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Factors influencing the public intention to use renewable energy technologies in South Korea: Effects of the Fukushima nuclear accident

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HIGHLIGHTS

- The factors influence public intention to employ renewable energy technologies.
- Fukushima accident made significant differences of public perceptions.
- Perceived benefits and risks are employed as key determinants of public attitude.
- Perceived cost and attitude are found as antecedents of the intention to use.
- Perceived trust is a notable motivation of public perceptions.

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ABSTRACT

The Fukushima accident has influenced public attitudes toward energy sources and technologies, including not only nuclear energy, but also other energy sources. Therefore, it is worth investigating how the accident influenced public perceptions of renewable energy and its technologies, between the time before the accident and after the accident. This study aims to explore the effects of the Fukushima accident on the public perceptions of renewable energy technologies in South Korea, the closest nation to Japan. This study found that there were notable differences of public perceptions, including public attitudes, perceived benefits, trust, intention to use, knowledge and risks between before and after the earthquake. In addition, the perceived cost of renewable energy technologies was the primary determinant of the intention to use the technologies before the accident, whereas public attitudes toward the technologies became the main antecedents of the intention after the accident. After the accident, we found that there is a multi-dimensional matrix of perceived trust-benefits (with risks)-attitude-intention to use, in explaining the public acceptance of renewable energy technologies. Moreover, we found significant roles of the perceived trust, benefits and risks in the research model. Based on the empirical findings, both implications and suggestions are presented.

1. Introduction

In the first week of March 2011, shocking news from Japan hit worldwide. An undersea earthquake of 9.0 moment magnitude from about 80 miles off the east coast hit Japan. This earthquake caused a huge tsunami, which penetrated about 6 miles inland. Due to this disaster, Japan recorded huge loss of life, with the known death of 15,000 people, and with about 8000 people missing (National Police Agency of Japan, 2011).

Moreover, together with the huge damage for humans, the whole world worried about other critical issues. Among the issues, nuclear power plants came to the fore as threats to global society. Tokyo Electric Power Company, named as TEPCO, has two nuclear plants in critical regions (Aoki and Rothwell, 2013). Because the tsunami caused over 15-meter-height waves, and the average sea defenses of Japan were designed to overcome about 6-meter high sea waves, two nuclear power plants were broken and inundated by sea waves. Therefore, all installed boiling water reactors, called BWRs, were stopped, by following the guidelines of the emergency manual, but they were overheated by a breakdown of the nuclear fuel control systems. Due to the overheated nuclear power plants, several parts of the nuclear reactors melted. There were also radiation releases to the outside of the reactors, and hydrogen explosions (National Regulation Authority of Japan, 2013).

The radioactive matter from this accident has spread throughout the whole northern hemisphere (Hirose, 2012). In April 2011, the Fukushima nuclear power plant accident was considered as the top emergency level of the International Nuclear and Radiological Event Scale, Level 7, from the International Atomic Energy Agency (International Atomic Energy Agency, 2011). Later,

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the level of the Fukushima nuclear accident was adjusted to Level 8, by creating new criteria. This means that this accident was the most serious nuclear-related accident in world history. Compared to the well-known nuclear accident from Chernobyl in 1986, it was highlighted for two reasons; more than a seven fold of radioactive matter was spilled, while the accident has not yet finished. Radionuclide matter is still being released from the Fukushima plants. To prevent the plants from spilling, TEPCO has so far attempted to achieve cooling status on two occasions, in July 2011 and January 2012 (Tokyo Electric Power Company, 2011), but nobody can ensure that there is no further damage from the radionuclide.

This accident has had significant industrial, political, and national impacts worldwide. For example, it led the German government to crucially change its nuclear power policies, to opt out of making nuclear power energy in future energy policies (Wittneben, 2012). The accident also prompted other countries to have deep discussions about whether they should develop or use nuclear plants (Bradford, 2012; Thomas, 2012). In particular in Asia, there are already many nuclear power plants in South Korea (20 plants), China (13 plants) and India (six plants). In the case of South Korea, because of its regional characteristics, there is drastic resistance to nuclear energy and related facilities (Kang, 2012).

Therefore, because nuclear energy and plants can directly affect crucial negative threats on humans' health, many nations and institutes have aimed at finding substitute sources of energy. With this trend, renewable energy is considered as one of the most possible solutions, to provide an alternative to nuclear energy.

It is also closely associated with climate change. Recently, climate change has become one of the most crucial threats to human life and the environment of the earth (Handmer and Dovers, 2013). Compared to the potential threats of climate pollution from nuclear energy, renewable energy sources can mitigate greenhouse gases, which mainly lead to climate change of the earth (Trainer, 2010).

In spite of the rapidly increased interest in renewable energy, only a few studies have investigated the public's attitude toward renewable energy technologies, including their costs, potential risks and benefits (Devine-Wright, 2005). Moreover, there are few studies that have aimed to explore the public's psychological, cognitive, and economic factors, and knowledge and information of renewable energy technologies regarding their acceptance and attitude of the technologies (Mallett, 2007; Wüstenhagena et al., 2007).

Therefore, this study aimed to investigate the following research questions:

- Is there any difference in the public's attitude toward renewable energy technologies between the time before the Fukushima accident and after the accident?
- What kinds of factors determine the public's attitude towards, acceptance of, and intention to employ renewable energy technologies?

Regarding the first question, this study attempted to track the significant differences of public perceptions toward renewable energy technologies. Because citizens could know the potential risks and possible damage from nuclear energy, which is in a substitutional relationship with renewable energy via the Fukushima accident, there could be significant changes of public perceptions toward renewable energy and its technologies.

Regarding the second question, although a large number of prior studies have aimed to explore the factors determining a particular technology acceptance, only a few studies have aimed to propose a comprehensive framework for renewable energy technologies and their applications (Devine-Wright, 2005; Krohn and Damborg, 1999). Therefore, the current paper aims to introduce a framework for the acceptance of renewable energy technologies that is able to be applied to enhancing the understanding of the technologies, to improve the social and environmental factors of the technologies.

The proposed integrated model highlights psychological and perceived factors that affect the public's attitude and behavior toward the technologies. The logicality and universal validity of the factors and relationships in the integrated model will be assisted by the findings of previous studies and the main survey.

First, we attempt to identify and seek the potential key determinants of public attitudes toward renewable energy technologies. Second, we aim to explore how these factors have changed between before the Fukushima nuclear plant accident and after the accident. Then, we discuss and explain whether these factors contribute to public attitudes toward renewable energy technologies. These factors may be significantly associated with general evaluations and attitudes of the particular technology. Finally, this study presents conceptual evaluations and relationships of the framework, which are significantly related to technological acceptance. We also explore the implications and applicability of the proposed framework.

The remainder of the current study is constructed as follows. We describe the brief trends of renewable energy technologies, and the general energy status of South Korea. Then, the literature review, hypotheses and research model are presented. After that, the research methodology is demonstrated. The results are shown in the following section. Finally, the discussion, conclusion, limitations and future research are presented.

2. Literature review and hypotheses

2.1. Trends and overview of renewable energy

Renewable energy is defined as "energy generated by sources whose supplies are regenerative and virtually inexhaustible" (Arizona Solar Center, 2013). Sunshine, water, wind and the heat from the earth are representative sources of renewable energy.

