a conservative one and puts emphasis on economic growth policies, and then won about two-third seats of the House of Representative. Many Japanese voters did not select the parties committed to the abolition of nuclear power.

On the other hand, from the results of this survey about utilization, usefulness and safety to use nuclear energy, the other fact is that the accident has continuously influenced to change the attitude over the three years. Then, the accident raised a big issue about the future use of nuclear energy in Japan. In other word, the accident has resulted in a heated public discussion about the future use of nuclear energy for electricity. People in general have tended to express opposition to the use of nuclear energy for electricity in Japan. It might be said that movement of nuclear power phase-out and many people have held demonstrations against nuclear power. This change in social condition confirms the findings of this survey.

Apparently, the opinion from the results in this survey and this voting behavior toward general election are not consistent. The important point to be discussed is the fact that there is difference between the results of this survey and the voting behavior. There seem to be two reasons to justify the gap.

First, in the light of survey, these questions of this survey cannot clarify and measure the mixed feelings about the future use of nuclear energy; for example, 'There is no way to use the nuclear energy at the present, but in the future it should be abolished.' Moreover, the target population of this survey is the residents in Tokyo metropolitan area, not all the people living in Japan.

Second, in the light of Japanese general election, it is generally considered that the electoral system of the House of Representative like a single-member district and low voter turnout might be affected. This problem needs more investigation from a socio-scientific standpoint.

In spite of the results of general election, no nuclear power plant in Japan has been operating up to this time (January 2015). Therefore, we should discuss other issue from the standpoint of re-starting the operation of nuclear power plant, on the basis of the results about this

survey. It confirmed that a large number of respondents have been getting more suspicious about the future use of nuclear energy from the results of three questions in this survey.

In addition, the authors focus on other questions relating to the future use of nuclear energy, but these questions were not asked in all the surveys.

Table 6 shows that the results of the questionnaires on '**To What extent do you agree or disagree about the following statement:**'

- (1) Nuclear power plant in Japan should not resume operation.
- (2) Japan must promote operation of nuclear power plant in the future.
- (3) I personally hate nuclear energy.

There are six response choices as 'agree', 'tend to agree', 'neither agree nor disagree', 'tend to disagree', 'disagree', and 'do not know/no answer', where, DK in the table indicates 'do not know/no answer'.

The overall views of the respondents about the above three questions show that they have increasingly tended to deny the future use of nuclear energy for electricity in Japan. Over half of the respondents oppose the use of nuclear energy. Only about one in ten respondents favor the future use of nuclear energy, and about four out of ten respondents hesitated to answer about the future use of nuclear energy, or had no answer.

These results of the questions presented here reinforce the reality that the accident has caused a major impact on Japanese views about further expanding the use of nuclear energy. Then, these results about the six questions in this survey clearly show that over half of the people would aim at the abolition of nuclear energy use as a source of electricity in the future. In this social situation, re-operation of nuclear power plant might be difficult.

However, we need to focus on the sense of the usefulness of nuclear energy. As shown in Table5, overall sense of the usefulness of nuclear energy would not be completely negative position. It is considered that the usefulness of nuclear energy promotes to be in favor of the use of nuclear energy. The research study of H. Arikawa et al. ^[10] based on internet surveys of Japanese people conducted in 2012 describes that the elasticity of electricity demand explains attitude to the use of nuclear energy.

Table 6 Results of question about

(1) Nuclear power plant in Japan should not resume operation.

	A	TA	N	TD	D	DK
2012						
2013	17.4%	16.0%	37.6%	17.6%	7.0%	4.4%
	↓ ++			↓ --		
2014	26.0%	15.8%	36.8%	8.2%	8.4%	4.8%

(2) Japan must be promoted operation of nuclear power plant in the future.

	A	TA	N	TD	D	DK
2012						
2013	3.8%	7.0%	31.2%	31.0%	20.6%	5.6%
				↓ --	↓ ++	
2014	2.2%	6.2%	31.4%	22.8%	32.8%	4.6%

	A	TA	N	TD	D	DK
2012						
2013	22.2%	23.0%	33.4%	14.4%	4.4%	2.0%
	↓ ++			↓ --		
2014	34.0%	20.0%	34.4%	5.2%	4.4%	2.0%

(3) I personally hate nuclear energy.

The percentages in the table may not always add up to 100% due to missing values and rounding

5. Summary and Conclusions

The most significant finding in this paper is that the impact of the accident is not a transient effect. Japanese citizens still oppose the use of nuclear energy for electricity about three years after the accident. Before and after the accident, public opinion about nuclear energy showed a dramatic change like the end of the war or the social revolution. A majority of the Japanese do not continue to favor the use of nuclear energy for electricity in Japan.

When discussing future energy options for Japan, it is important to have a full grasp of the public attitudes towards nuclear energy. The authors anticipate that this survey will contribute to the decision making of the future use of nuclear energy.

Notes

- 1) 'agree' and 'tend to agree' aggregated
- 2) 'disagree' and 'tend to disagree' aggregated

References

- [1] H. Kimura: "What is the Cognitive Gap between People in the Tokyo Metropolitan Area and Members of the Atomic Energy Society of Japan Regarding Nuclear Power?", *Journal of the Atomic Energy Society of Japan*, 51(9), 29-31 (2009). [In Japanese]
- [2] H. Kimura: "The Perception Gap of Nuclear Energy between Public and Experts after the Fukushima Nuclear Power Plant Accident", *Journal of the Atomic Energy Society of Japan*, 54(9), 42-46 (2012). [In Japanese]
- [3] A.Kitada: "Public Opinion on Nuclear Power Generation Measured in Continuous Polls", *Trans. AT, Energy Soc. Jpn.* 12(3), 177-196 (2013). [In Japanese]
- [4] M.Yokote: "Public Opinion Survey Result in FY2012", *Journal of the Atomic Energy Society of Japan*, 55(6), 43-45 (2013). [In Japanese]
- [5] Y.Shinoda: "Consideration on the Interaction between Society and Nuclear Technology", *Trans. AT, Energy Soc. Jpn.* 6(2), 97-112 (2007). [In Japanese]
- [6] Y.Shinoda, N. Yamano and H. Tori-i: "Public Opinion Survey on Relationship between Society and Nuclear Energy", *Trans. AT, Energy Soc. Jpn.* 7(4), 350-369 (2008). [In Japanese]
- [7] Y.Shinoda, S. Tuchida, and H. Kimura: "Periodical Public Opinion Survey on Nuclear Energy (Inhabitants Living in the Tokyo Metropolitan Area)", *Trans. AT, Energy Soc. Jpn.* 13(3), 94-112 (2014). [In Japanese]
- [8] B.L.Welch: "The Significance of the Difference Between Two Means when the Population Variances are Unequal", *Biometrika*, 29(3), 350-362 (1938).
- [9] G.E.P.BOX: "NON-NORMALITY AND TESTS ON VARIANCE", *Biometrika*, 40(3), 318-335 (1953).
- [10] H.Arikawa, Y.Cao and S.Matsumoto, "Attitudes toward nuclear power and energy-saving behavior among Japanese households", *Energy Research & Social Science*, 2, 12-20 (2014).