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Original Article

The relationship between public acceptance of nuclear power generation and spent nuclear fuel reuse: Implications for promotion of spent nuclear fuel reuse and public engagement

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ABSTRACT

Nuclear energy sources are indispensable in cost effectively achieving carbon neutral economy, where public opinion is critical to adoption as the consequences of nuclear accident can be catastrophic. In this context, discussion on spent nuclear fuel is a prerequisite to expanding nuclear energy, as it leads to the issue of radioactive waste disposal. Given the dearth of study on spent nuclear fuel public acceptance, we use text mining and big data analysis on the news article and public comments data on Naver news portal to identify the Korean public opinion on spent nuclear fuel. We identify that the Korean public is more interested in the nuclear energy policy than spent nuclear fuel itself and that the alternative energy sources affect the position towards spent nuclear fuel. We recommend relating spent nuclear fuel issue with nuclear energy policy and environmental issues of alternative energy sources to further promote spent nuclear fuel.

1. Introduction

Nuclear power generation has been essential in the Korean energy industry and is indeed considered as an inevitable choice in achieving carbon neutral economy in a cost effective manner [1]. However, as nuclear power plants may lead to catastrophic consequences such as the ones of Chernobyl and Fukushima, public acceptance is crucial in expanding nuclear power generation, especially in democratic societies where public opinion must be considered. While there has been a wealth of literature on the public acceptance of nuclear energy [2–5], spent nuclear fuel, defined as a high-level radioactive material that is discharged after being used as a reactor fuel [6], has received little attention in the perspective of public acceptance.

Spent nuclear fuel is critical, because it is inevitably generated by the nuclear power plant and therefore needs to be stored or reprocessed after use, where the former leads to the issue of public acceptance of radioactive waste disposal facility. Indeed, there has been relevant discussions in Korea in technological lens [7–9]. Considering the importance of spent nuclear fuel and the public opinion in nuclear power generation, it is necessary to analyze public opinion and gauge the public acceptance of spent nuclear fuel in Korea. In this paper, we employ text analysis to investigate social perceptions regarding spent nuclear fuel in Korea.

2. Literature review

The technological discussions on spent nuclear fuel include the following. First, Choi et al. [10] provide enhancements to the spent nuclear fuel disposal system. Second, Kook et al. [8] take a first step towards developing a criterion for evaluating the integrity of spent nuclear fuel disposal system based on U.S. and Japanese cases. Third, Kim et al. [7] promote Sodium Fast Reactor (SFR) as a means to reuse the spent nuclear fuel, reducing the amount of waste.

In terms of public acceptance of nuclear energy in general, Visschers et al. [4] develop a theoretical framework of trust, affect, benefit perception, risk perception and public acceptance of nuclear energy. Some researchers qualitatively review the Fukushima accident and highlight the importance of transparency and long-term planning of radioactive wastes [5,11]. There are also some that evaluate the perception of nuclear energy by the Korean public

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[2,3,12] quantitatively and provide comparative analysis.

With regards to research on spent nuclear fuel in the social science lens, Kang and Feiveson [13] review comprehensively the history of nuclear energy in Korea and highlight that reprocessing of spent nuclear fuel is not necessary for Korea citing various technological and political considerations. Kang et al. [14] follow up [13] with more updated information and consider the issue of public acceptance. They recommend building more radioactive waste disposal facilities than adopting spent nuclear fuel reprocessing.

The literatures described above provide good insights and recommendations for the nuclear energy generation technology and public acceptance, but public acceptance of spent nuclear fuel is not covered in sufficient depth, justifying the originality and necessity of this paper.

3. Research model and methodology

This research takes two parallel approaches. First, we analyze the vast amount of text data available on the online news portal. Second, we use the theoretical framework of Visschers et al. [4] (see Fig. 1) to further interpret the results of the text analysis and provide recommendations.

For text analysis, we focus on the main concepts and the subtopics contained in the documents, as well as their trends per different points in time. To do so, we employ Term Frequency (TF), Term Frequency-Inverse Document Frequency (TF-IDF) and Semantic Network Analysis (SNA).