Although investment in renewable energy technologies and related systems has gradually increased in the world, the present contribution of renewable energy to global energy supplies is moderate. In 2008, the Intergovernmental Panel on Climate Change (IPCC) indicated that renewable energy accounted for about 13% of the primary energy supply in the whole world (Intergovernmental Panel on Climate Change, 2011). However, excluding the use of agricultural and traditional biomass, other renewable energy technologies, such as wind and solar, comprised a very minimal share in the global energy supply (Gross et al., 2003; IEA, 2000). In 2000, these 'new' renewable energy technologies contributed only about 2% of the global energy supply (IEA, 2000). This rate was about 3.0% of the global energy supply in 2009 (KNREC, 2011).

However, after the Fukushima accident, several nations have started to change their energy policies. As mentioned above, the reactions of nations are very varied. For instance, Germany, where nuclear power is one of the major providers of energy supplies, plans to stop all nuclear power plants in 2020, while the policies of the Korea government have not significantly changed (Fauzen and Schiller, 2011).

2.2. Nuclear energy

Nuclear energy plays a significant role in providing energy and electricity to a large number of nations. In 2009, nuclear energy provided approximately 14% of the electrical power in the world.

However, this share went down to about 10% in 2011, because Germany and Japan reduced about 200 TWh from nuclear energy (Ferstl et al., 2012). After the Fukushima accident in 2011, a large number of nations that planned to use nuclear energy, or already had nuclear power plants, have entered intense discussions concerning their plans. Several nations have retracted their plans to proceed with nuclear power projects, and some nations have strengthened their nuclear power plants, to make nuclear plants more secure against natural accidents, while several nations have discarded their plans and found alternative plans (Fauzen and Schiller, 2011).

Another important issue of nuclear power plants is old nuclear plants, which are nearing expiry of their useable life span. These plants need to obtain operating licenses, if they wish to continue their operations. Likewise, they will need to be decommissioned; this decommissioning is also neither cheap nor easy. Previous studies indicated that more than 5 billion US dollars are spent when each nuclear plant is decommissioned, including costs of site restoration, and discarding and storage of used fuel (World Nuclear Association, 2013). In addition to the cost, there are other important concerns, such as the limitation of space. Although nuclear energy can significantly contribute to minimizing CO_2, which is one of the most notable threats leading to climate change, other kinds of environmental and social problems occur, which can become a menace to society, leading to critical pollution of the earth (Davis et al., 2010).

Therefore, a large number of countries have aimed to develop alternative energy production methods, to minimize the level of dependence on nuclear energy.

2.3. Renewable energy status and general energy status of South Korea

Organization for Economic Co-operation and Development (OECD) indicated that only 0.7% of the total energy supply of Korea in 2011 was provided by the six primary renewable energy types: geothermal, tide, hydro (excluding pumped storage), solar, wind, and wave (OECD, 2011), but the Korean government announced that 2.8% of the total energy supply was provided by renewable energy in 2011 (KNREC, 2013). Although there are notable differences in the definitions of renewable energy used by these two statistics, it is obvious that the portion of renewable energy is quite small relative to the total energy supply of South Korea. For example, 11.3% of the total energy supply in Germany and 6.1% of the total energy supply in USA were provided by renewable energy. Table 1 presents the contributions of the six primary renewable energy types to the total energy supply (OECD, 2011).

From 2.1% in 2003 to 2.8% in 2011, the growth of renewable energy use in Korea has been slow (e-National Index, 2012). Therefore, the Korean government has implemented a basic plan to raise the share of renewable energy. In this plan, the government will grow the share of renewable energy in the total electricity supply from 2.1% (2003) to 7.7% (2030). To achieve this modest goal, the government has set up several specific plans, including (1) commercialization with strategic research and development; (2) 10 green projects with green power, green post, and green factory; (3) large ocean wind plants; (4) compulsory renewable energy production; (5) export revitalization; (6) international collaborations; and (7) the creation of new funds (KDI, 2012; Lee et al., 2009; Moon et al., 2011). Examples of governmental plans for increasing renewable energy use are presented in the following sections.

Table 1
The contribution of six primary renewable energy types to the total energy supply; unit: % (*Source*: OECD, 2011).

Nation	2008	2009	2010	2011
South Korea	0.6	0.7	0.7	0.7
Iceland	81.3	81.8	82.5	84.3
USA	5.1	5.4	5.6	6.1
Japan	3.3	3.4	3.3	3.4
China	12.6	12.0	11.6	–
United Kingdom	2.6	3.2	3.4	4.1
OECD	7.5	7.5	7.8	8.5
World	12.7	13.1	13.0	–

2.3.1. Solar energy

Solar energy technologies based on photovoltaic system technology have reached the starting point of utilization and commercial stages. Many users have installed solar energy power plants in a large number of small and isolated places (e.g. islands). However, because the maintenance and installation cost of these plants are quite high, the volume of these plants accounted for only 0.2% of the total South Korean energy resource in 2011 (e-National Index, 2012). Although all capacities of solar energy technologies based on photovoltaic systems were 4.0 MWp in 2001 (Korea Energy Management Corporation, 2002), the Korea government plans to install solar energy plants based on photovoltaic systems of 1045.6 MW in 2018 (Ministry of Knowledge Economy in South Korea, 2008). In addition, the government found that a 3 kW power system of solar energy for residential housing can provide about 15% greater efficiency, compared to the traditional systems (Korea Energy Management Corporation, 2002).

2.3.2. Wind power

As a landmark of South Korean wind power generation, Jeju special province in South Korea is pushing forward a wind power project. In 2010, the total capacity of 40 power units of Jeju Island was about 77.545 MW (KNREC, 2011). Compared to other kinds of energy generation factories and renewable technologies, the technological reliability and capacity of wind power plants with wind turbines are commercially more attractive and widely used (Ministry of Knowledge Economy in South Korea, 2008). In addition, the Korea government announced that the total capacity of wind power will be improved from about 360 MW in 2010 (including all national and individual plants) to 7301 MW in 2030 (KNREC, 2011).

2.3.3. Waste incineration energy

Plants for waste incineration energy make electricity from the heat of waste incineration (KNREC, 2011). In South Korea, there are more than 40 large plants and several middle-sized plants that are generating waste incineration energy. In 2003, the total output generation of the plants was 99 GWh (Ministry of Environment in South Korea, 2003). Since 2006, exclusive refuse derived fuel (RDF) power generation plants have been installed. As of end of 2012, seven RDF plants, which can generate about 500 toes (ton of oil equivalent) per day, are in operation (KNREC, 2013).

2.3.4. Other renewable energy sources

Currently, other kinds of renewable energy technologies, including energy from hydrogen fuel cells, biology, geothermal power plants, hydroelectric power generations, landfill gas generations, and tidal plants, have been developed and used in South Korea. However, the total energy capacity of the energy from these plants is limited (Table 2).

Table 2
The overview of renewable energy status in South Korea; unit: TOE (Korea Energy Management Corporation, 2013).

Types / Year	2008	2009	2010	2011
Total primary energy	240,752,000	243,311,000	263,805,000	275,688,000
Supply proportion of renewable energy (%)	2.43	2.50	2.60	2.75
Sum of renewable energy	5,858,481	6,086,249	6,856,284	7,582,846
Solar heat energy (%)	28,036 (0.5)	30,669 (0.5)	29,157 (0.4)	27,435 (0.4)
Sunlight energy (%)	61,128 (1.0)	121,731 (2.0)	166,152 (2.4)	197,198 (2.6)
Bio-energy (%)	426,760 (7.3)	580,419 (9.5)	754,623 (11.0)	963,363 (12.7)
Wind power energy (%)	93,747 (1.6)	147,351 (2.4)	175,644 (2.6)	185,520 (2.4)
Water energy (%)	660,147 (11.3)	606,629 (10.0)	792,294 (11.6)	965,373 (12.7)
Fuel cell (battery) (%)	4367 (0.1)	19,193 (0.3)	42,346 (0.6)	63,344 (0.8)
Waste energy (%)	4,568,568 (78.0)	4,558,131 (74.9)	4,862,296 (70.9)	5,121,534 (67.5)
Geothermal energy (%)	15,726 (0.3)	22,126 (0.4)	33,449 (0.5)	47,833 (0.6)
Ocean (marine) energy (%)	–	–	223 (0.0)	11,246 (0.1)

Table 3
The total primary energy status of South Korea; unit: million-TOE (KNREC, 2013).

Source	1990	2000	2010	2011
Coal (%)	24.4 (26.2)	42.9 (22.2)	75.9 (28.9)	79.4 (29.3)
Oil (%)	50.2 (53.4)	100.3 (52.0)	104.3 (39.7)	105.1 (38.7)
LNG (%)	3.0 (3.2)	18.9 (9.8)	43.0 (16.4)	46.5 (17.1)
Water energy (%)	1.6 (1.7)	1.4 (0.7)	1.4 (0.5)	1.7 (0.6)
Nuclear energy (%)	13.2 (14.2)	27.2 (14.1)	31.9 (12.1)	32.3 (11.9)
Renewable energy (%)	0.8 (0.9)	2.1 (1.1)	6.1 (2.3)	6.4 (2.4)
Total	93.2	192.9	262.6	271.4

2.3.5. General energy status of South Korea

As shown in Table 3, the first energy consumption volume of South Korea is 271.4 million-toe in 2011. Although coal, oil and LNG account for the greater part of energy production, the share of nuclear power energy cannot be negligible (Table 3). In addition, the Korea Energy Economics Institute also forecasts that the total production from nuclear power energy will steadily increase from 150 TWh in 2011 to 198.4 TWh in 2016, with a 5.7% average increasing rate (cf., the average annual increasing rate of first energy in South Korea will be about 2.8%; KNREC, 2013).

2.4. Acceptance model of renewable energy technologies

There have been a large number of quantitative studies that have investigated public attitudes toward particular energy technologies by using social research methodologies, including surveys (Krohn and Damborg, 1999).

Previous studies have aimed to identify the degree of public awareness regarding different energy technologies as well as their effects (Ku and Yoo, 2010; Lund, 2005). Due to the varied environments of the studies conducted, the results have indicated mixed sets of findings. McGowan and Sauter (2005) indicated that more in-depth knowledge and understanding of different energy sources vary remarkably, although individuals do not have professional and clear information about different energy sources. In addition, McGowan and Sauter (2005) also identified that about 70% of the public in UK agreed to invest in renewable energy technologies, while about 30% agreed to invest in nuclear energy.

Although there are a large number of previous studies for diverse levels of public acceptance of different renewable energy sources and technologies, only few studies have been conducted and analyzed between the time before the shocking accident and the time after the accident, which may significantly change public attitudes toward energy sources (Eiser et al., 1989). Public attitudes toward and preferences of energy sources started in the 1970s (Richman, 1979). Because of the first oil crisis in the early 1970s, energy policies, including sources and plants, were gradually one of the most important public concerns.

Among many energy surveys, citizen–opinion surveys that are conducted using the hypothesis-based approach are more complete and accurate than those using other kinds of approaches (Prati and Zani, 2013). Studies with this approach have produced complex and compositive results, in terms of psychological, socio-demographic and cognitive factors. Therefore, the conceptual model with these factors can be helpful and constructive, in understanding and improving users' acceptance of, and behavioral intention to employ, renewable energy technologies.

2.4.1. Attitude toward technology

Attitudes toward technology indicate a public's belief in the capacity of technological growth to be a great help to the drawbacks and limitations of our society in the future (Sparks et al., 1994). Because technologies can be sometimes considered as intrinsically risky, it is essential to understand the public's attitude toward technologies (Kasperson et al., 2003). Ajzen (1991) proposed a theory of planned behavior, in which the individual's intention to act is determined by their attitudes and subjective norms. Ajzen and Gilbert Cote (2008) indicated that the individual's attitude toward a particular technology is the best predictor of the individual's intention to use that technology.

The theory proposed by Ajzen (1991) is also used to explain the acceptance of a particular technology. For instance, an individual's attitude was the best predictor of that individual's energy-related activities (Fox-Cardamone et al., 2000). Molin (2005) also indicated that the public attitude toward particular energy sources (e.g. hydrogen) leads to the public's willingness to employ the related technologies. Therefore, based on the previous studies, the current study hypothesized:

- H1. Public attitude toward renewable energy technologies has positive effects on the public intention to use renewable energy technologies.

2.4.2. Perceived (social) trust

If the public do not have enough experience of a particular technology, the public's perceptions can be altered by the public's trust, which is formed by the society and their knowledge, as a heuristic, or systematic decisions of the public's opinion (Midden and Huijts, 2009; Siegrist, 2010). Although there is no attempt to define the definition of trust and subjective determinants in the field of energy technologies, Rousseau et al. (1998) tried to define it as "a psychological state comprising the intention to accept vulnerability based upon positive expectations of the intentions or behavior of another".

Previous studies have identified that perceived trust formed by the society, or affected by other individuals in the society, significantly influences the public's perceived benefits and risks (Siegrist, 1999, 2000). For example, this relationship has been found in the majority of advanced technologies these days, such as nuclear energy technology (Siegrist and Cvetkovich, 2000), micro-nano technology, bio-medical technology and carbon–hydrogen technology (Midden and Huijts, 2009; Montijn-Dorgelo and Midden, 2008).

In addition, prior studies have found that perceived trust has indirect effects on the users' attitude toward, and intention to employ particular technologies, via perceived benefits and risks (Midden and Huijts, 2009; Montijn-Dorgelo and Midden, 2008; Siegrist et al., 2007), indicating that individuals' trust could lead to a more positive perception, which could make the individuals feel higher degrees of risks and benefits. Therefore, based on the identified paths proposed by previous studies, this study hypothesized:

- H2. Perceived trust has positive effects on the perceived benefits of renewable energy technologies.
- H3. Perceived trust has negative effects on the perceived risks of renewable energy technologies.

2.4.3. *Knowledge of renewable energy technologies*

A large number of previous studies have indicated that an individual's knowledge about particular technology, including understanding of the impacts of the technology, can affect the individual's perception of benefits and risks of that technology (Chen et al., 2013; Windschitl and Wells, 1996). They also have found that it indirectly affects the individual's acceptance and intention to use the technology. Sjoberg et al. (2004) showed that the degrees and conceptions of knowledge are significantly associated with risk perception. As an example in the field of energy technology, Molin (2005) indicated that the public's higher degree of knowledge about a specific energy source that can cause environmental pollution could lead to the public having a higher degree of perceived risks toward energy technologies in general, while the perceived risks lead to a lower degree of public attitude toward, and intention to use the technologies. Compared to a large number of studies that have indicated the relationships between knowledge of a technology, and the intention to use the technology, there is little research in the field of renewable energy technology (Ellis et al., 2007). Therefore, to address this issue, the current study hypothesized:

- H4. Knowledge of renewable energy technologies has positive effects on the perceived benefits of renewable energy technologies.
- H5. Knowledge of renewable energy technologies has negative effects on the perceived risks of renewable energy technologies.