Term frequency (TF) measures how frequently a term occurs in a document. Specifically, it counts the number of times a term occurs in the text. Although simple and powerful, the problem with using TF is that relevance does not necessarily increase with usage. For instance, pronouns, definite and indefinite articles occur frequently but are not significant. Therefore, to adjust for such cases, an inverse weighting is introduced, which is referred to as Inverse Document Frequency [15]. Together, TF-IDF captures the relative importance of words in a set of documents or a collection of texts (see equation (1) below).

$$w_{i,j} = tf_{i,j} \times \log\left(\frac{N}{df_i}\right) \quad (1)$$

$$tf_{i,j} = number\ of\ occurrences\ of\ i\ in\ j$$

$$df_i = number\ of\ documents\ containing\ i$$

$$N = total\ number\ of\ documents$$

Semantic Network is a network of words that is organized based on the proximity of words extracted from unstructured text through morphological analysis [16]. Semantic Network Analysis (SNA) extracts words in unstructured text data and organizes inter-word networks based on adjacency between the extracted words. Therefore, nodes in a semantic network are the extracted words, and links are adjacent relations between those words. The size of the node increases with importance.

4. Data and results

To analyze Korean public opinion on spent nuclear fuel, we analyzed Korea's major portal Naver. We searched Naver news with the keyword 'Spent Nuclear Fuel' and extracted 5,747 articles, 109,242 comments and 33,445 reply to comments during the timeframe of May 2017 to December 2020. We not only analyze the comments (along with the replies to those comments) that exhibits public opinion, but we also analyze the articles to ensure that the viewpoint presented by the media is not skewed to the extent of altering the public opinion (comments and replies).

4.1. Result: articles

We collected a total of 5747 articles from 2017 to 2020. Table 1 shows TF/TF-IDF results: the nouns that appeared the most from 2017 to 2020. Terms such as 'Policy', 'President', 'Construction' that were not considered important in TF were discovered using TF-IDF. The SNA results indicate that the keywords "temporary storage facility", "safety", and "policy" are connected to "management of spent nuclear fuel" (Fig. 2). From this, we confirm that the Korean media covered 1) temporary storage facilities for waste management, 2) communities near nuclear facilities, and 3) energy policies related to nuclear spent nuclear fuel.

4.2. Results: comments & reply to comments

A total of 109,242 comments and 33,445 replies to comments were analyzed. Unlike the results of the article analysis, new keywords such as 'Solar power', 'Panel', 'Wind Power' appeared in SNA (Figs. 3 and 4). This implies that the public is interested in the current regime's energy policy which is to reduce the use of nuclear

Table 1
Top 5 keywords for TF/TF-IDF results of articles.

Rank	TF	TF-IDF
1	Nuclear power plant	Safety
2	Nuclear spent fuel	Construction
3	Government	President
4	Safety	Nuclear power
5	Technology	Policy

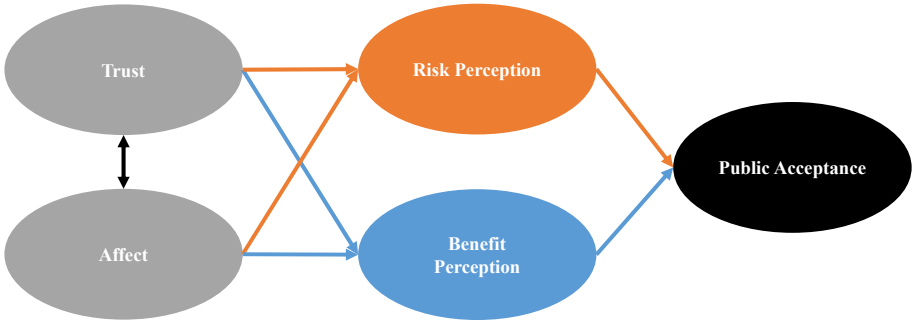

Fig. 1. Theoretical framework.