2.4.4. *Perceived risks and benefits*

Many people that use renewable energies can conceive of their potential benefits and risks, including financial effects and possible adverse effects (Chen et al., 2013), because renewable energy technologies and the sources of renewable energy are well-known. The perceived benefits of renewable energy technologies cover not only the extensive use of renewable energy sources in producing usable energy (e.g. electricity), but also the processing technologies in producing usable energy.

A large number of psychological studies have indicated affective minds significantly related to public attitudes in the field of chemical technology (Chen et al., 2013). Previous studies of the theory of planned behavior and the technology acceptance model have identified that public's affective minds have an indirect effect on the public's behavioral intention to employ and use a particular technology, while they have direct effects on the public's attitude toward the technology (Aboelmaged, 2010; Mathieson, 1991). That is, the public attitude, which is referred to as “the users' evaluative integration when they cognitively utilize particular technologies”, is mainly determined by both cognitive perceived risks and benefits (Davis, 1989; Venkatesh and Davis, 2000). Affective minds, including perceived benefits and risks, can be significantly related to the outcome of decisions, when the public think about a particular technology. Compared to what engineers and experts in this field worry about, the public's perceived fears toward technology risks are not direct risks from the technology, but indirect risks from the environmental and social circumstances in which the technology is used (Chen et al., 2013).

In particular, if the risks of technology advancement are not natural, and the potential detriments are not immediate and striking harm, but time-consuming and gradually emergent, the technology advancement can be all the more terrifying. On the other hand, the public can feel a better expectation of feeling more benefits with fewer risks, when they meet specific technologies, if the public feel that technological advancement is able to provide more wellbeing, and improve the public's life-quality (Starr, 1969). Therefore, the current study hypothesized:

- H6. Perceived benefits have positive effects on the public attitude toward renewable energy technologies.
- H7. Perceived risks have negative effects on the public attitude toward renewable energy technologies.

2.4.5. *Perceived cost*

Although there are numerous issues associated with newly introduced technologies, many scholars have found that the concept of cost is one of the most important variables relating to users' behaviors and perceptions (Wu and Wang, 2005). In estimating users' intentions, the users may compare the potential benefits of the technology with its cost. In particular, the cost factor can be one of the most significant reasons that may slow down and delay the distribution and development of renewable energy technologies (Hartmann and Apaolaza Ibanez, 2007). This is a comprehensive concept that includes the cost of research and development for renewable energy technologies, the initial founding cost, and the cost of maintenance.

Hartmann and Apaolaza Ibanez (2007) indicated that perceived costs include not only monetary and psychological costs, but also the opportunity costs that are the estimated benefits when using traditional energy technologies. In addition, they also found that users' perspectives toward a particular energy technology could be positively improved when using reasonably priced technology. Moreover, prior studies have indicated that perceived cost is one of the most important factors in energy efficiency (Oxera, 2006; Reddy and Painuly, 2004). In addition, Ansolabehere and Konisky (2009) found that there is a significant relationship between the perceived cost and new power plants adoption of wind power facilities, which is one of the renewable energy technologies. Therefore, based on the previous studies, the current study hypothesized as follows:

- H8. Perceived cost has negative effects on the public intention to use renewable energy technologies.

2.4.6. *The proposed research model*

Based on the suggested hypotheses (H1–H8), the research model is proposed and shown in Fig. 1.

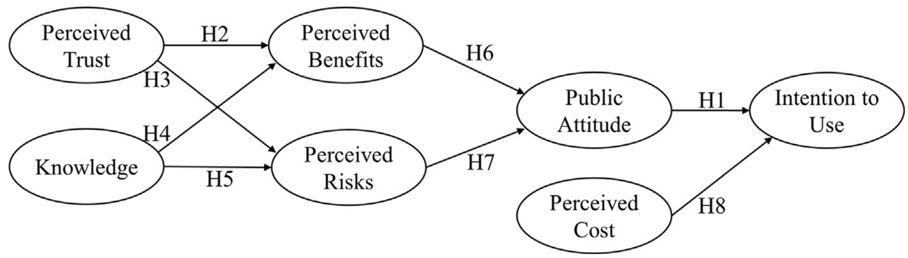

Fig. 1. The research model.

2.5. The relationship between Fukushima accident and the public perceptions toward renewable energy technologies

Because there is a substitutional relationship between nuclear energy and renewable energy, the change of one energy source can significantly affect those of another (Apergis et al., 2010). For example, previous studies have indicated that a citizen's trust on nuclear energy technologies and their attitudes toward the technologies are significantly decreased after nuclear accidents, as in the Chernobyl (Verplanken, 1989), and Fukushima accidents (Prati and Zani, 2013), while their environmental beliefs and altruism are significantly increased (Prati and Zani, 2013). That is, nuclear accidents could make changes of social beliefs, public perceptions, and environmental issues. In particular, as consecutive effects of the accidents, they make the public concerned about environmental issues. Then, raised concerns would lead to a higher degree of interest in renewable energy technologies, which could minimize environmental pollution and risks (Panwar et al., 2011). Therefore, in this perspective, the current study hypothesized:

- H9. The degree of the public's intention to use (renewable energy technologies) after the Fukushima accident is higher than those of the public's intention to use them before the accident.
- H10. The degree of the public's attitude (toward renewable energy technologies) after the Fukushima accident is higher than those of the public's attitude before the accident.
- H11. The degree of the public's perceived trust (of renewable energy technologies) after the Fukushima accident is higher than those of the public's perceived trust before the accident.
- H12. The degree of the public's knowledge (of renewable energy technologies) after the Fukushima accident is higher than those of the public's knowledge before the accident.
- H13. The degree of the public's perceived benefit (of renewable energy technologies) after the Fukushima accident is higher than those of the public's perceived benefit before the accident.
- H14. The degree of the public's perceived risk (of renewable energy technologies) after the Fukushima accident is lower than those of the public's perceived risk before the accident.
- H15. The degree of the public's perceived cost (of renewable energy technologies) after the Fukushima accident is lower than those of the public's perceived cost before the accident.

3. Study method

3.1. Questionnaire design

To develop the survey and collect data, this study examined the following steps, suggested by Venkatesh and Davis (2000):

1. Identify and define practicable characteristics.
2. Operationalize selected variables.
3. Investigate the reliability of the selected factors.
4. Conduct a pre-test and analyze data of the test.
5. Administer the main survey.

The survey questionnaire items were examined in three rounds by a panel organized by three communication professors, three engineers and three researchers who majored in energy technologies, as well as professional experts on renewable energy technologies. Also, three rounds of pre-survey testing were examined. Twenty graduate and undergraduate students took part in the pre-tests, with a nine-day interval between testing periods. All students in the pre-tests were strongly asked to tell the experimenter if they were curious about the presented questions, or did not fully understand a presented individual item, to enhance the integrity of the survey. In addition, we could eliminate several poor items, which are not able to satisfy the threshold value of item-to-total correlation, by calculating Cronbach's alpha. Therefore, all Cronbach's alpha values of the final pre-testing were acceptable (from 0.881 to 0.932; Cronbach, 1971).

A questionnaire survey was conducted two times, in January 2010 and January 2012, in South Korea (they were annual investigations conducted by two national institutes). The survey was administered in six regions and 18 cities. Based on the administrative area classification, a stratified quota sampling method was used, to make sure of the enhanced representativeness of the sample in the survey.

In the first time, which was from January to February 2010, 2392 samples from 4300 questionnaires were collected. Among 2400 samples, 2102 samples were validated and finalized as our samples, after eliminating invalidated samples, such as incomplete responses. The first page of the survey was a cover letter elucidating the information of the experimenter, and the confidentiality and purpose of the survey.

In the second time, which was from January to February 2012, we aimed to collect data from the respondents who took part in the first time survey. Among 2102 respondents in the first time survey, 1510 samples were collected. Among 1500 samples, 1429 samples were validated and used in our analysis, after eliminating incomplete responses (Table 4).

3.2. Measurements

The measurements employed in the current study were based on previous validated studies. All respondents answered each questionnaire item, marked on a 7-point Likert scale (from 1: strongly disagree to 7: strongly agree).

The perceived trust of renewable energy technologies was organized by three items previously used by Koufaris and Hampton-Sosa (2004), Jarvenpaa et al. (2000), and Gefen (2000). The perceived benefits of renewable energy technologies consisted of three items previously validated by Cobb and Macoubrie (2004) and Scheufele and Lewenstein (2005). Perceived risks of renewable energy technologies were composed of three items adapted from Cobb and Macoubrie (2004) and Scheufele and Lewenstein (2005). The perceived cost of renewable energy technologies was organized by three items previously used by Hung et al. (2003), Luarn and Lin (2005), and Wu and Wang (2005). The public attitude toward renewable energy technologies was composed of three items adapted from Davis (1989). The public's intention to use renewable energy technologies consisted of three items previously used by Davis (1989). The public knowledge of renewable energy technologies was organized by three items adapted by Bang et al. (2000) and Scheufele and Lewenstein (2005). All finalized measurements and descriptions are presented in Table 5.

4. Data analysis

Two methods were used to test the suggested hypotheses. First, a series of *t*-tests were conducted, to investigate the effects of the Fukushima accident on the measurements, followed by post hoc analyses via Student's *t*-test (H9–H15). Second, a structural equation modeling (SEM) method was used to test the proposed hypotheses in the proposed research model (H1–H8). In addition, by conducting SEM twice (before the Fukushima accident and after the accident), this study can track the differences of the statistical results between the conceptual relationships in the research model.

5. Result 1: a series of *t*-test

A series of *t*-tests were conducted, with two conditions featuring two times of the surveys (before the Fukushima accident and after the accident). Data of 1429 respondents who took part in both the first survey and the second survey were used in the series of *t*-tests. The results from the *t*-tests with a subsequent post hoc test found that the accident had effects on all measurements, without perceived cost. However, the gap values between the two times were very varied. The degree of public's perceived trust after the accident ($M=5.30$, SD=0.79) was significantly higher than the degree before the accident ($M=4.79$, SD=0.75; $t(1428)=441.90$, $p<0.001$), supporting H11. Respondents after the accident ($M=5.75$, SD=1.26) reported a significantly greater degree of perceived benefits than those before the accident ($M=5.09$, SD=1.31; $t(1428)=17{,}539.73$, $p<0.001$; Fig. 2), supporting H13. The public's attitude after the accident ($M=4.91$, SD=0.68) was also higher than those before the accident ($M=4.22$, SD=0.70; $t(1428)=2212.09$, $p<0.001$), supporting H10, while the public's intention to use after the accident ($M=5.29$, SD=0.89) was significantly higher than those before the accident ($M=4.99$, SD=1.23; $t(1428)=122.87$, $p<0.001$; Fig. 3), supporting H9.

Compared to the changes of the degrees of perceived trust (H11), benefits (H13), attitude (H10), and intention to use (H9), the gaps of the public's knowledge and perceived risks between the two times were moderated. The public's knowledge after the accident ($M=2.90$, SD=1.08) was slightly higher than those before the accident ($M=2.78$, SD=1.07; $t(1428)=3804.96$, $p<0.001$), supporting H12, while the public's risks after the accident ($M=2.80$, SD=1.55) was slightly higher than those before the accident ($M=2.74$, SD=1.47; $t(1428)=11.56$, $p<0.01$), supporting H14.

Table 4
Demographic information of respondents in this study.

Items	Descriptions	$n=1429$	
		N	%
Age	19–29	387	27.1
	30–39	415	29.0
	40–49	277	19.4
	50–59	209	14.6
	More than 60	141	9.9
Gender	Male	741	51.9
	Female	688	48.1
Education	High school	444	31.1
	College	745	52.1
	Graduate or above	240	16.8
Annual income	No regular	301	21.1
	Below US$ 10,000	121	8.5
	US$ 10,000–20,000	462	32.3
	US$ 20,000–50,000	445	31.1
	US$ 50,000–75,000	77	5.4
	US$ 75,000–100,000	14	1.0
	Over US$ 100,000	9	0.6
Residential area	Metropolis	921	64.5
	Small and middle-sized cities	314	22.0
	Rural area	167	11.7
	Others	27	1.9

Table 5
Questionnaire items used in the main survey.

Constructs	Descriptions
Public attitude	ATT1: applying renewable energy technologies is extremely good for us ATT2: applying renewable energy technologies is extremely wise for us ATT3: I strongly agree with the use of renewable energy technologies
Perceived benefits	PB1: renewable energy technologies may lead to new and better ways to clean up the environment PB2: renewable energy technologies may help us develop increased industrial competitive advantages PB3: renewable energy technologies may lead to new and better ways to treat and solve social problems
Perceived trust	PT1: I have trust in renewable energy technologies and generators in South Korea PT2: I believe that renewable energy technologies can improve our energy generation industry successfully PT3: I feel that renewable energy technologies and generators installed in South Korea are generally reliable
Intention to use	IU1: if I could, I would prefer to use renewable energy technologies and generators IU2: I predict our society will use renewable energy technologies and generators in the near future IU3: if I could, I would like to use renewable energy technologies and generators
Public knowledge	PK1: how familiar are you with renewable energy sources and technologies? PK2: how familiar are you with electricity of renewable energy technologies from the source including wind and water? PK3: how knowledgeable are you about renewable energy?
Perceived risks	PR1: renewable energy technologies and plants in South Korea are not safe PR2: renewable energy technologies and plants can harm our society including animals and plants PR3: I am worried about the danger of renewable energy technologies and plants in South Korea
Perceived cost	PC1: I think the equipment cost of employing renewable energy technologies and generators is expensive PC2: I think the maintenance cost of using renewable energy technologies and generators is expensive PC3: it takes a considerable amount of effort and cost to use renewable energy technologies and generators

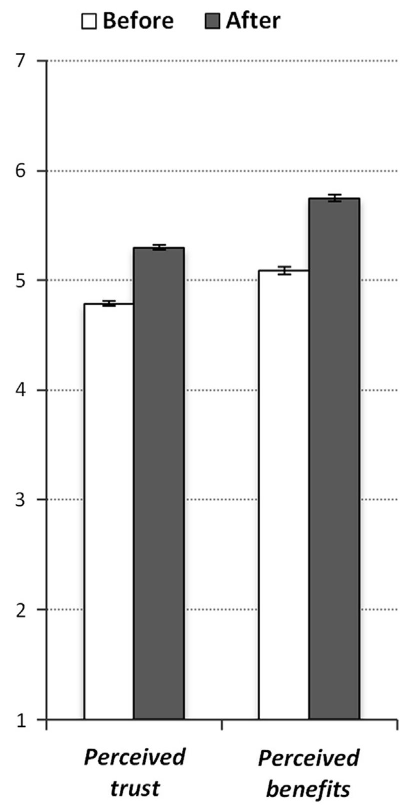

Fig. 2. Effects of Fukushima accident on perceived trust and benefits.