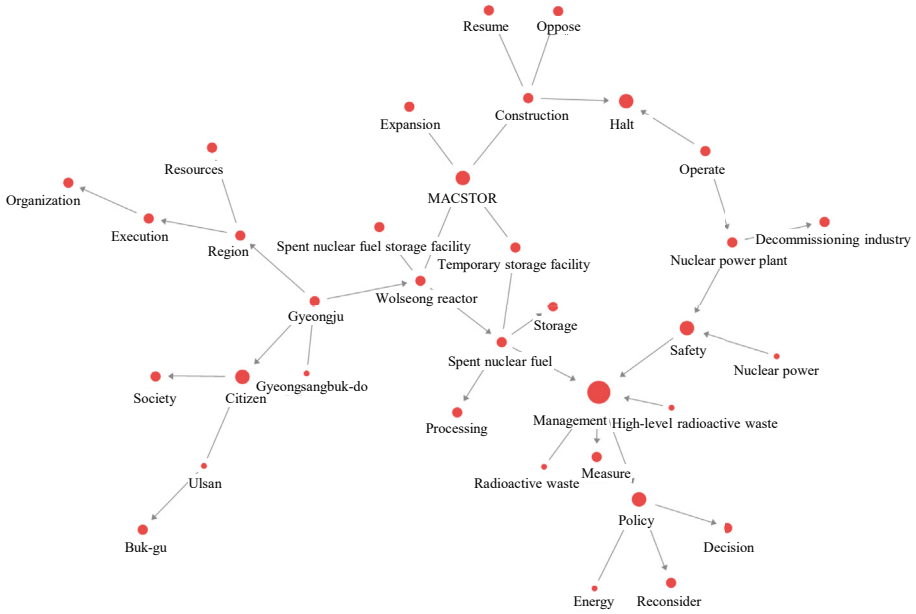

Fig. 2. Semantic Network Analysis of NAVER articles, related to 'Nuclear Spent Fuel' (2017–2020).

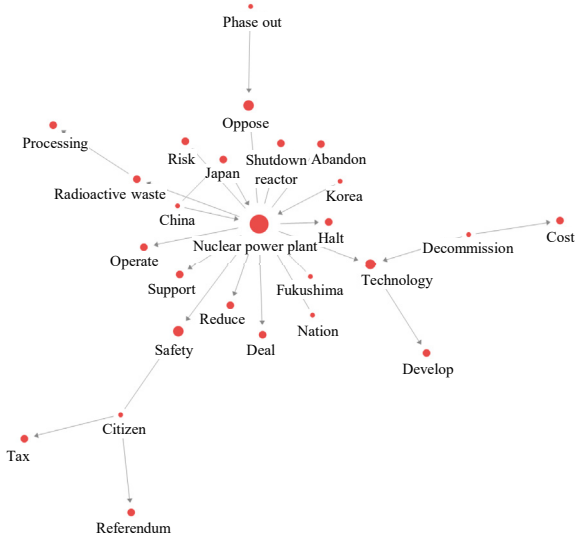

Fig. 3. Semantic Network Analysis of comments, related to 'Nuclear Spent Fuel' (2017–2020).

power plants and increase the use of renewable energy. Furthermore, keywords "support" and "oppose" appeared around the "nuclear power plant" keyword, indicating that there were both positive and negative opinion on nuclear power plants in the comments. Top ranked keywords in replies to comments were "electricity price", "electricity", "money", "cost", "tax", "increase" as seen from TF/TF-IDF/SNA (Tables 2 and 3). It seems that the public is more interested in the nuclear power generation than spent nuclear fuel itself, because it is an issue that directly impacts their lives (electricity).

5. Discussion and implications

From the results, we identify that the public opinion on spent nuclear fuel is closely related to the government's nuclear policy. Indeed, from the trends in the number of articles, comments/reply and likes/dislikes, we confirm that the public actively discussed on the issue when the government was proposing its nuclear phase out policy in June and October 2017 (Fig. 5). On the other hand, while there were many articles (i.e., push from the media) on spent nuclear fuel, there was not much response from the public on issues which were not directly related to energy policy overall, such as the release of spent nuclear fuel related publications (Nuclear Spent nuclear fuel Review committee inaugurated in May 2019, Review committee concluded in July 2020). Relating the above with the theoretical framework (Fig. 1), we note that both the primary (trust, affect) and secondary (benefit/risk perception) factors of public acceptance of spent nuclear fuel is almost identical to the case of the public acceptance of nuclear energy.

Furthermore, we note that the public opinion on nuclear energy and spent nuclear fuel is also interrelated with the opinion on alternative energy sources. Considering the result that keywords related to photovoltaic energy and wind energy sources were identified in the replies to comments semantic network, we find that the factors of the public acceptance of nuclear energy is also affected by their counterparts in other energy sources.