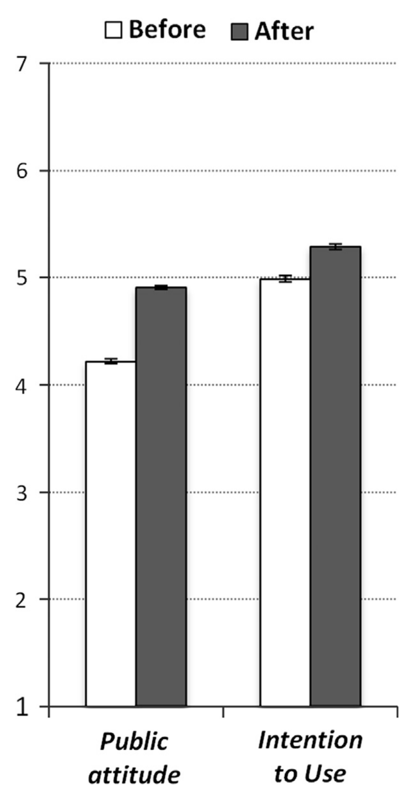

Fig. 3. Effects of Fukushima accident on public attitude and intention.

However, the accident did not affect the public's perceived cost of renewable energy technologies ($t(1428)=0.019$, $p=0.890$; Fig. 4), not supporting H15. All descriptive statistics are presented in Table 6.

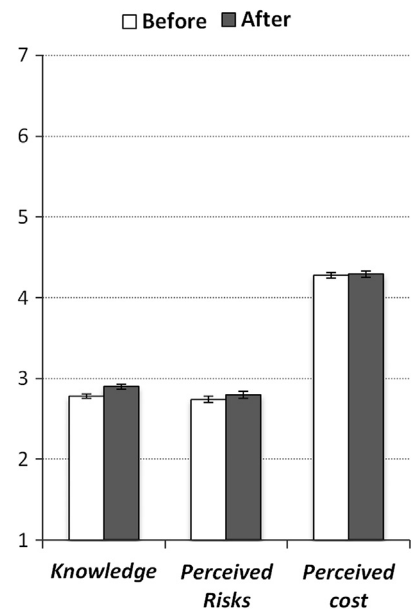

Fig. 4. Effects of Fukushima accident on knowledge, perceived risks and cost.

6. Discussion of result 1

The revealed effects of the accident on the public's knowledge, perceived benefits, risks, attitude and intention to use are several intriguing findings. Although the accident was not associated with renewable energy technologies, the public's perceptions of the technologies were significantly influenced by the crucial issue, which had a great impact on society, of nuclear energy technologies. This means that because renewable energy technologies have a substitutional relationship with nuclear energy technologies (Kim and Chang, 2012), there can be significant differences in the public's perspectives towards the two energy technologies. However, we still do not know the following points:

- What factors contribute to the public's acceptance of renewable energy technologies?
- How much did the factors and conceptual relationships change between the time before the Fukushima accident and the time after the accident?

Thus, to address these points, we conducted a SEM analysis in the following section.

7. Result 2: the structural equation modeling (SEM) approach

7.1. Analysis methods

The hypothesized causal connections were examined by the SEM method. With LISREL 8.70, a confirmatory factor analysis (CFA) was used, in order to evaluate the validity and reliability of the constructs. Considering that prior studies indicated that more than 200 sample sizes are recommended for the accurate results of SEM (Anderson and Gerbing, 1988), this study met this criterion.

7.2. Measurement reliability and validity

The overall fit indices indicated that the data from the survey was well represented by the measurement model without the ratio of the χ^2/df. About the ratio of the χ^2/df., prior studies indicated that this ratio is too sensitive, given the size of samples (Table 7; Hair et al., 2006).

Table 6
Descriptive analysis of the constructs between two times.

Constructs	Before Fukushima accident		After the accident		The gap between the moments	t-value
	Mean	SD	Mean	SD		
Public attitude	4.22	0.70	4.91	0.68	0.69	2212.09**
Perceived benefits	5.09	1.31	5.75	1.26	0.66	17,539.73**
Perceived trust	4.79	0.75	5.30	0.79	0.51	441.90**
Intention to use	4.99	1.23	5.29	0.89	0.30	122.87**
Public knowledge	2.78	1.07	2.90	1.08	0.12	3804.96**
Perceived risks	2.74	1.47	2.80	1.55	0.06	11.56*
Perceived cost	4.28	1.33	4.29	1.42	0.01	0.019 (ns)

ns, no-significance.
* $p<0.01$
** $p<0.001$

Table 7
The fit indices of the measurement model.

Fit indices	Before Fukushima accident	After Fukushima accident	Recommended level	Source
χ^2/df	4.08 ($p<0.001$)	4.44 ($p<0.001$)	<3.0	Hair et al. (2006) and Holbert and Stephenson (2002)
Normed Fit Index (NFI)	0.944	0.912	>0.900	Fornell and Larcker (1981) and Bentler and Bonnet (1980)
Incremental Fit Index (IFI)	0.970	0.941	>0.900	Fornell and Larcker (1981) and Bentler and Bonnet (1980)
Comparative Fit Index (CFI)	0.942	0.922	>0.900	Joreskog and Sorbom (1996)
Goodness-of-Fit Index (GFI)	0.948	0.961	>0.900	Bagozzi and Yi (1988) and Hoe (2008)
Adjusted Goodness-of-Fit Index (AGFI)	0.947	0.953	>0.900	Fornell and Larcker (1981), Hoe (2008) and Brown and Cudeck (1993)
Standardized Root Mean Square Residual (SRMR)	0.050	0.048	<0.080	Bagozzi and Yi (1988) and Hoe (2008)
Root Mean Square Error of Approximation (RMSEA)	0.043	0.048	<0.060	Joreskog and Sorbom (1996) and Brown and Cudeck (1993)

To evaluate the reliability of the measured constructs, values of Cronbach's alpha and composite reliability were computed. All computed values met the recommendations of prior studies (above 0.70; Cronbach, 1971). Moreover, previous studies identified that all factor loadings should be higher than 0.50, to make sure of convergent validity (Anderson and Gerbing, 1988; Hair et al., 2006). As presented in Tables 8 and 9, all factor loadings were above the recommended degree for convergent validity (ranged from 0.705 to 0.902).

Fornell and Larcker (1981) also recommended that the square root of the average variance extracted must be greater than the correlations between the two constructs. As shown in Table 10, all constructs met the satisfied levels for discriminant validity.

7.3. Hypothesis testing

The hypothesized connections were explored, to investigate conceptual relationships. Identical with the fit indices of the measurement model, the model fit indices of the proposed model were acceptance without the ratio of χ^2/df (Table 11). As presented in Table 12 and Fig. 5, the statistical results corroborated the same hypotheses. However, the detailed analyses were different between the two times.

7.3.1. Before the Fukushima accident

The results of the data before the Fukushima accident supported six hypotheses. Two hypotheses related to the knowledge of renewable energy technologies were not supported (H4, $\beta=-0.004$, CR$=-0.154$, $p=0.878$; H5, $\beta=-0.010$, CR$=-0.390$, $p=0.697$). The perceived benefits had a significantly positive effect on the public attitude (H6, $\beta=0.834$, CR$=95.674$, $p<0.001$), while the perceived risks had a moderately negative effect on the public attitude (H7, $\beta=-0.416$, CR$=-47.756$, $p<0.001$). Similarly, compared to the positively moderate effect of the public attitude on the intention to use (H1, $\beta=0.297$, CR$=20.145$, $p<0.001$), the perceived cost had a negatively stronger effect on the intention to use (H8, $\beta=-0.776$, CR$=-52.704$, $p<0.001$). In addition, the perceived trust was significant antecedents of the perceived benefits and risks (H2, $\beta=0.201$, CR$=-7.767$, $p<0.001$; H3, $\beta=-0.156$, CR$=-5.968$, $p<0.001$), whereas the knowledge of renewable energy technologies did not significantly affect the perceived benefits and risks (H4 and H5).

About the variances of the constructs, 89.1% of the variance in the public attitude was elucidated by perceived benefits and risks. The public attitudes and perceived cost explained 69.0% of the variance in intention to use.

7.3.2. After the accident

The results of the data after the accident also supported six hypotheses without knowledge-related hypotheses (H4, $\beta=-0.012$, CR$=-0.461$, $p=0.644$; H5, $\beta=-0.003$, CR$=-0.102$, $p=0.919$). Both perceived benefits (positive) and risks (negative) had significant effects on the public attitude (H6, $\beta=0.775$, CR$=167.888$, $p<0.001$; H7, $\beta=-0.592$, CR$=-104.659$, $p<0.001$). Public attitude significantly affected the intention to use (H1, $\beta=0.857$, CR$=84.689$, $p<0.001$), while the perceived cost had a moderate effect on the intention to use (H8, $\beta=-0.345$, CR$=-34.078$, $p<0.001$). The perceived trust significantly affected the perceived benefits (positively; H2, $\beta=0.281$, CR$=11.047$, $p<0.001$) and risks (negatively; H3, $\beta=-0.142$, CR$=-5.423$, $p<0.001$), while the knowledge of renewable energy technologies did not have significant effects on the perceived benefits and risks (H4 and H5).

Table 8
Convergent validity and internal reliability of the constructs before Fukushima accident.

Construct	Item	Internal reliability		Convergent validity		
		Cronbach's alpha	Item-total correlation	Factor loadings	Composite reliability	Average variance extracted
Perceived trust	PT1	0.951	0.855	0.846	0.887	0.724
	PT2		0.884	0.811		
	PT3		0.896	0.894		
Public knowledge	PK1	0.912	0.879	0.810	0.819	0.602
	PK2		0.864	0.777		
	PK3		0.806	0.739		
Perceived benefits	PB1	0.910	0.824	0.752	0.800	0.572
	PB2		0.848	0.794		
	PB3		0.820	0.722		
Perceived risks	PR1	0.878	0.811	0.811	0.801	0.573
	PR2		0.798	0.722		
	PR3		0.777	0.735		
Public attitude	ATT1	0.924	0.818	0.804	0.838	0.634
	ATT2		0.834	0.799		
	ATT3		0.846	0.785		
Perceived cost	PC1	0.909	0.841	0.858	0.841	0.639
	PC2		0.839	0.712		
	PC3		0.884	0.821		
Intention to use	IU1	0.900	0.846	0.840	0.885	0.720
	IU2		0.901	0.877		
	IU3		0.854	0.828		

Table 9
Convergent validity and internal reliability of the constructs after the accident.

Construct	Item	Internal reliability		Convergent validity		
		Cronbach's alpha	Item-total correlation	Factor loadings	Composite reliability	Average variance extracted
Perceived trust	PT1	0.929	0.840	0.850	0.852	0.657
	PT2		0.811	0.789		
	PT3		0.839	0.791		
Public knowledge	PK1	0.902	0.808	0.795	0.847	0.648
	PK2		0.888	0.818		
	PK3		0.856	0.802		
Perceived benefit	PB1	0.891	0.794	0.778	0.843	0.641
	PB2		0.840	0.823		
	PB3		0.812	0.801		
Perceived risk	PR1	0.910	0.824	0.801	0.824	0.610
	PR2		0.831	0.811		
	PR3		0.797	0.728		
Public attitude	ATT1	0.922	0.835	0.801	0.801	0.573
	ATT2		0.798	0.762		
	ATT3		0.710	0.705		
Perceived cost	PC1	0.844	0.840	0.865	0.853	0.660
	PC2		0.861	0.854		
	PC3		0.726	0.709		
Intention to use	IU1	0.928	0.900	0.902	0.893	0.736
	IU2		0.848	0.812		
	IU3		0.865	0.857		

For the variances of the constructs, 85.4% of the variance in intention to use was explained by the perceived cost and public attitude, while the perceived benefits and risks explained 95.5% of the variance in the public attitude.

7.4. Supplemental analyses

We examined additional SEM analyses according to age level, gender, education level, annual income, and residential area in order to examine whether there were notable structural differences in public acceptance across subjective groups. The results found that all subjective groups showed similar conceptual patterns of public acceptance to those indicated by the whole group.

8. Discussion of result 2

Although the supported causal connections before the Fukushima accident were significant after the accident, there were notable

Table 10
Results of discriminant tests; square roots of the average variance extracted are shown in diagonal elements.

Constructs	1	2	3	4	5	6	7
Before Fukushima accident							
1. Perceived trust	0.851						
2. Public knowledge	−0.009	0.776					
3. Public benefit	0.201	−0.006	0.757				
4. Perceived risk	−0.156	−0.009	0.816	0.757			
5. Public attitude	0.364	0.004	0.771	0.413	0.796		
6. Perceived cost	−0.130	−0.002	−0.322	−0.170	−0.417	0.799	
7. Intention to use	0.167	−0.012	0.394	0.207	0.497	−0.626	0.849
After the accident							
1. Perceived trust	0.810						
2. Public knowledge	0.012	0.805					
3. Public benefit	0.280	−0.008	0.801				
4. Perceived risk	−0.142	−0.004	0.752	0.781			
5. Public attitude	0.579	−0.011	0.631	−0.018	0.757		
6. Perceived cost	−0.165	0.008	−0.304	−0.144	−0.284	0.812	
7. Intention to use	0.424	0.013	0.541	0.076	0.733	−0.634	0.858

Table 11
The fit indices of the research model.

Fit indices	Before Fukushima accident	After Fukushima accident	Recommended level	Source
χ^2/df	4.07 ($p<0.001$)	4.01 ($p<0.001$)	<3.0	Hair et al. (2006) and Holbert and Stephenson (2002)
NFI	0.951	0.931	>0.900	Fornell and Larcker (1981) and Bentler and Bonnet (1980)
IFI	0.964	0.912	>0.900	Fornell and Larcker (1981) and Bentler and Bonnet (1980)
CFI	0.944	0.901	>0.900	Joreskog and Sorbom (1996)
GFI	0.940	0.922	>0.900	Bagozzi and Yi (1988) and Hoe (2008)
AGFI	0.952	0.941	>0.900	Fornell and Larcker (1981), Hoe (2008) and Brown and Cudeck (1993)
SRMR	0.059	0.054	<0.080	Bagozzi and Yi (1988) and Hoe (2008)
RMSEA	0.049	0.047	<0.060	Joreskog and Sorbom, (1996) and Brown and Cudeck (1993)

Table 12
Summary of hypothesis tests.