Overall, we find that the public is: 1) more interested in nuclear power plant policy than in the spent nuclear fuel policy issue; 2) there are both positive and negative opinions on nuclear power in the spent nuclear fuel article; 3) the public is interested in the government's energy policy because it is related to everyday life in terms of 'economy' and 'stability of supply and demand'. Our results

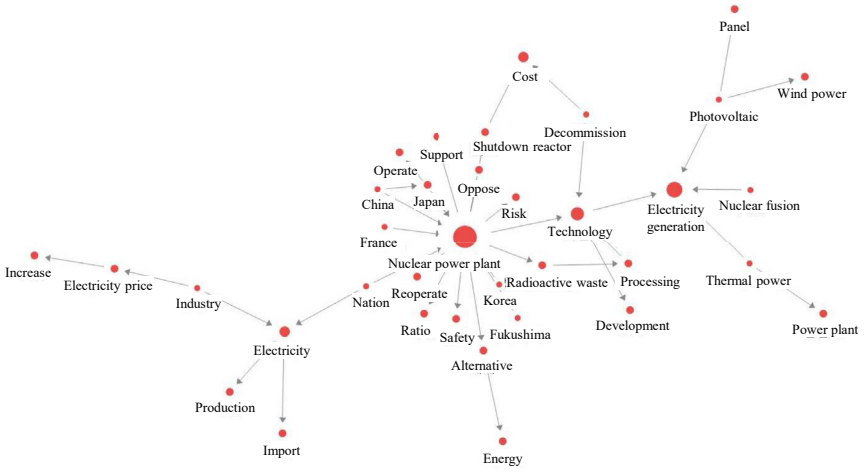

Fig. 4. Semantic Network Analysis of reply to comment, related to 'Nuclear Spent Fuel' (2017–2020).

Table 2
Top 5 keywords for TF/TF-IDF results of comments.

Rank	TF	TF-IDF
1	Nuclear power plant	Nuclear power plant
2	President	President
3	Nation	Nation
4	Phase-out	Phase-out
5	Citizen	Citizen

Table 3
Top 5 keywords for TF/TF-IDF results of Reply to comment.

Rank	TF	TF-IDF
1	Nuclear power plant	Nuclear power plant
2	President	President
3	Nation	Nation
4	Electricity	Thought
5	Thought	Electricity

suggest that not only should nuclear-related organizations endeavor to provide sufficient information to the public regarding spent nuclear fuel, but also to relate the issue of spent nuclear fuel to the nuclear power plant issue and issues related to alternative energy sources (e.g., disruption to bird ecosystem and pollution in manufacturing of renewable energy generators).

5.1. Limitations and topics for further study

This research has two limitations. First, we analyzed the internet news and the comments revolving around the articles. Therefore, the sample may be biased toward the vocal ones and may not have considered the silent majority fully. Second, while the results indicated relation to other energy sources, the analysis here focused on spent nuclear fuel only. To complement these limitations, we propose that future studies conduct national survey on the issue of spent nuclear fuel reuse and also include topics such as the environmental issues of other energy sources.

A topic worth studying further is the public opinion on the necessity of reprocessing facilities or disposal site for the spent nuclear fuel. While it is not feasible to evaluate it at this point in time, once the technical discussions conclude and public engagement on spent nuclear fuel technologies proceed, it would be a critical topic for the nuclear industry to study further.

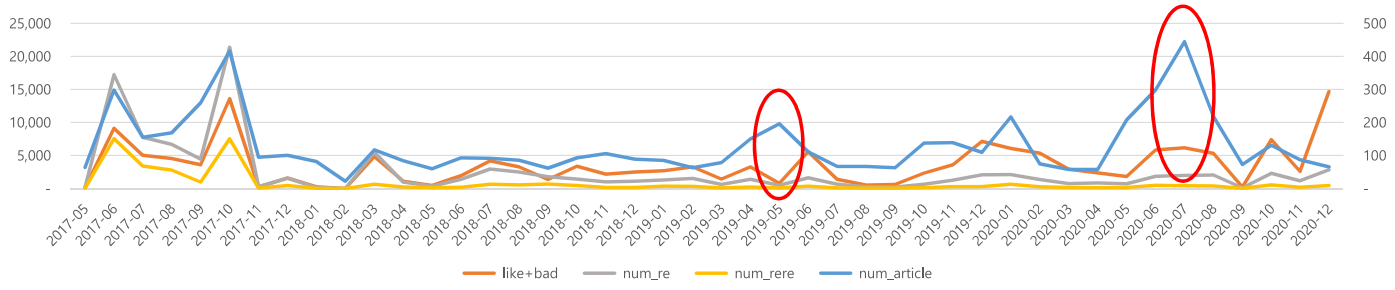

Fig. 5. Trends in the number of articles, comments/reply and likes/dislikes.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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