Hypothesis	Before Fukushima accident				After the accident			
	Path coefficient	SE	CR	Results	Path coefficient	SE	CR	Results
H1.ATT→IU	0.297**	0.016	20.145	Supported	0.857**	0.009	84.689	Supported
H2.PT →PB	0.201**	0.045	7.767	Supported	0.281**	0.041	11.047	Supported
H3.PT →PR	−0.156**	0.051	−5.968	Supported	−0.142**	0.051	−5.423	Supported
H4.KN→PB	−0.004	0.032	−0.154	Not supported	−0.012	0.030	−0.461	Not Supported
H5.KN→PR	−0.010	0.036	−0.390	Not supported	−0.003	0.038	−0.102	Not supported
H6.PB →ATT	0.834**	0.007	95.674	Supported	0.775**	0.010	167.888	Supported
H7.PR →ATT	−0.416**	0.006	−47.756	Supported	−0.592**	0.020	−104.659	Supported
H8.PC →IU	−0.776**	0.013	−52.704	Supported	−0.345**	0.010	−34.078	Supported

ATT, public attitude; IU, intention to use; PT, perceived trust; PB, perceived benefits; PR, perceived risks; KN, knowledge; PC, perceived cost.
** $p<0.001$.

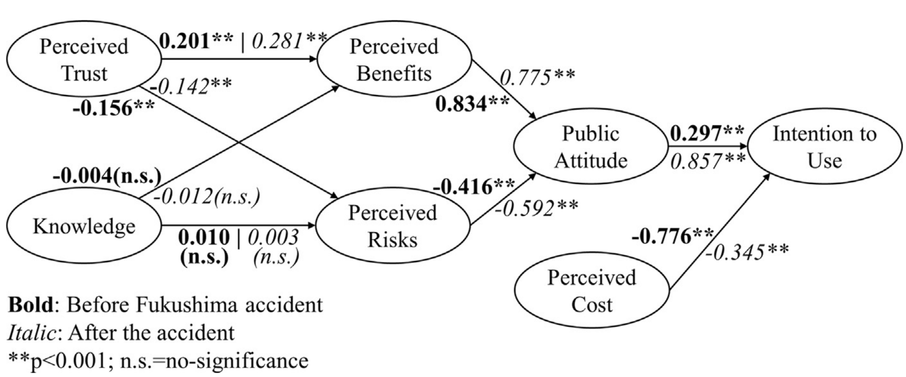

Fig. 5. Results of the research model.

transitions of public perceptions. First, the main determinant of intention to use was changed. Before the accident, the perceived cost (H8, $\beta=-0.776$) showed a stronger effect on intention to use than the public attitude (H1, $\beta=-0.297$). However, after the accident, the public attitude (H1, $\beta=0.857$) became the more powerful antecedent of the intention to use, than the perceived cost (H8, $\beta=-0.345$).

That is, although the Fukushima accident was not triggered and operated by renewable energy technologies, it resulted in providing the public with energy-related issues from more diverse perspectives, not only as regards their current or potential cost, but also their individual evaluation of particular energy technologies.

Second, the effect of the perceived risks on the public attitude was enhanced (H7, $\beta = -0.416 \rightarrow \beta = -0.592$), while both the perceived benefits and the risks significantly affected the public attitude (H6). This means that the accident allowed the public to know the potential risks and be concerned when their government, or they, produce energy, including electricity, and install new energy generation plants.

Third, in both the times, knowledge did not have significant effects on the perceived benefits and risks (H4 and H5). It may be that it was too difficult to know professional or detailed information of the renewable energy technologies. Instead of the knowledge, the social and environmental effects of the technologies, including potential risks and benefits, were more highlighted and issued.

9. Conclusions

The purpose of the current study was to investigate the effects of the Fukushima accident, one of the most shocking nuclear energy accidents ever, on the intention to employ renewable energy technologies with primary and conceptual approaches. The current study aims to find the primary antecedents of the intention to employ renewable energy technologies, generators and their applications. Two variables of perceived cost and public attitude lead to the intention to use, while the antecedents of the public attitude toward the technologies via two constructs of perceived risks and benefits of using the technologies.

From the antecedents, a deeper understanding of the perceived trust that guides the two constructs (benefits and risks) of the technologies could significantly aid engineers and researchers in elucidating a higher degree of variance in the attitude toward the technologies. The statistical results from the empirical study indicated that there are notable changes of public perceptions, public attitude, perceived benefits, trust, intention to use and public knowledge, between the two times, while the research model sufficiently elucidates the collected data.

The public attitude is mainly determined by the perceived risks and benefits, in accordance with prior research. The perceived benefits and risks are significantly affected by the perceived trust. However, an individual's knowledge is not associated with the individual's perceived benefits and risks of employing renewable energy technologies. It is a notable point that there is little or no interrelationship between an individual's knowledge of particular energy technologies, including their applications, and the individual's perceived risks and benefits.

In addition, the results after the Fukushima accident contribute to systematic understandings of the multi-dimensional and interactive structure of individual knowledge-perceived benefits (with risks)-public attitude-intention to use, while there is a relatively low degree of systematic interrelationships between the significant paths before the accident.

10. Implications, limitations and future studies

This study found that the higher degree of perceived trust of renewable energy technologies leads to the public's benefits and risks from using the technologies, and vice versa. The public's more increased perceived benefits and more decreased risks allowed the public to have a more positive attitude toward renewable energy technologies. In addition, the more positive attitude and lower degree of perceived cost are significant contributors to determine the public's intention to use the technologies. Although there are several minor changes between the time before the accident and the time after the accident, the above-mentioned relationships did not change.

As shown in this study, although the public's perceived cost still hinders the public's intention to use renewable energy technologies, prior studies indicated that they are far safer than nuclear energy technologies (Dresselhaus and Thomas, 2001). Because the Fukushima accident becomes the most representative case that identifies the potential risks of nuclear energy technologies, and gives priceless lessons to the public, the importance of substitutional energy sources has risen, and the public's focal point is moving from the cost of the technologies and applications, to the public attitude that is mainly determined by the perceived benefits and risks of the technologies and applications.

In addition, as presented in the current study, trust plays a major role in the public assessment of renewable energy technologies. One of the most significant findings is to foster the individual's social trust in the public area of the potential benefits and risks for employing renewable energy technologies. That is, industry and government have to take responsibility for guiding the proper distributions of technologies, and supporting public consumption. In detail, they also have to revise legislation, including political, environmental, and economical regulations, to allow the public to incubate moods of social trust. Extensive policies, including not only supporting allied industries and potential users, but also helping build their awareness and trust around renewable energy technologies, should be examined and addressed.

Moreover, prior studies identified that the public's perceptions positively enhance the public's trust, when the public think that professional experts, including scientists, engineers and researchers, take their interests and concerns into account. Therefore, the government has to include the public in important decision-making tasks, in a significant effort to improve public perceptions (Barben et al., 2007; Rejeski, 2006).

The findings presented by this study are beneficial for the understanding of the public's intention to use renewable energy technologies and their applications, and provide considerable issues for future studies in related fields. However, several limitations remain. First, it is difficult to generalize the findings, because the two surveys were conducted with self-reported methods. Moreover, our respondents participated in the surveys voluntarily, hence, they might be a particularly motivated party of citizens. Second, this study did not consider respondent-related factors. Prior studies found that the facilitating variables, individual differences (e.g. age), and social influence (e.g. subjective norm) can affect the public's intention to use particular technologies (Venkatesh and Davis, 2000). Third, this study employed five factors as determinants of the public's intention to use renewable energy technologies. However, there can be other notable factors that are significantly associated with the intention. Fourth, because this study used the data from South Korea, there can be several differences of public perceptions between South Korea and other countries. For example, Devine-Wright (2007) indicated that political and environmental beliefs, regional differences, and place attachment can affect public attitudes and acceptance of renewable energy technologies. Devine-Wright (2007) also found that there are notable differences in public understanding and awareness of energy and environmental issues as well as differences in attitudes regarding different energy technologies among EU nations. Therefore, future studies have to explore ways to address the above-mentioned limitations of this study.

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